STUDIES AND LIGHTING DESIGN OF COMMERCIAL AND ARCHITECTURAL PLACES

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENT FOR DEGREE OF

MASTER OF ENGINEERING

IN

ILLUMINATION ENGINEERING

Submitted by

ARNAB BISWAS

Exam Roll No. - M4ILN22009
University Registration No. - 154032 of 2020-2021

UNDER THE SUPERVISION OF
Prof. (Dr). Saswati Mazumdar

ELECTRICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING AND TECHNOLOGY
JADAVPUR UNIVERSITY
KOLKATA – 700032

AUGUST 2022

JADAVPUR UNIVERSITY
FACULTY OF ENGG. AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT

RECOMMENDATION CERTIFICATE

This is to certify that the thesis entitled "**STUDIES AND LIGHTING DESIGN OF COMMERCIAL AND ARCHITECTURAL PLACES"** submitted by **ARNAB BISWAS** (Exam. Roll No. M4ILN22009, Registration No.154032 of 2020-2021) of this university in partial fulfilment of requirements for the award of degree of Master of Engineering in Illumination Engineering, Department of Electrical Engineering, is a bonafide record of the work carried out by him under my guidance and supervision.

_____

Prof. (Dr). Saswati Mazumdar
Head of the Department, Supervisor
Electrical Engineering Department,
Jadavpur University,
Kolkata - 700032.

_____

Prof. Chandan Mazumdar
Dean, Faculty of Engg. And Technology
Jadavpur University,
Kolkata - 700032.

JADAVPUR UNIVERSITY
FACULTY OF ENGG. AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT

CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a creditable study in the area of Illumination Engineering, carried out and presented by **ARNAB BISWAS**, in a manner of satisfactory warrant its acceptance as a pre-requisite to the degree for which it has been submitted. It is notified to be understood that by this approval, the undersigned do not necessarily endorse or approved the thesis only for the purpose for which it has been submitted.

FINAL EXAMINATION FOR EVALUATION OF THESIS.

BOARD OF EXAMINERS
..……

…….....

..……

…….....
(Signature of Examiners)

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my Master of Engineering in Illumination Engineering studies.

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

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

NAME **:** **ARNAB BISWAS**

EXAM ROLL NO. **:** **M4ILN22009**

THESIS TITLE **:** "**STUDIES AND LIGHTING DESIGN OF COMMERCIAL AND ARCHITECTURAL PLACES"**

SIGNATURE & DATE:

21-Jul-2022

Certificate

This is to certify that Mr Arnab Biswas has successfully completed internship from 18-Nov-2021 to 30-Apr-2022 in Wipro Consumer Care & Lighting under the guidance of Mr Shubhajit Das, Asst Manager - Lighting Solutions.

During this period, his conduct was found to be good. We wish him the very best for future endeavors.

Yours sincerely
For Wipro Enterprises (P) Ltd

Abhishek Jha
Senior Manager - HR (B2B Business)
Consumer Care & Lighting

Business Office:
Wipro Consumer Care & Lighting
'Wipro House', No 8, 7th Main,
80 Feet Road, Koramangala,
1st Block, Bengaluru - 560 034,
Karnataka, INDIA.

Registered Office:
Wipro Enterprises (P) Limited
'Wipro House', No 8, 7th Main,
80 Feet Road, Koramangala,
1st Block, Bengaluru - 560 034,
Karnataka, INDIA.

T : +91 80 6199 0100
E : communications.wel@wipro.com
W : wiproenterprises.com
C : U15141KA2010PTC054808

ACKNOWLEDGEMENT

A lot of inputs from various sources have gone into the making of this thesis and the analysis that has been carried out. I take this opportunity to express my gratitude and indebtedness to my university guide **Prof. (Dr.) Saswati Mazumdar,** HOD of Electrical Engineering Department, Jadavpur University, for being a helpful and understanding institutional guide for this project and her constant guidance and supervision.

I would like to express my sincere gratitude to my industrial guides at Wipro Consumer Care & Lighting, Kolkata– **Mr. Shubhajit Das (Assistant Manager – Lighting Solutions)**, **Mr. Indrajit Banerjee (Regional Manager – Lighting Solutions)**, **Mr. Sayantanu Dutta (Account Manager – Lighting Solutions)**, **Mr. Dipankar Roy (Senior Executive, QA & Sourcing)** for providing me their constant support and guidance during my internship which has helped in successful completion of the project.

I would also like to express my sincere gratitude to Management of Wipro Consumer Care & Lighting for giving me an opportunity to carry out internship in their prestigious organization which has helped me in gaining valuable technical knowledge as well as industrial experience.

I would like to acknowledge my sincere thanks to **Prof. (Dr.) Suddasatwa Chakraborty**, **Prof. (Dr.) Biswanath Roy**, **Prof. (Dr.) Sangita Sahana** from Department of Electrical Engineering, Jadavpur University for providing me their valuable suggestions and encouragement in carrying out this project work.

Arnab Biswas

Date:

JADAVPUR UNIVERSITY
Kolkata-700032

CONTENTS

CHAPTER 1

INTRODUCTION

1.1. Introduction to the project:

Good lighting can make office spaces functional and fun to be, where art and architecture look great. Indoor lighting can be both effective and efficient. Effective so it can evoke a mood, light a task or provide security. Efficient so that the employees can use the least amount of energy and still get the job done right. Effective and efficient commercial lighting requires a mix of artistic and scientific skills.

On the other hand, Architectural facade lighting compliments the exterior of any building or structure. A facade refers to the frontal exterior of an architectural structure. That means this type of lighting is a technique that highlights the frontal part of a building – whether that is to light as a whole or to highlight only specific parts or designs. As amazing as the architectural design may be, it all fades into darkness once the night-time comes. The only way to make it come to life at night is to install the right light fixtures around it.

When designing indoor lighting for energy efficiency, some basic design principles and methods have to be considered. Energy-efficient lighting design principles include the following:

- Maximizing the use of daylighting.
- More light is not necessarily better; light quality is as important as quantity.
- Matching the amount and quality of light to the performed function.
- Installing task lights where needed and reduce ambient light elsewhere.
- Using energy-efficient lighting components, controls, and systems (i.e., timers, occupancy sensors and connected office apps).

1.2. Motivation and Aim of the project:

A good lighting plan should be economical with energy, offer a sufficient degree of illumination to see the surroundings, and be comfortable for the eyes. Designing an efficient lighting solution while taking into account cost-effectiveness, energy efficiency, and environmental friendliness is difficult for a lighting engineer. Today, the choice of luminaires and lamps, as well as the characteristics of the surfaces being illuminated, greatly influence the lighting's quality.

This project is about the indoor lighting design of a commercial place along with a façade lighting design of an architectural structure. Different types of indoor lighting and façade lighting design ideas from luminaires manufacturing companies motivated me to proceed with this project. Along with energy saving, a uniqueness in lighting design should be given same importance. Some of the past projects on indoor lighting and façade lighting are shown below.

Fig 1.1: Indoor Decorative Lighting Design with suspended luminaires **[1]**

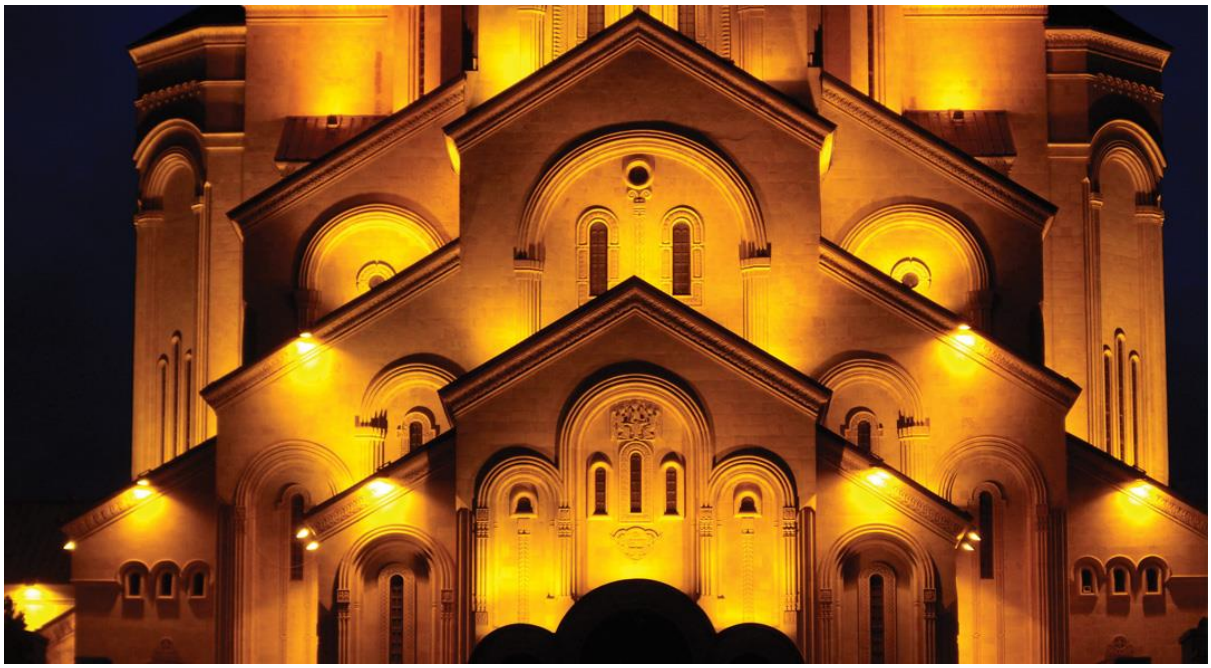


Fig 1.2: Façade Lighting Design **[2]**

1.3. Definitions of Lighting Design Parameters:

In case of Lighting Designs projects, the parameters usually considered are as following –

a) **Illuminance (E):** At a point of surface, quotient of the luminous flux incident on an element of the surface containing the point by the area of that element. [**3**].
Unit = Lux, lx.
b) **Luminance (L):** The luminous intensity distribution of any surface in a given direction per unit of projected area of the surface as viewed from that direction.
Unit = $Cd/m^{2.}$
c) Luminous Flux (φ): Rate of flow of total luminous energy responsible for visual sensation.
Unit = Lumen.
d) **Luminous Intensity (I):** Luminous intensity of a source in a given direction is quotient of the luminous flux leaving the source propagated in an element of solid angle containing the given direction, by the element of solid angle.
Unit = Candela, Cd.
e) **Luminaire:** Apparatus that distributes, filters or transforms the light given by a lamp or lamps and which includes all the items necessary for fixing and protecting these lamps and for connecting them to the supply circuit.
f) **Colour Rendering Index (CRI):** Relative scale (ranging from 0 - 100). indicating how perceived colours match actual colours. It measures the degree that perceived colours of objects, illuminated by a given light source, conform to the colours of those same objects when they are lighted by a reference standard light source. The higher the colour rendering index, the less colour shift or distortion occurs.
g) **Correlated Colour Temperature (CCT):** The temperature of a black body which emits radiation of nearest chromaticity to that of the light source being considered.
Unit – Kelvin, K.
h) **Luminous Efficacy (lm/W):** It is the ratio between the luminous efficacy of the lamp and the power consumed by the lamp. **Unit =** lm/W. When the power consumed by control gear is taken into account, this term is sometime known as lamp circuit luminous efficacy and is expressed in lumens/circuit watt.
i) **Light Loss Factor (LLF):** Ratio of the average illuminance on the working plane after a specific period of use of a luminaire to the average illuminance achieved under identical conditions at the time of installation.
j) **Reflectance (Reflection Factor):** Ratio of the reflected radiant or luminous flux to incident flux for a surface.
k) **Overall Uniformity Ratio (U_0):** Ratio of the minimum illuminance to the average illuminance on the working plane.
l) **Glare:** When an unsuitable distribution or range of luminance or to extreme contrasts in space or time causes discomfort or reduction in the ability to see significant objects, it is called glare. Glare is generally of two types-

- *Disability Glare:* Glare which impairs the vision of objects without necessarily causing discomfort.
- *Discomfort Glare:* Glare which causes discomfort without necessarily impairing the vision of objects.

CHAPTER 2

INDIAN STANDARDS FOR LIGHTING DESIGN

2.1. IS 3646, Part 1, First Revision:

The Indian Standard Code of Practice for Interior Illumination (IS 3646, Part 1, First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Illuminating Engineering and Luminaires Sectional Committee and approved by the Electrotechnical Division Council [**3**]. It primarily depicts the lighting design of working interiors like offices, commercial places, workshops, factories, public buildings, hospitals, schools etc.

2.1.1. Objectives of IS 3646:

The objectives of this Indian Standard Code of Practice are –

- To indicate the factors which should be taken into consideration for achieving good lighting.
- To make the task on the working plane easy to see.
- To create a good visual environment which is agreeable and beneficial to the user.
- To ensure the safety of people in the interior.

Co-ordination and exchange of information about various aspects of lighting design from the very beginning among the parties concerned such as the architect, the consultant and the illumination engineer are necessary for developing a good lighting system.

The Indian Standard series which illustrates the code of practice for interior illumination consists of the following parts –

- Part 1- General requirements and recommendations for working interiors
- Part 2- Method of calculation of the glare indices for interiors
- Part 3- Recommendations for lighting in industries
- Part 4- Recommendations for lighting in offices
- Part 5- Recommendations for lighting in hospitals
- Part 6- Recommendations for lighting in libraries
- Part 7- Recommendations for lighting in educational institutions
- Part 8- Emergency lighting. [**3**]

2.1.2. Functions of Lighting: An indoor lighting design should primarily have three functions –

- *Safety* - This is ensured by making any hazardous area visible.
- *Task performance* – By making the relevant details of the intended task well lit, this is achieved.
- *Visual environment* – Good visual environment can be created by changing the relative emphasis given to different objects and surfaces of the interior.

Although, these above three aspects are main functions of lighting, emphasis given to them can vary for different interior lighting e.g., in case of factory, the lighting on the task should be a matter of concern rather than the appearance of the room whereas in case of hotel, restaurants it is reversed. However, this does not mean than the other aspects are being completely neglected. A good lighting design integrates the various aspects of lighting into a unity appropriate to the design objectives.

2.1.3. Aspects of Lighting Requirements: Lighting requirements are generally based on the following aspects –

2.1.3.1. Lighting Engineering Criteria: The necessary criteria of lighting requirements are as following –

- Lighting level,
- Luminance distribution,
- Glare restriction,
- Direction of incidence of light and shadow effect,
- Colour appearance and colour rendering. [**3**]

Although, all the quality criteria have to be satisfied, priority to one or more criteria should be given depending on the nature of the visual task or the type of the room.

2.1.3.2. Criteria for Visual Tasks: The important details of the task are –

- Their contrast with the background,
- The speed at which these details have to be perceived,
- The desired reliability of recognition,
- The duration of the visual work. [**3**]

With the complexity of the visual task, the lighting quality requirements increase.

2.1.3.3. Economic Aspects: The selection of nominal illuminance for specific activity must also consider economic factors. Although improved lighting costs more in the long run, the benefits of enhanced productivity and a lower accident rate may outweigh the expenses. Often, a compromise must be reached between acceptable illuminance levels and those that are feasible given the current economic circumstances. As a result, it may be necessary to accept a lower lighting quality than what would be required from the standpoint of performance.

Using lamps with a high luminous efficacy and luminaires with a high efficiency and appropriate light distribution can minimise the overall costs of a lighting installation.

2.1.3.4. Illuminance: The illuminance produced on a specific plane (generally known as working plane) usually determines the lighting level delivered by a lighting installation. The amount of light emitted by an installation has an impact on both task performance and task completion as well as the space's appearance.

2.1.3.4.1. Illuminance Scale: A brightness of around 1 cd/m^2 (approximately 20 lx- minimum illuminance for all non-working interiors.) is required to simply distinguish characteristics of the human face. A factor of approximately 1.5 represents the minimum significant difference in scale of illuminances as shown below –

20-30-50-75-100-150-200-300-500-750-1000-1500-2000 etc lux. [**3**]

2.1.3.4.2. Illuminance Ranges: Because different interiors used for the same application or different conditions for the same sort of activity may significantly vary circumstances, a range of illuminances is recommended for each type of interior or activity instead of a single value of illuminance. Each range consists of three steps in the recommended illuminance scale.

*Characteristics of Illuminance Range***:**

1. The values of the illumination range are linked with the task's visual criteria, the users' comfort, practical experience, and the necessity for energy efficiency. Table 1 gives

some of the recommended illuminance ranges for different tasks and activities. For full table of National Standard illuminance ranges please refer to IS 3646, Part 1. [**3**]. The three values in the illumination range represent as –

a) The lower value of the range should be used when –
   - Reflectance or contrasts are unusually high;
   - Speed and accuracy are not important;
   - The task is executed only occasion. [**3**]
b) The middle value of each range indicates the recommended service illuminance that would be used unless one or more of the factors concerned to higher or lower value are applicable.
c) The higher value should be used when –
   - The task contains unusually low reflectance or contrasts;
   - Errors are costly to correct;
   - Visual work is vital;
   - accuracy or increased productivity are critical;
   - The worker's visual capacity demands it. [**3**]

2. The values in the table are obtained as an average during the maintenance cycle, generally known as service values. They correspond to the reference surface's average illuminance. The working plane is generally the reference surface for illumination.
3. Conditions for considering the reference surface which must be clearly stated are –
   - When the task locations are known and precisely specified, the reference surface might be limited to the region of the working zone(s) or the task area(s).
   - When the task is not in a horizontal plane or at a variable height, the reference surface should be at a certain angle or height. [**3**]

	Type of Interior or Activity	**Range of Service Illuminance in Lux**	**Quality Class of Direct Glare Limitation**	**Remarks**
1	AGRICULTURE AND HORTICULTURE			
1.1	Inspection of Farm Produce Where Colour is Important	300-500-750	1	Local lighting may be appropriate
	Other Important Tasks	200-300-500	2	Local lighting may be appropriate
1.2	Farm Workshops			
1.2.1	General	50-100-150	3	
1.2.2	Workbench or machine	200-300-500	2	Local or portable lighting may be appropriate

2	COAL MINING (SURFACE BUILDINGS)		
2.1	Coal Preparation Plant		
2.1.1	Walkways, floors under conveyors	30-50-100	3
2.1.2	Wagon loading, bunkers	30-50-100	3
2.1.3	Elevators, chute transfer pits, washbox area	50-100-150	3

Table 2.1: *Recommended illuminance ranges for different tasks and activities* [**3**]

2.1.3.5.4. Glare Rating G: The stepped scales of the glare rating G are based on the following interpretation of observers' impressions:

- 0 = No glare,
- 2 = Perceptible,
- 4 = Uncomfortable,
- 6 = Intolerable glare.

representing quality classes from 1 to 3, for various values of illuminance.

The relevance and scope of glare control varies depending on the interior activity. As a result, appropriate quality classes ranging from 1 to 3 must be chosen for varied illuminance values-

- Class 1: High Quality
- Class 2: Medium Quality
- Class 3: Low Quality

Table 1 of IS 3646 Part 1 lists the guidance as to which quality class has to be used along with recommended luminance values.

2.1.3.5.5. Restriction of Reflected Glare: Reflected glare can be caused by the reflection of a high luminance (for example, from a luminaire or a window) towards the eyes if any of the task's or its immediate surroundings' luminance is substantially dependent on the direction of incidence of light and on the viewing direction.

- The most efficient strategy to reduce reflected glare is to position the worker and the light source so that reflections from the light source are directed away or to the sides, rather than towards the eyes.
- It should also be reduced by employing large-area, low-luminance luminaires and non-glassy furniture, equipment, and room surfaces.

2.1.3.6. Structures and Modelling: Interiors seem better when its structural characteristics, as well as the items and people within them, are lit in such a way that shapes are seen clearly and pleasingly, and shadows are generated without being confused. When light flows substantially more in one direction than in any other, this occurs. The term "modelling" refers to the process of lighting revealing the shapes of three-dimensional objects.

2.1.3.6. Stroboscopic Effect and Flicker: The frequency, regularity, and amplitude of the oscillation in light flux relative to the frequency and regularity of the object's movement determine the strength of any stroboscopic effect. The flicker is a source of distraction and

discomfort for people, especially because it may be seen by peripheral vision and hence is difficult to ignore. For safety reasons, whenever a major stroboscopic effect or flickering is anticipated, the lighting should always be designed to limit such effects.

2.1.3.7. Colour Appearance and Colour Rendering Groups of Lamps: Although each lamp type has a specific correlated colour temperature, but for practical use the correlated colour temperatures have been grouped into three classes (**Table 2.2**). The function of the room usually determines the choice of appropriate apparent colour of light source in a room. This could include psychological characteristics of the colour, such as the sense of warmth, relaxation, clarity, and so on, as well as more practical concerns, such as the necessity to have a colour appearance that is compatible with daylight while still providing a white colour at night.

The capacity of a light source to accurately render the colours of surfaces can be measured using the general colour rendering index. The colour rendering groups of the various lamps to be used for lighting of interiors are specified in **Table 2.3**.

Correlated Colour Temperature (CCT) (1)	CCT Class (2)
CCT<3300K	Warm
3300K<CCT<5300K	Intermediate
5300K<CCT	Cold

Table 2.2: Correlated Colour Temperature

Colour Rendering Groups	CIE General Colour Rendering Index (Ra)	Typical Application
1A	Ra>40	Wherever accurate colour matching is required, for example, colour printing inspection
1B	80<Ra<90	Wherever accurate colour judgements are necessary and/or good colour rendering is required for reasons of appearance, for example, shops and other commercial premises
2	60<Ra<80	Wherever moderate colour rendering IS required

3	40<Ra<60	Wherever colour rendering is of little significance but marked distortion of colour is unacceptable
4	20<Ra<40	Wherever colour rendering is of no importance at all and marked distortion of colour is acceptable

Table 2.3: Colour Rendering Index

2.1.3.8. Choice of Lamps and Luminaires: The designer must select lamp(s) that are appropriate for the application while also meeting the design goals. Unless a unique effect is sought, adjacent regions should not be illuminated with sources of significantly varying apparent colour.

The designer can use a combination of professional judgement, personal preference, and economic analysis to select a luminaire. Luminaires may be subjected to a number of environmental factors, including vibration, moisture, dust, ambient temperature, vandalism, and so on. Furthermore, it is the designer's responsibility to define safer equipment.

2.1.3.9. Maintenance Factors and Schedule: The average illuminance values obtained during the maintenance cycle are always less than the initial illuminances by a ratio based on the installation's characteristics. This loss of light can be classified into three categories –

i. Lamp Lumen Depreciation: The luminous flux emitted by all lamps declines over time, although the rate at which it drops differs greatly amongst lamp types.
ii. Luminaire Depreciation: The accumulation of dirt on the lamp and luminaire surfaces causes even more light loss. The rate at which this soiling happens is largely determined by the type of luminaire, the interior's nature, and the building's location.
iii. Room Surface Depreciation: In most circumstances, the illuminance produced on relevant interior surfaces is influenced to some extent by inter-reflection from other surfaces in the room. The light distribution of the luminaires and the reflectance of the relevant surfaces will determine the proportion of illuminance produced.

Inter-reflection will have little effect on luminaires with a high proportion of direct illuminance, such as downlighters, but indirect designs will be fully dependent on it. Dirt deposited on room surfaces reduces reflectance over time, resulting in a loss of illuminance.

2.1.3.9.1. Light Loss Factor: The light loss factor (LLF) is the ratio of the illuminance produced by the same installation when fresh to the illuminance produced by the same installation when old. It calculates the impact on the illuminance by decrease in lamp luminous flux over time and depreciation caused by dirt deposited on luminaires and room surfaces. So, the light loss factor is the product of three additional factors –

Light-loss factor = Lamp lumen maintenance factor x Luminaire maintenance factor x Room surface maintenance factor.

The light loss factor can be employed in the lumen method of illuminance calculation to determine how much light the installation will produce at any given point in its life. This is achieved by the following mathematical expression-

$$E = \frac{\emptyset_{1n}\ x\ n\ x\ N\ x\ U\ x\ LLF}{A}$$

Where

E = Illuminance in Lux.
$\emptyset_{1n}$ = Initial flux of the light source;
n = Numbers of lamps per luminaire;
N = Number of luminaires;
A = Area to be lit (in m^2);
U = Utilization factor for type of luminaire in specific room conditions;
LLF = Light Loss Factor.

It is feasible to estimate the pattern of illuminance produced by the installation in relation to elapsed time by computing the light loss factor for various maintenance patterns. This pattern can be used to consider the benefits of various maintenance schedules.

2.1.3.9.2. Maintenance Schedule: In a big installation, it may be more cost-effective to replace all of the lamps at once rather than as they fail. Individual light replacement is frequently costly, inconvenient in busy areas of a building, and can cause visible changes in lamp colour and luminance. The economic cleaning interval for a given installation is determined by the type of luminaire, on the rate of dirt accumulation and on the cleaning cost. The luminaire cleaning period should be set to correspond to the lamp replacement interval for best cost savings.

2.2. National Lighting Code 2010 - IS SP 72: 2010:

The goal of this code is to conveniently outline the standards for ethical social, commercial, and engineering conduct for lighting designers, manufacturers, and suppliers. Achieving fundamental goals for environmental protection and social safety depends in large part on lighting technology.
The purpose of this code is to promote energy-efficient lighting techniques and systems that preserve utility, utility, safety, and productivity while reducing light pollution, glare, and light trespass.

2.2.1. Objectives of IS SP 72: 2010:

The objectives of this NATIONAL LIGHTING CODE (NLC) are as following-

- Guidance on illuminating engineering practices to be followed by various types of occupancies;
- Guidance on good engineering practices to be followed in the design, selection, installation and maintenance of lighting systems for indoor and outdoor areas;
- Matters related to the science of illumination such as physics of light, electric light sources, luminaires and photometry;
- Coordination aspects to be considered while designing the lighting systems such as daylighting; and

- Aspects relating to energy management and energy conservation in lighting installations including guidelines for design and good practices to be adopted for effective and efficient use of light sources. [**4**]

IS SP 72 generally depicts national lighting standards for outdoor lighting i.e. streetlighting, sports lighting, landscape lighting and façade lighting.

2.2.2. Important Factors in Façade Lighting:

A monument or building must not be practically overwhelmed with light when floodlighting it. It is possible to highlight the relief of the various planes or volumes by tactfully using more light, less light, or shadow. The relief of a facade is highlighted by the presence of shadows. The modelling effect must be provided by the lighting setup.

2.2.2.1. Angle of Incidence: Since there are no shadows created by lighting that is perpendicular, the surface seems to be flat. The relief of the surface and the angle of the light's incidence both affect the size of the shadow. The average minimal lighting directional angle shall be 45 degrees with the normal to the surface. This angle has to be increased for highlighting a particularly low relief.

2.2.2.2. Aiming of Luminaires: All shadows must be cast in the same direction for the lighting effect to appear natural and balanced (as happens under natural light). As a result, the major floodlights (luminaires) lighting surfaces visible in a single field of view must all be oriented in the same direction. Large projections, however, might cast a wide shadow that hides some areas. A light source with lower intensity should be used to attenuate this shadow at a 90-degree angle (complementary floodlights) from the main lighting source.

2.2.2.3. Aiming vis-a-vis Viewpoint of Observers: For the shadow and resulting relief to be apparent, the light's direction must be distinct from the viewers' viewing direction. These two directions must form an angle of at least 45 degrees. For monuments that may be seen from various locations, a primary observation point needs to be identified, and lighting needs to be planned for this favoured viewing angle.

2.2.2.4. Daytime Appearance of the Installation: It is crucial to make sure that the luminaire placements chosen for night-time floodlighting are aesthetically pleasing and do not obstruct the daytime view of the site.

2.2.2.5. Glare: Direct and/or reflected glare that can annoy residents of surrounding buildings or drivers of motor vehicles on nearby roads must be eliminated.

2.2.2.6. Maintenance: It should be as simple as possible to change lamps, clean luminaires, and readjust damaged luminaires for periodic maintenance. To ensure easy handling of the installation and luminaires, care must be made at the design phase.

2.2.3. Lighting Design Calculation Parameters:

2.2.3.1. Luminance: The mean luminance of an illuminated facade must be proportionate to the demands of the environment, the size, and the location of the concerned monument in order to ensure proper visibility. The higher the mean luminance of the environment, particularly the background, the greater should be the luminance of the monument.

Generally accepted mean luminances for various situations are-

- Rural areas poorly or dimly lit – 4 cd/m^2
- Small towns, suburban areas – 6 cd/m^2
- Recreational and commercial centres in urban areas – 12 cd/m^2. [**4**]

2.2.3.2. Illuminance and Reflection Factor: The illuminance on a facade or surface can be calculated from its luminance and reflecting properties with the following equation applicable to diffused surfaces-

$$E = L\frac{\pi}{\rho}$$

Where,

E = the illuminance in lux;
L = the average luminance in cd/m^2;
ρ = the mean reflection factor.

Since the reflection factor is not always the same at all points on a surface, the mean value must be used. This value can be determined by an appropriate instrument or usually estimated from known values.

2.2.3.3. Luminous Flux: After deciding on the illuminance required, the luminous flux required can be found by using the following formula –

$$\Phi = \frac{E.S}{U}$$

Where,

Φ = the luminous flux in lumens;
E = the maintained average illuminance in lux;
S = the total area to be illuminated in m^2;
U = the efficiency coefficient of the system. (Typical value 0.3).

This efficiency co-efficient 'U' depends on the following factors –

- The light output ratio of the luminaire (obtained from published data of the manufacturer);
- The maintenance factor, which is dependent on environmental conditions and the frequency of cleaning and lamp replacement and can be assumed to be 0.8 very generally for regular cleaning and lamp replacement;
- The waste-light factor; depending on the beam angle of the floodlight, dimensions of the area to be illuminated, the distance between the luminaire and the surface, light scattering due to the amount of dust in the atmosphere, etc, a part of the luminous flux may miss the subject. [**4**]

2.2.4. Backlighting: This is accomplished by lighting the background of the main subject, which stands out as a dark object against the background, using floodlights. A reasonably uniformly bright background must be produced by the floodlighting.

On occasion, a very low intensity of light on the subject's facade may be required to highlight the contour of the subject.

By lighting the subject's back surface, backlighting effects can also be produced. Due to some construction features or projections on the back surface, it is feasible to produce lighting patterns that highlight the volumes and openings.

2.2.5. Use of Coloured Light: The use of coloured light in decorative floodlighting is quite subtle. It must only be employed when the spectator can quickly and clearly understand the implied notion or circumstance.

It is important to keep in mind that coloured light enhances complementary hues while diminishing those of other tones. Using various colours might result in stark contrasts, but contrasting colours also brighten up nearby surfaces.

A facade constructed of various materials needs to be handled with the same care. The tonal values are altered by coloured light, creating an imbalanced effect.

2.3. ECBC 2017:

ECBC 2017 includes a set of futuristic building performance standards that the construction sector can work toward, regardless of whether ECBC is updated. Three tiers of energy performance standards have been defined in the updated code as following –
In ascending order of efficiency,

- ECBC compliant building,
- ECBC+ Building and
- Super ECBC Building.

The only necessary level for demonstrating compliance with the code is to fulfil requirement specified for ECBC building level of efficiency whereas other two are voluntary. Subsequent revisions to ECBC, the goal will be to make ECBC+ and Super ECBC Buildings the standard for energy efficient buildings in the country.

2.3.1. National Standards for Interior Lighting Power Consumption:

The interior lighting power allowance for a building or a separately metered or allowed section of a building shall be determined in accordance with 6.3.4, and shall not exceed the interior lighting power allowance determined in accordance with either 6.3.2 or 6.3.3. Interior lighting power allowance trade-offs are not permitted between areas of the structure for which a different method of calculation was applied.

Different methods for determining interior light power allowances are as following –

2.3.1.1. Building Area Method: To determine interior lighting power (watts) by building area method, the following steps are to be followed –

i. The allowed lighting power density for each appropriate building area type from Table 6-1 for ECBC Buildings, from Table 6-2 for ECBC+ Buildings and from Table 6-3 for SuperECBC Buildings has to determined. These mentioned tables can be found in **ECBC 2017** [**5**].
ii. Then the gross lighted carpet area for each building area type has to be calculated.
iii. The interior lighting power allowance is therefore the sum of the products of the gross lighted floor area of each building area times the allowed lighting power density for that building area type.

Building Type	LPD for different types of Buildings (W/m2) ECBC Buidings	ECBC+ Building	SuperECBC Building
Restroom	9.5	7.8	5
Storage	9.7	7.6	4.9
Conference/ Meeting	9.5	7.8	4.8
Stairway	9.43	7.5	4.7
Corridor/Transition	10.2	8.2	5.1
Parking Driveways (covered/ basement)	10.5	8.4	5.3

Table 2.4: Interior Lighting Power by Building Area Method

The above table (**Table 2.4**) show some of the Interior Lighting Power allowances for ECBC Buildings, ECBC+ Buildings and SuperECBC Buildings using Building Area Method. The complete lists of Interior Lighting Power allowances are given in **ECBC 2017** [**5**].

2.3.1.2. Space Function Method*:* To determine interior lighting power (watts) by space function method, the following steps are to be followed –

i. From Table 5 for ECBC Buildings, ECBC+ Buildings, and SuperECBC Buildings the right building type and lighting power density are determined. When a common space type and a building specific space type are both specified, the building specific space type LPD gets priority.
ii. The gross carpet area by measuring to the face of the partition wall for each space enclosed by partitions 80 percent or greater than ceiling height is determined. Any projects such as balconies or other projections. The 80 percent partition height rule does not apply to retail areas are to be included.
iii. By the summation of the lighting power allowances for all spaces the interior lighting power allowance can be achieved whereas the lighting power allowance for a space is the product of the gross lighted carpet area of the space times the allowed lighting power density for that space.

Building Type	LPD for different types of Buildings (W/m2) ECBC Buildings	ECBC+ Building	SuperECBC Building
Restroom	7.7	6.1	3.8
Storage	6.8	5.4	3.4
Conference/ Meeting	11.5	9.2	5.7
Stairway	5.5	4.4	2.7
Corridor/Transition	7.1	3.6	2.3
Parking Driveways (covered/ basement)	3	2.5	1.5

Table 2.5: Interior Lighting Power by Surface Function Method

2.3.2. Installed Interior Lighting Power:

All power utilised by luminaires, including lamps, ballasts, current regulators, and control devices, must be included in the installed interior lighting power calculated for compliance with tabulated values given in 6.3 of ECBC 2017. [**5**]

If two or more independently functioning lighting systems are controlled in a space to prevent simultaneous user operation, the installed interior lighting power must be based only on the lighting system with the highest power.

2.3.2.1. Luminaire Wattage: Luminaire efficacy should be 0.7 or above. The wattage of luminaires incorporated into the installed interior lighting power shall be determined as follows –

- The wattage of incandescent luminaires with medium base sockets and not containing permanently installed ballasts shall be the maximum labelled wattage of the luminaires.

- The wattage of luminaires containing permanently installed ballasts shall be the operating input wattage of the specified lamp/ballast combination. Operating input wattage can be either values from manufacturers' catalogues or values from independent testing laboratory reports.

- The wattage of all other miscellaneous luminaire types not described in the above two points shall be the specified wattage of the luminaires.

- The wattage of lighting track, plug-in busway, and flexible-lighting systems that allow the addition and/ or relocation of luminaires without altering the wiring of the system shall be the larger of the specified wattage of the luminaires included in the system or 135 Watt per meter (45 W/ft.). Systems with integral overload protection, such as fuses or circuit breakers, shall be rated at 100% of the maximum rated load of the limiting device. [**5**]

2.3.3. Exceptional Circumstances:

The wattage for the following lighting equipment and applications shall not be included in the installed interior lighting power, nor should the wattage for such lighting be considered for computing the interior lighting power allowance. Any such illumination, however, is not exempt unless it is used in combination with general lighting and is controlled by a separate control device.

- Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments,
- Lighting that is integral to equipment or instrumentation and is installed by its manufacturer,
- Lighting specifically designed for medical or dental procedures and lighting integral to medical equipment,
- Lighting integral to food warming and food preparation equipment,
- Lighting for plant growth or maintenance,
- Lighting in spaces specifically designed for use by the visually impaired,

- Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions,
- Lighting in interior spaces that have been specifically designated as a registered interior historic landmark,
- Lighting that is an integral part of advertising or directional signage,
- Exit signs,
- Lighting that is for sale or lighting educational demonstration systems,
- Lighting for theatrical purposes, including performance, stage, and film or video production, and
- Athletic playing areas with permanent facilities for television broadcasting.

CHAPTER 3

COMPUTER AIDED LIGHTING DESIGN APPLICATIONS

3.1. Introduction:

Lighting design of a certain building or landscape can be done using computer applications like DIALux 4.13, DIALux Evo, AGi 32, Lighting Reality pro, Relux, CGLux, Calculux, Photolux, Sunlux, Lumen Micro, Lumen Designer etc. These applications incorporate different approaches to simulate the lighting design but their aim is same nevertheless. In addition to that AutoCAD is also used for visualizing the luminaires positions in an area. Different company uses different lighting software as per their convenience. In Wipro Lighting mostly DIALux 4.13, DIALux Evo, AutoCAD are used.

3.2. DIALux: One of the top programmes for lighting design is called DIALux. It is used to calculate and visualise interior and outdoor lights which is a time-saving software when compared to the manual calculation. [**6**].

DIALux calculates the amount of energy your light solution needs while you're designing it and assists you in complying to the relevant national, and international standards. DIALux has the most creative flexibility possible during the design process because they support the luminaires of the top manufacturers in the globe.

3.2.1. Advantages of DIALux-

- DIALux is a completely free software.
- Virtual worlds can be created simply and intuitively with DIALux.
- Daylight and artificial light scenarios can also be simulated.
- Support any photometric data file in required format(.ies).
- Results can be compared with international standard result.
- CAD file (site planning file) can be imported or exported.
- Dynamic light scenes with LED or other colour changing luminaires.
- Planning 3D model and simulate photometric data to any buildings, landscape, façade or roadway model.
- Daylight and artificial light scenarios can also be simulated.

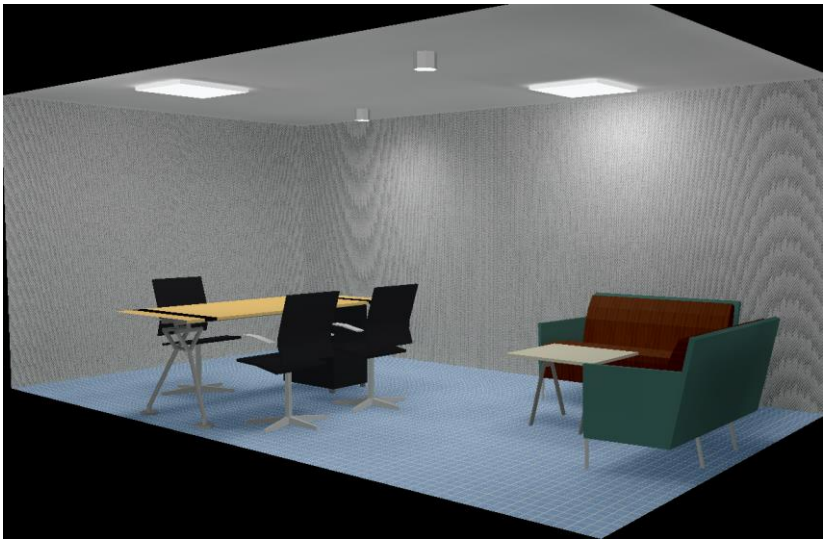


Fig 3.1: Lighting Design in DIALux 4.13

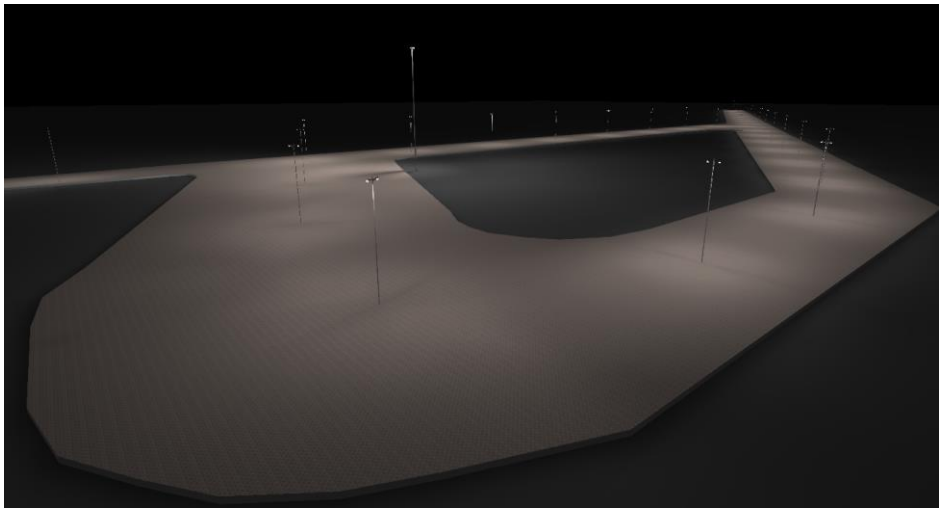


Fig 3.2: Lighting Design in DIALux Evo 10.0

3.3. Agi32: AGi32 is as a calculating tool for precise photometric predictions. A technical tool that can calculate illumination in any circumstance, assist with luminaire placement and aiming, and verify compliance with a variety of lighting requirements.

By generating a virtual model of a proposed design, AGi32 can replace mock-ups and save time and money because it allows users to clearly see results for the entire project. It can show traits and outcomes that would be difficult to find in anything else than the finished installation. Among the other design tools, AGi32 can be incredibly useful in the practise of professional lighting design and analysis.

3.3.1. Advantages of Agi32 are-

- Support any photometric file in required format(.ies).
- Dynamic light scenes with LED or other colour changing luminaires.
- Better realistic view can be achieved.
- Result can be compared with international standard results.
- CAD file can be imported or exported.
- Planning 3D model and simulate photometric data to any buildings, landscape, façade or roadway model.

Fig 3.3: Lighting Design using Agi32 [**7**].

3.4. <u>AutoCAD:</u> AutoCAD is a global application. It is being used globally by product development teams, manufacturing facilities, medical professionals, in educational institutions, by professionals and engineers. AutoCAD comprises integrated design layouts of various templates specially designed for architectural planning and infrastructure constructions; the users can work on plans that include creating architectural arrangements for construction purposes without having to master the software.

In case of lighting design, AutoCAD is used –

- To correct and modify the dwg file provided by the client.
- To develop the lighting layout for the plan.
- To create the lighting legends for the luminaires used in the design.

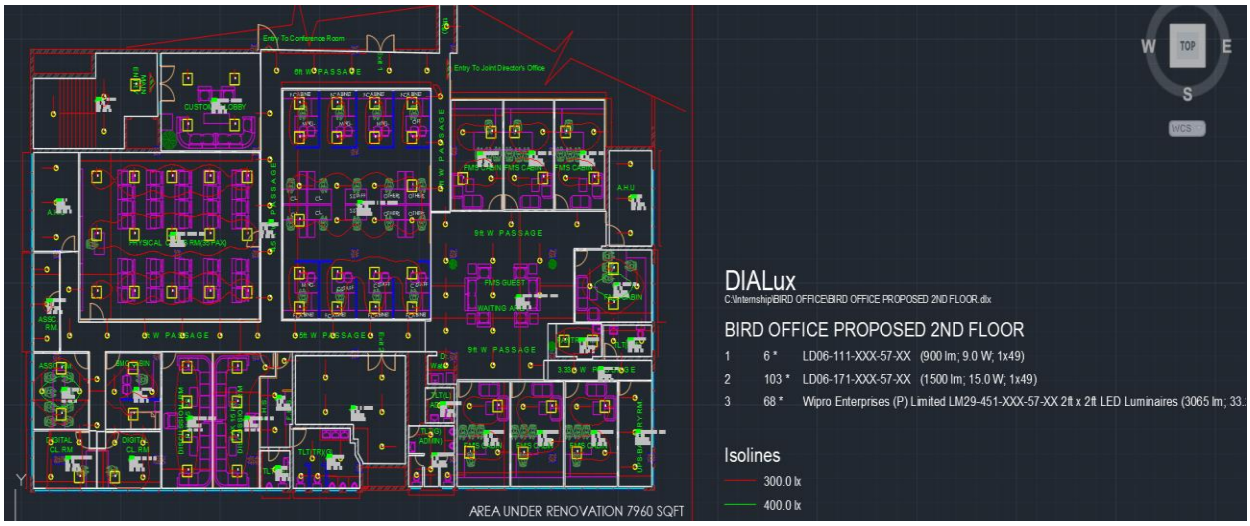


Fig 3.4: Lighting Layout Design in AutoCAD

CHAPTER 4

PROCESSES INVOVLED IN COMPUTER AIDED LIGHTING DESIGN

4.1. Introduction:

Computer aided lighting design creates a virtual environment to visualize how the area to be lit would look after implementing the lighting installation. Therefore, to create a perfect visual environment, there are certain steps to be followed. Each and every step has its own significance in lighting design.

1. **Client Meet and Site Visiting:** The lighting designer should visit the client and the site at which the lighting installation would take place to understand the requirements. This information will help the designer to determine the procedure of lighting design. Certain important factors such as Maintenance Factor, Reflectance Factors etc are considered after visiting the site.

2. **AutoCAD Layout:** The next thing the design should acquire from the client is the AutoCAD layout of the site which is the most important data to understand the site. Important details such as the height of the floors, type of ceilings, dimensions of the rooms or areas, furniture positions etc can be found out from the AutoCAD layout. The AutoCAD layout is imported in the lighting design tools to process the lighting design. Sometimes when the client is unable to provide the AutoCAD layout, the at least the pdf version of the plan is necessary to proceed with the design.

3. **Compliance of National and International Standard:** The appropriate standards and code of practice for the specific design must be studied and consulted by the designer. This guarantees the proper level of design parameters as well as the visual comfort and safety of those who will be using those locations. For office lighting, for instance, IS3646: 1992 (Part 1 & Part 2) [**3**] and Energy Conservation Building Code 2011 (ECBC) [10] are followed to. The recommended illuminance level and uniformity for the road surface are stated in IS 1944 Part 1 and 2 1970 [**8**].

4. **Selection of Luminaires:** The designer should select the luminaires according to the area to be lit. For instance, in case of indoor lighting design the designer can use 2x2 LED panel, downlights, 4 ft LED batten etc whereas in case of sports field or façade lighting, floodlights of desired wattage can be used. Sometimes the client or consultant specify their requirements for the type of luminaires which needs to be followed.

5. **Importing AutoCAD file in Lighting Designing Software:** The AutoCAD layout provided by the client is to be imported in lighting designing tool such as DIALux, Agi32 etc. Proper scaling of the dimensions of the layout must be done before importing the layout to process the lighting design accurately.

6. **Steps involved to simulate the lighting design:** After importing the AutoCAD layout successfully, the particular steps to be followed to simulate the lighting design in DIALux are as following –

    - The category of the area to be lit and the tasks to be performed in that area is to be decided.
    - After consulting IS 3646 (for indoors) and IS SP 72 (for outdoors) and according to the requirements of the client, the required illuminance level [**3**]

and uniformity ratio is decided. Although the ideal uniformity ratio for indoor lighting design is greater than or equals to 0.7 but in practice a uniformity ratio above 0.4 holds good.

- The dimensions of the area are to be specified and according to that, rooms are to be drawn in DIALux to simulate the lighting design.
- The Maintenance Factors and Reflectance Factors of different portions of the rooms are to be specified. Generally, for indoor areas with air-conditioning the M.F is kept as 0.85 and Reflectance of ceiling, walls and floor are kept as 50%, 30% and 20% respectively. In case of industrial areas, the M.F is considered as 0.8 and Reflectance of ceiling, walls and floor are kept as 30%, 20% and 10% respectively.
- The mounting heights of the luminaires need to be specified according to the height of the area and type of ceiling (e.g. False ceiling, Grid ceiling, Gypsum ceiling, true ceiling etc.).
- Calculation surfaces are to be taken where the task is to be performed. By default, at a height of 0.8m, a calculation surface is specified although the designer has the freedom to choose other calculation surfaces as per the requirements.
- As per the layout, the furniture is to be placed. If the client specifies, then the surface textures for the walls, floors can be applied.
- After the above steps are followed, the luminaires are to be placed as per the uniformity and illuminance level requirements. A general mathematical formula for evaluating the number of luminaires is as following –

$$N = \frac{A * E_{avg}}{n * \varphi * MF * UF}$$

Where,
N= Number of luminaires,
A = Area of the zone to be illuminated in m^2,
E_{avg} = Average maintained horizontal illumination level in lux,
n = Number of lamps per luminaire,
φ = Lumen output of Lamp in Lumens,
MF = Maintenance Factor,
UF = Utilization Factor.

Maintenance Factor (MF): Maintenance Factor, also known as Light Loss Factor (LLF), is the ratio of present illuminance for a given area to the value that would have occurred if the lamps had operated at their (initial) rated lumens and if no system variation or depreciation had occurred.

Utilization Factor (UF) or Coefficient of Utilization (COU): Utilization Factor of a luminaire is the percentage of the light emitted by the light source, which contributes to illuminance on a surface. This factor takes into account the direct as well as indirect component of light, so it is dependent on the shape and size of the room, mounting height and also the reflection properties of the surroundings.

7. **Analysis of Results:** After the initial necessary input factors are considered, the computer simulation is done and the results i.e. average illuminance value and overall uniformity are compared with the requirements. The dwg file exported from the DIALux is imported in AutoCAD and placed on the original layout plan for the client

to understand the positions of the lighting fixtures. After the design has been completed and all design requirements have been met followed by the installation of the lighting fixtures, a final site visit is necessary. The practical on-site results are achieved using testing tools like luxmeters, luminance metres, etc. To determine if the design is effective or not, the acquired values are compared with the results of the software simulation.

CHAPTER 5

COMPUTER AIDED INDOOR LIGHTING DESIGN FOR A COMMERCIAL BUILDING

5.1. Introduction:

The GRIDCO Building in Odisha is a unique commercial place for its shape and structure because of which the lighting design of this place should be eye-catching to maintain its uniqueness.

Efficiency, symmetry, applicability, glare, maintainability, and long life should all be considered while designing the lighting. The lighting plan should produce a bright appearance, prevent any dark places, and provide simple, secure access to every location. The lighting system requirements associated with the electrical systems and equipment should comply with the relevant latest standards and codes of practice.

5.2. Prerequisites and Important Parameters:

5.2.1. Requirements mentioned by the client: SPACE ARCH, the architect company of the GRIDCO building specified their requirements for the lighting design such as –

- Lighting designer needs to incorporate the INFORM lighting fixtures (informal luminaires – suspended, decorative luminaires) in the lighting design.
- The minimum average illuminance value for the work places in the building must be greater than 300 lx.
- There should be an aesthetic look in the lighting design.

5.2.2. Important factors for design and selections of luminaires: Selection of lighting equipment will depend on the following factors:

- Ceiling type – false ceiling (Grid ceiling, Gypsum ceiling, True ceiling),
- Mounting height,
- Application areas,
- Criticality of restricting glare,
- Importance of colour rendering index for selection of lamps,
- Use of lamps with proper colour temperature.

LED Luminaires should be preferred over other light sources because of its benefits and long life.

5.2.3. Design Parameters to be evaluated:

- Average Illuminance (E_{avg}): It is calculated as the average of the illuminance values at all the grid points for a calculation surface. Its unit is – Lux/ lx.
- Overall Uniformity (U_o): It is the ratio of the minimum Horizontal Illuminance (E_{min}) to the average Horizontal Illuminance (E_{avg}) on the area under consideration. A good overall uniformity ensures that all surfaces on the area is sufficiently visible.

5.2.4. GRIDCO Building Plan Layout: The architect provided AutoCAD layout of the building to proceed with the lighting design swiftly. Although the layout contains the plan for all floors in one file, for ease of importing in DIALux, the plans for different floors are divided and one Dwg file for each floor was created.

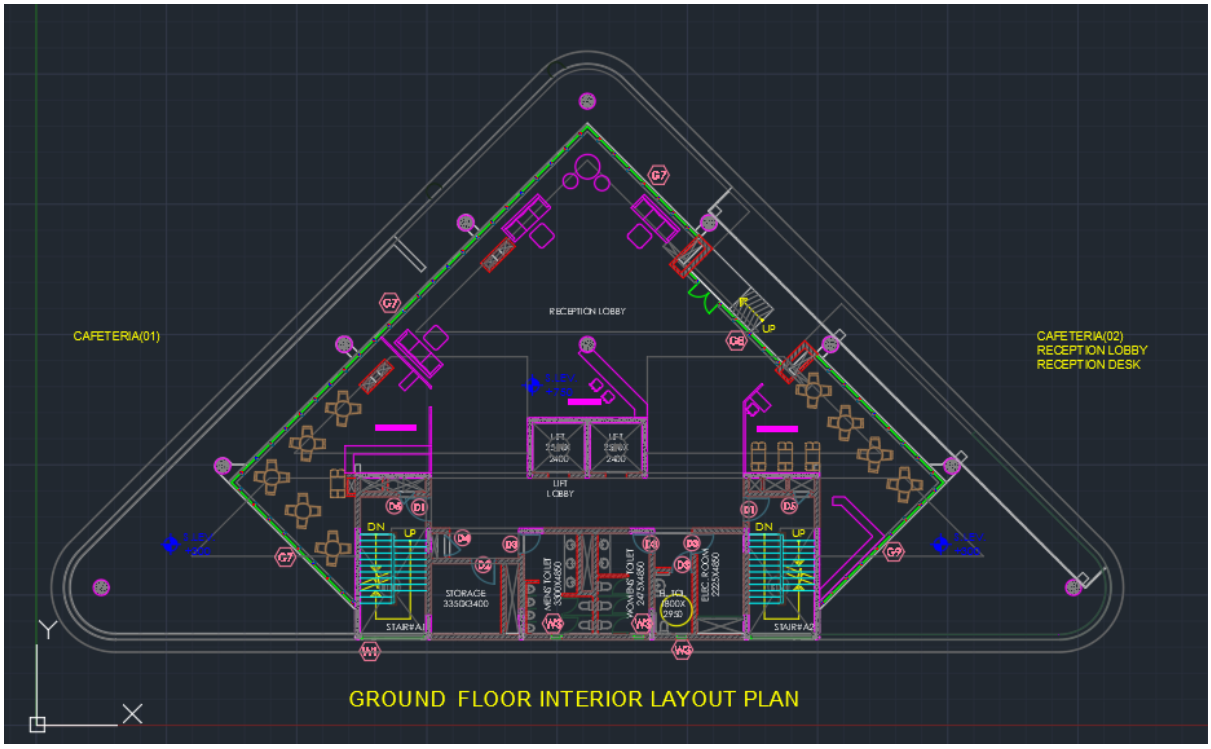


Fig 5.1: AutoCAD layout for Ground Floor of GRIDCO Building

5.2.5. Design Input Parameters: One of the main factors for selecting the type of luminaires is the ceiling type of different rooms and mounting heights. The ceiling type and mounting height of different rooms are given below –

Room Name	Floor	Room Height (m)	Ceiling Type	Mounting Height (m)
Cafeteria	Ground Floor	3.6	False Ceiling	3
Reception, Lobby	Ground Floor	3.6	False Ceiling	3
Lift Lobby	Ground Floor	3.6	False Ceiling	3
Electrical Room	Ground Floor	3.6	True Ceiling	3.6
Storage	Ground Floor	3.6	True Ceiling	3.6
Stairs	Ground Floor	3.6	True Ceiling	3.6
Toilet	Ground Floor	3.6	True Ceiling	3.6
Open Work-Station and Lobby	First Floor	3.6	False Ceiling	3
DGM Cabin	First Floor	3.6	False Ceiling	3
Battery Room	First Floor	3.6	True Ceiling	3.6
Board Room 1	First Floor	3.6	False Ceiling	3
Board Room 2	Second Floor	3.6	False Ceiling	3
Managing Director Cabin	Third Floor	3.6	False Ceiling	3

Table 5.1: Different application areas with heights and ceiling heights

Dimensions of different rooms are provided in the AutoCAD layouts.

5.2.6. Maintenance Factor and Reflectance: As GRIDCO building is majorly air-conditioned, the maintenance factor is considered as 0.85 and the reflectance of ceiling, walls and floor are 50%, 30% and 20% respectively.

5.3. Lighting design for different areas:

Now, the indoor lighting design for different areas of the GRIDCO building is shown separately under the following sections – DIALux design (Floor plan and 3D rendering), Characteristics of the luminaires used and results.

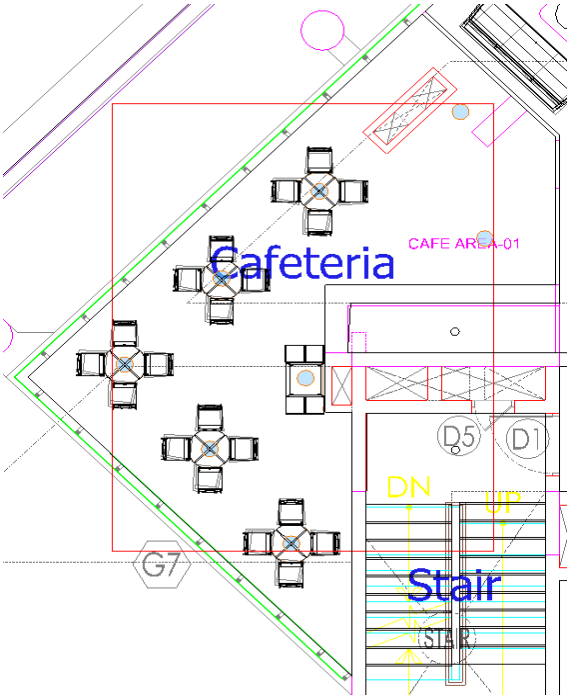
5.3.1. Ground Floor Rooms:

The AutoCAD layout of ground floor is given above. **(Refer Fig 5.1)**

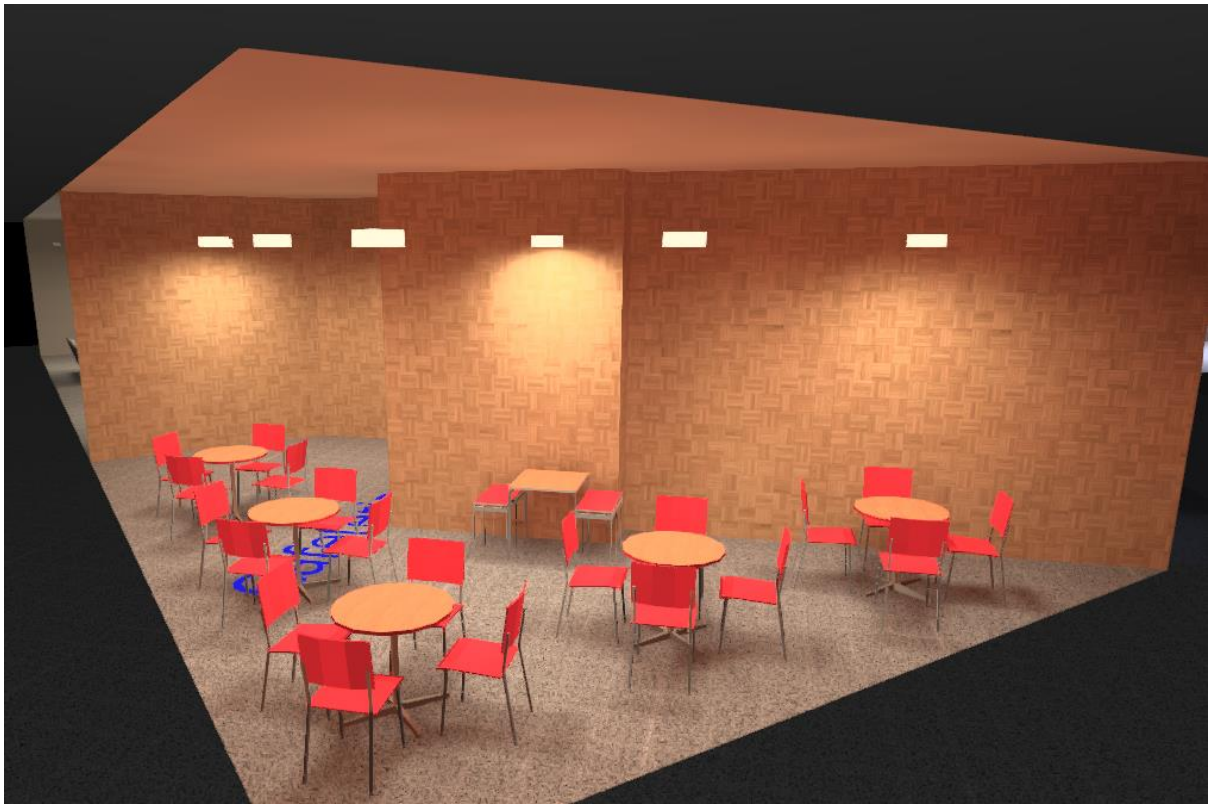
5.3.1.1. Cafeteria: The cafeteria located at the ground floor of the building has been illuminated using decorative lighting fixtures.

5.3.1.1.1. DIALux Design: After importing the ground floor dwg file in DIALux, the cafeteria room is drawn according to the layout with height of the room given as 3.6 m as specified. Some texture has been considered on the walls and floor (keeping the reflectance same as mentioned above) to generate an aesthetic look of the area. The luminaires were mounted just above the café tables to focus the lighting on the foods (task plane).

Floor Plan:



3D Rendering:



5.3.1.1.2. Luminaire Characteristics:

a. **Coral - LM56-301-XXX-40-WH** (Decorative Suspended)

Fig 5.2: Coral Luminaire [**10**]

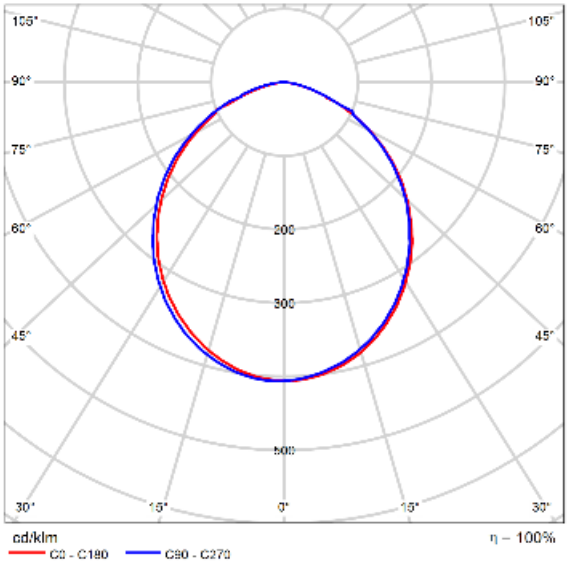


Fig 5.3: Polar LDC of Coral Luminaire

Type	Round LED Downlight
Mount Type	Suspended
Housing	Pressure die-cast Aluminium housing
Diffuser	High transmitive PMMA diffuser
System Lumen Output	2555 Lumen
Power	30 W
CCT	4000K
CRI	80 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.95
THD	<15%

Table 5.2: Characteristics of Coral (LM56-301-XXX-40-WH)

5.3.1.1.3. Result:

The lighting simulation of the cafeteria produces the following result –

Building 1 · Storey 1 · Cafeteria (Light scene 1)

Summary

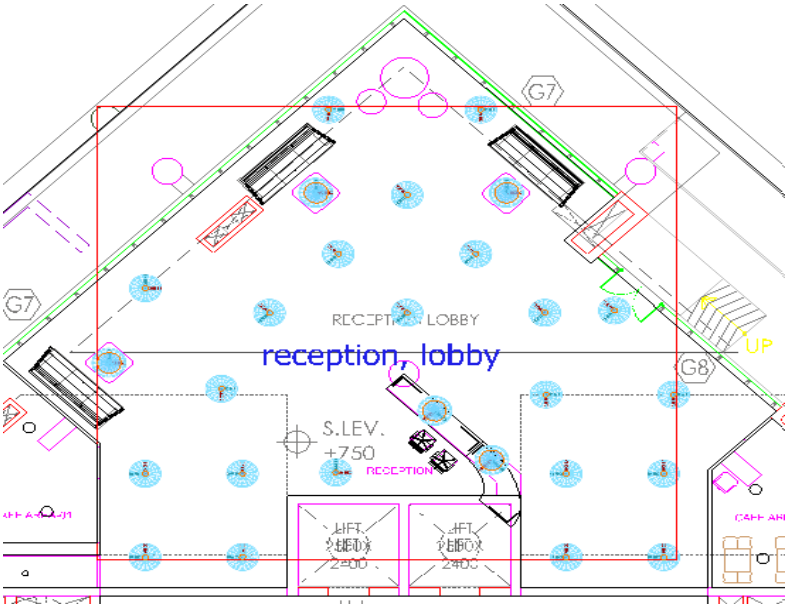
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	256 lx	≥ 200 lx	✓	WP9
	g_1	0.21	-	-	WP9
Consumption values	Consumption	40 kWh/a	max. 1650 kWh/a	✓	
Room	Lighting power density	5.26 W/m²	-	-	
		2.05 W/m²/100 lx	-	-	

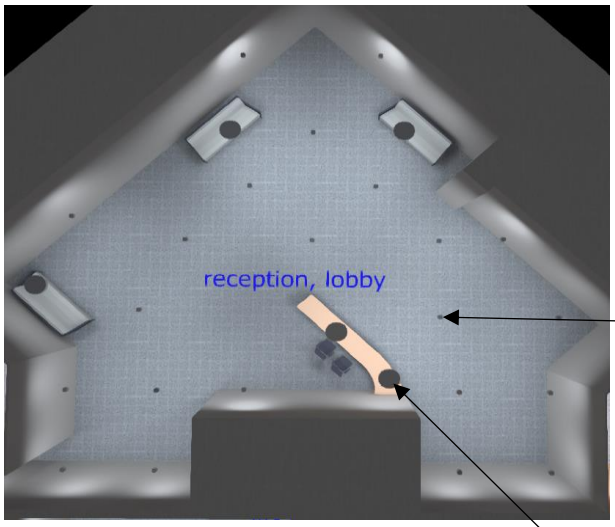
5.3.1.2. Reception, Lobby: The reception and lobby area located at the ground floor of the building has been illuminated using suspended lighting fixtures.

5.3.1.2.1. DIALux Design: After importing the ground floor dwg file in DIALux, the reception-lobby room is drawn according to the layout with height of the room given as 3.6 m as specified. Some texture has been considered on the walls and floor (keeping the reflectance same as mentioned above) to generate an aesthetic look of the area. The suspended luminaires were mounted at a height of 3 m from floor.

Floor Plan:

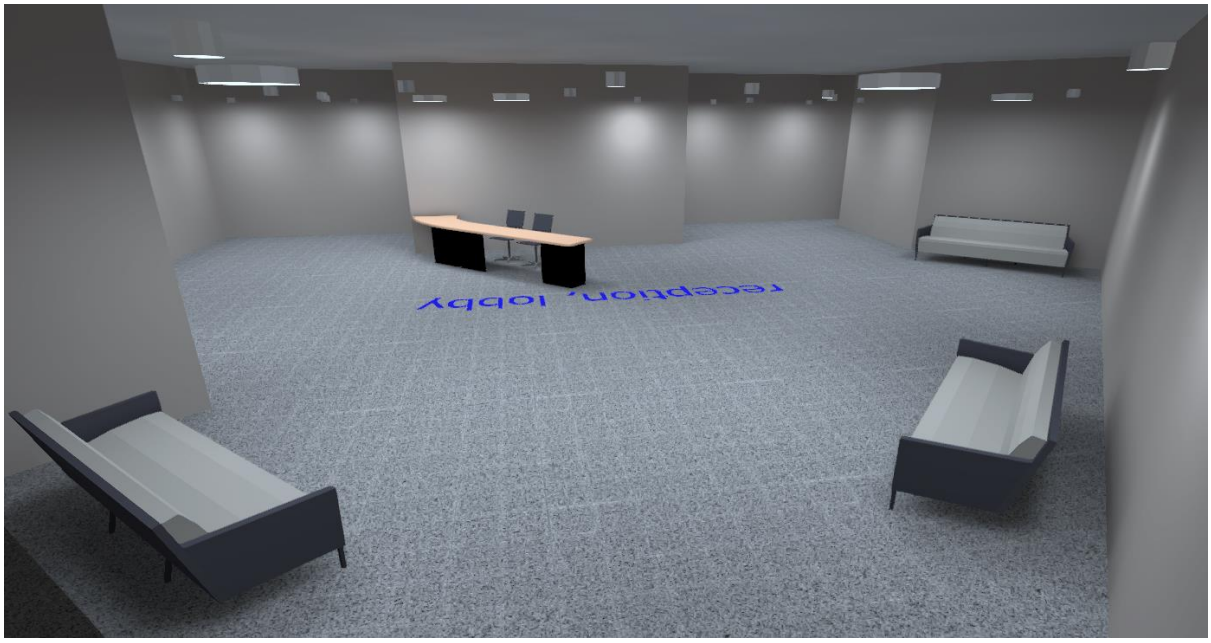


3D Rendering:



b. Halo Plus Luminaire

a. Orbit Ring Luminaire



5.3.1.2.2. Luminaire Characteristics:

a. Orbit Ring - LM230R-621-XX57-XW

Fig 5.5: Orbit Ring Luminaire [**10**]

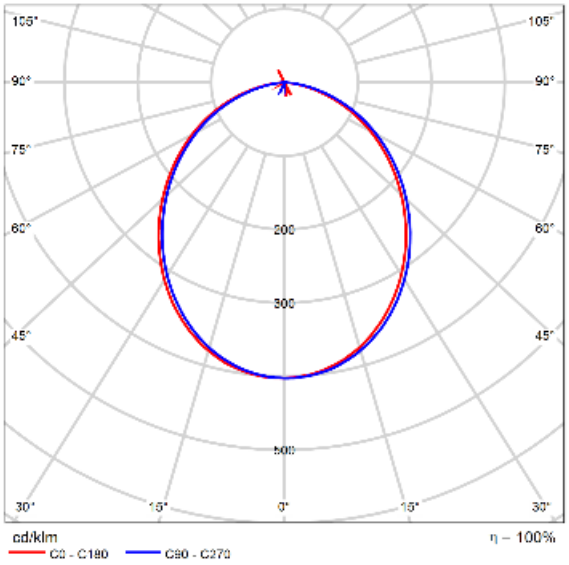


Fig 5.6: Polar LDC of Orbit Ring Luminaire

Type	Round LED Downlight
Mount Type	Suspended
Housing	Pressure die-cast Aluminium housing
Diffuser	High transmitive PMMA diffuser
System Lumen Output	2400 Lumen
Power	35 W

CCT	5700K
CRI	80 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.95
THD	<15%

Table 5.3: Characteristics of Orbit Ring (LM230R-621-XX57-XW)

b. Halo Plus - LD99-281-XXX57PMBL

Fig 5.7: Halo Plus Luminaire [**10**]

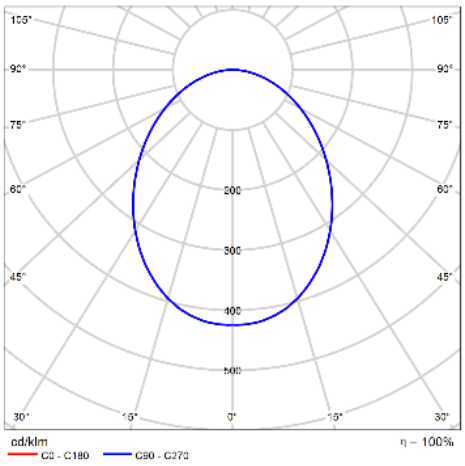


Fig 5.8: Polar LDC of Halo Plus Luminaire

Type	Round LED Downlight
Mount Type	Suspended
Housing	CRCA powder coating housing
Diffuser	Highly efficient transmissivity diffuser
System Lumen Output	1800 Lumen
Power	18 W
CCT	5700K
CRI	>80 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.95
THD	<10%

Table 5.4: Characteristics of Halo Plus (LD99-281-XXX57PMBL)

5.3.1.2.3. Result:

The lighting simulation of the Reception-Lobby area produces the following result –

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Reception desk Perpendicular illuminance Height: 0.801 m	286 lx	211 lx	327 lx	0.74	0.65	CG1

Building 1 · Storey 1 · reception, lobby (Light scene 1)

Summary

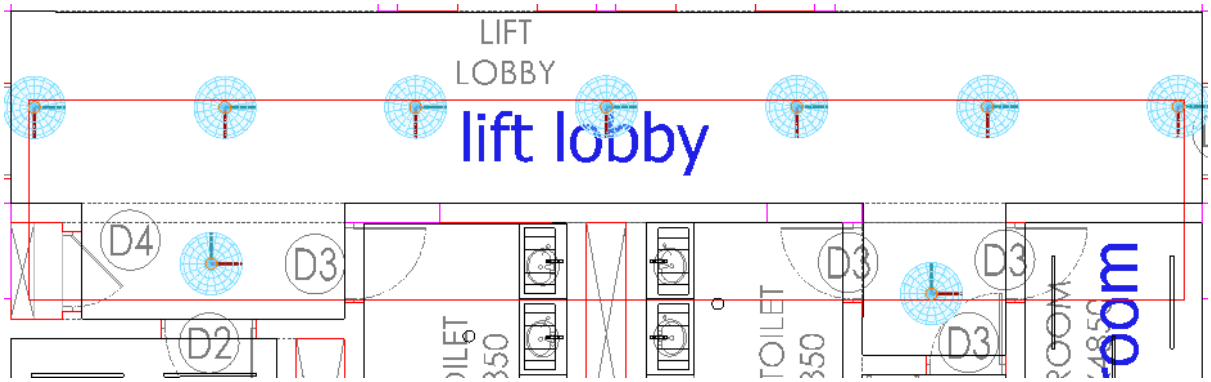
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$E_{perpendicular}$	210 lx	≥ 200 lx	✓	WP11
	g_1	0.22	-	-	WP11
Consumption values	Consumption	97 kWh/a	max. 6350 kWh/a	✓	
Room	Lighting power density	3.27 W/m²	-	-	
		1.56 W/m²/100 lx	-	-	

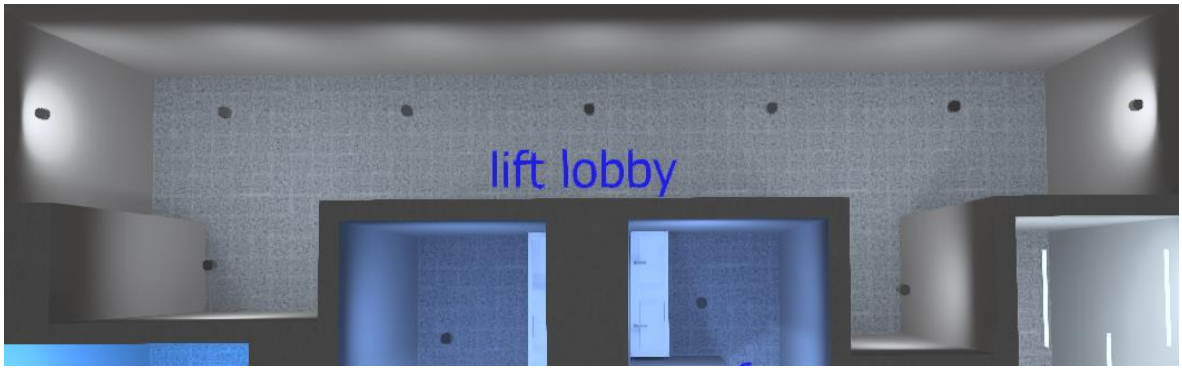
5.3.1.3. Lift Lobby: The lift lobby area located at the ground floor of the building has been illuminated using suspended lighting fixtures.

5.3.1.3.1. DIALux Design: After importing the ground floor dwg file in DIALux, the lift lobby room is drawn according to the layout with height of the room given as 3.6 m as specified. Some texture has been considered on the walls and floor (keeping the reflectance same as mentioned above) to generate an aesthetic look of the area. The suspended luminaires were mounted at a height of 3 m from floor.

Floor Plan:



3D Rendering:



5.3.1.3.2. Luminaire Characteristics: The characteristics of the luminaire used (**Halo Plus - LD99-281-XXX57PMBL)** is given in the section **5.7.1.2.2.**

5.3.1.3.3. Results:

The lighting simulation of the Lift Lobby area produces the following result –

Building 1 · Storey 1 · lift lobby (Light scene 1)

Summary

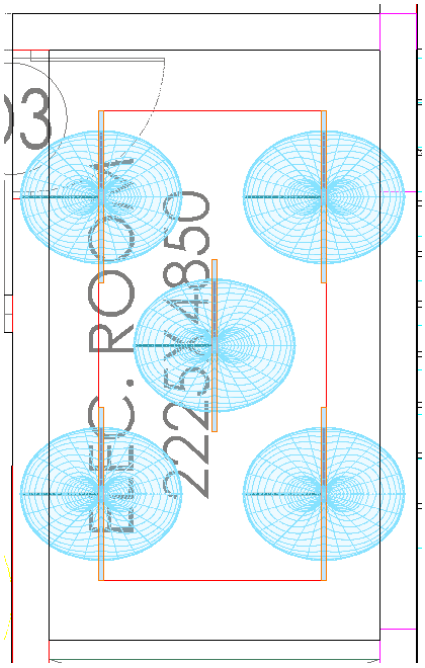
Results

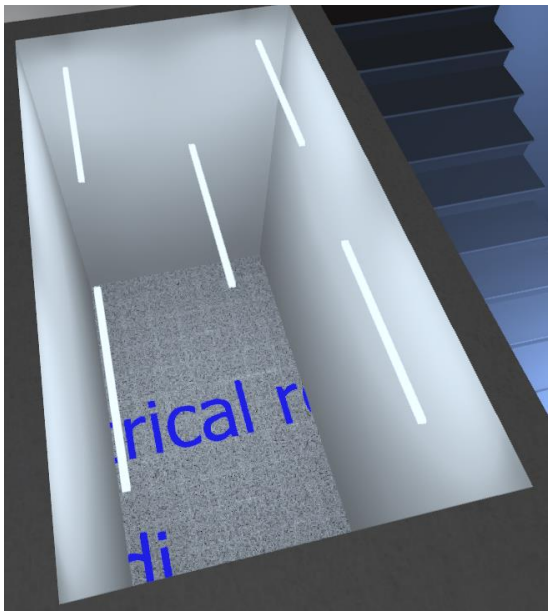
	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	178 lx	≥ 150 lx	✓	WP10
	g_1	0.45	-	-	WP10
Consumption values	Consumption	27 kWh/a	max. 1550 kWh/a	✓	
Room	Lighting power density	3.67 W/m²	-	-	
		2.07 W/m²/100 lx	-	-	

5.3.1.4. Electrical Room: The Electrical room located at the ground floor of the building has been illuminated using LED Batten type lighting fixtures.

5.3.1.4.1. DIALux Design: After importing the ground floor dwg file in DIALux, the Electrical room is drawn according to the layout with height of the room given as 3.6 m as specified. The suspended luminaires were mounted at a height of 3.6 m from floor as the luminaires are surface mounting type.

Floor Plan: *3D Rendering*:





5.3.1.4.2. Luminaire Characteristics:

a. Trim Neo LED Batten - LL20-221-XXX-65NE3

Fig 5.9: Trim Neo LED Batten Luminaire [**9**]

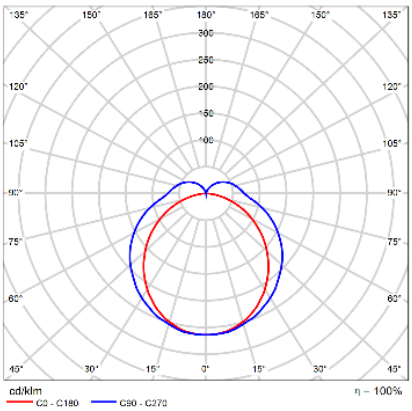


Fig 5.10: Polar LDC of Trim Neo LED Batten Luminaire

Type	4 ft LED Batten
Mount Type	Surface (Ceiling/wall)
Housing	Specially designed Co-extruded channel in thermally conductive material
Diffuser	HET diffuser
System Lumen Output	2001 Lumen
Power	20 W
CCT	6500K
CRI	80 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.9
THD	<20%

Table 5.5: Characteristics of Trim Neo LED Batten (LL20-221-XXX-65NE3)

5.3.1.4.3. Result: The lighting simulation of the Electrical room produces the following result –

Building 1 · Storey 1 · Electrical room (Light scene 1)

Summary

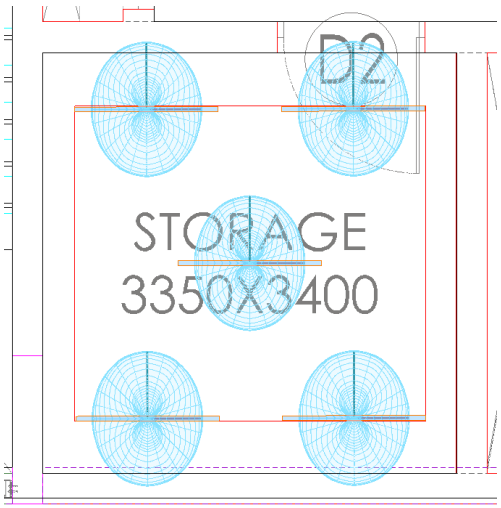
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	228 lx	≥ 200 lx	✓	WP3
	g_1	0.71	-	-	WP3
Consumption values	Consumption	17 kWh/a	max. 350 kWh/a	✓	
Room	Lighting power density	11.31 W/m²	-	-	
		4.95 W/m²/100 lx	-	-	

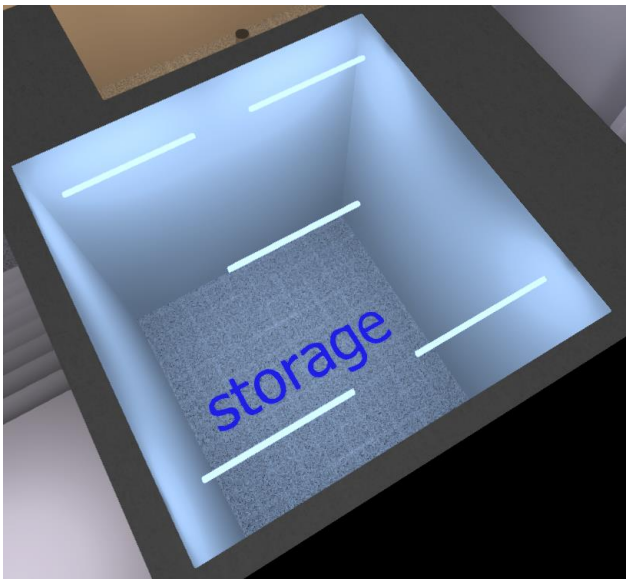
5.3.1.5. Storage: The Storage room located at the ground floor of the building has been illuminated using LED Batten type lighting fixtures.

5.3.1.5.1. DIALux Design: After importing the ground floor dwg file in DIALux, the Storage room is drawn according to the layout with height of the room given as 3.6 m as specified. The luminaires were mounted at a height of 3.6 m from floor as the luminaires are surface mounting type.

Floor Plan:



3D Rendering:



5.3.1.5.2. Luminaire Characteristics: The characteristics of the luminaire used (**Trim Neo LED Batten - LL20-221-XXX-65NE3)** is given in the section **5.7.1.4.2.**

5.3.1.5.3. Result: The lighting simulation of the Storage room produces the following result –

Building 1 · Storey 1 · storage (Light scene 1)

Summary

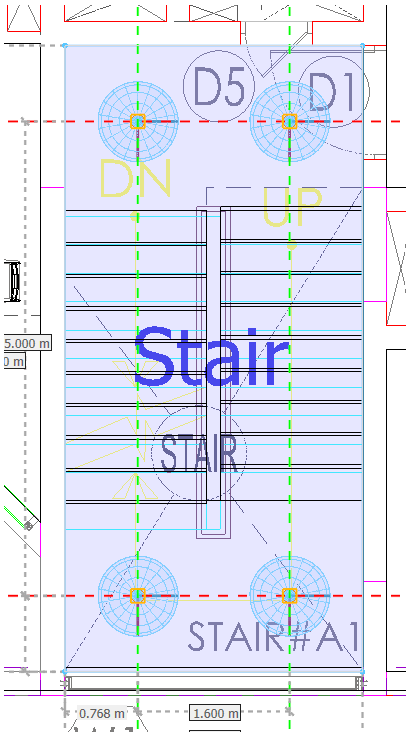
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	206 lx	≥ 200 lx	✓	WP2
	g_1	0.70	-	-	WP2
Consumption values	Consumption	17 kWh/a	max. 450 kWh/a	✓	
Room	Lighting power density	8.77 W/m²	-	-	
		4.25 W/m²/100 lx	-	-	

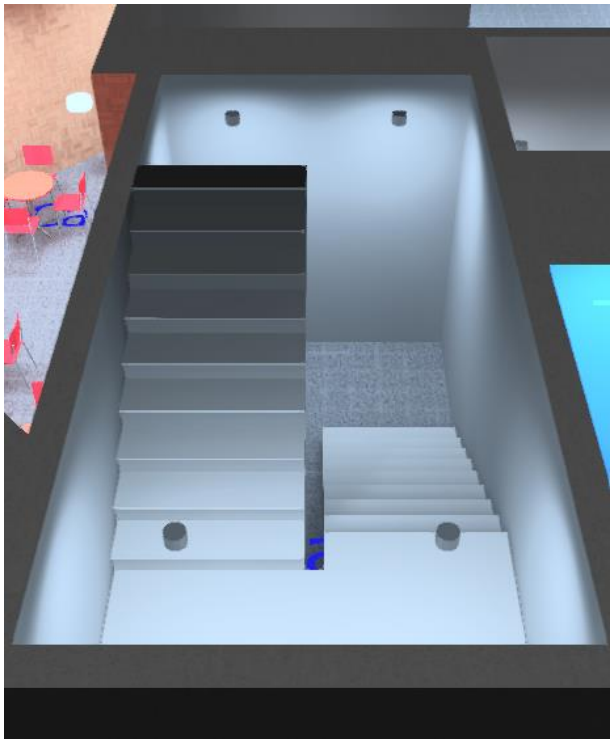
5.3.1.6. Stairs: The Stairs located at each floor of the building has been illuminated using LED Downlight luminaires.

5.3.1.6.1. DIALux Design: After importing the ground floor dwg file in DIALux, the Stairs is considered as a room and is drawn according to the layout with height of the room given as 3.6 m as specified. The suspended luminaires were mounted at a height of 3.6 m from floor as the luminaires are surface mounting type.

Floor Plan:



3D Rendering:



5.3.1.6.2. Luminaire Characteristics:

a. Mollis Surface - LD06-221XXX-57SMG1

Fig 5.11: Mollis Surface Luminaire [**10**]

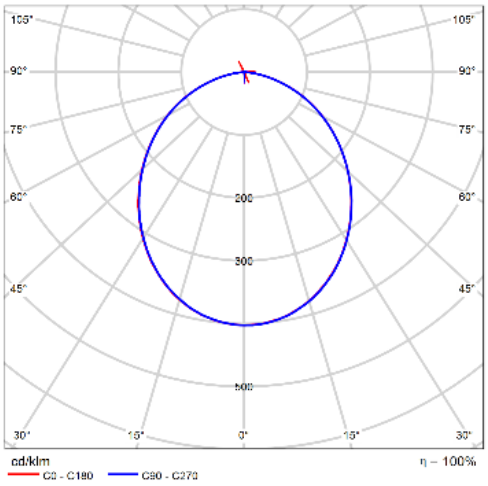


Fig 5.12: Polar LDC of Mollis Surface Luminaire

Type	Round LED Downlight
Mount Type	Surface
Housing	pressure die-cast Aluminium housing
Diffuser	high transmitive PS diffuser
System Lumen Output	1800 Lumen
Power	18 W
CCT	5700K
CRI	80 Ra
Voltage Range	90 V-265 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 40
Power Factor	0.9
THD	<10%

Table 5.6: Characteristics of Mollis Surface (LD06-221XXX-57SMG1)

5.3.1.6.3. Result: The lighting simulation of the Stairs area produces the following result –

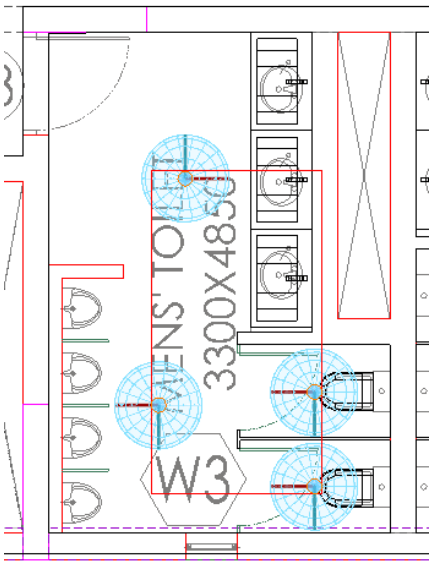
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	62.1 lx	≥ 50.0 lx	✓	WP1
	g_1	0.006	-	-	WP1
Consumption values	Consumption	12 kWh/a	max. 750 kWh/a	✓	
Room	Lighting power density	3.49 W/m²	-	-	
		5.62 W/m²/100 lx	-	-	

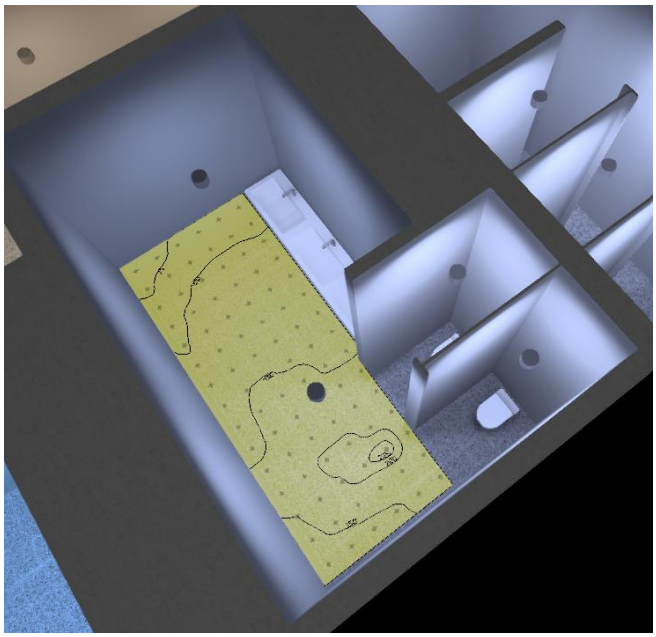
5.3.1.7. Toilet-Male: The male washroom located at each floor of the building has been illuminated using LED Downlight luminaires.

5.3.1.7.1. DIALux Design: After importing the ground floor dwg file in DIALux, the toilet is drawn according to the layout with height of the room given as 3.6 m as specified. The suspended luminaires were mounted at a height of 3.6 m from floor as the luminaires are surface mounting type. A calculation surface named ‘men's toilet open area’ is considered to check the overall uniformity as the default calculation surface is being covered by the extrusion bodies such as wash basin, toilet etc.

Floor Plan:



3D Rendering:



5.3.1.7.2. Luminaire Characteristics: The characteristics of the luminaire used (**Mollis Surface - LD06-221XXX-57SMG1)** is given in the section **5.7.1.6.2.**

5.3.1.7.3. Result: The lighting simulation of the men's toilet area produces the following result –

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
men's toilet open area Perpendicular illuminance Height: 0.800 m	139 lx	62.4 lx	236 lx	0.45	0.26	CG2

Building 1 · Storey 1 · toi-m (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Workplane	$Ē_{perpendicular}$	126 lx	≥ 100 lx	✓	WP5
	g_1	0.023	-	-	WP5
Consumption values	Consumption	12 kWh/a	max. 500 kWh/a	✓	
Room	Lighting power density	5.30 W/m²	-	-	
		4.22 W/m²/100 lx	-	-	

5.3.2. First Floor Rooms:

The first floor of GRIDCO Building basically consists of open workstation, personal cabins, conference and board rooms. The AutoCAD layout of first floor is given below –

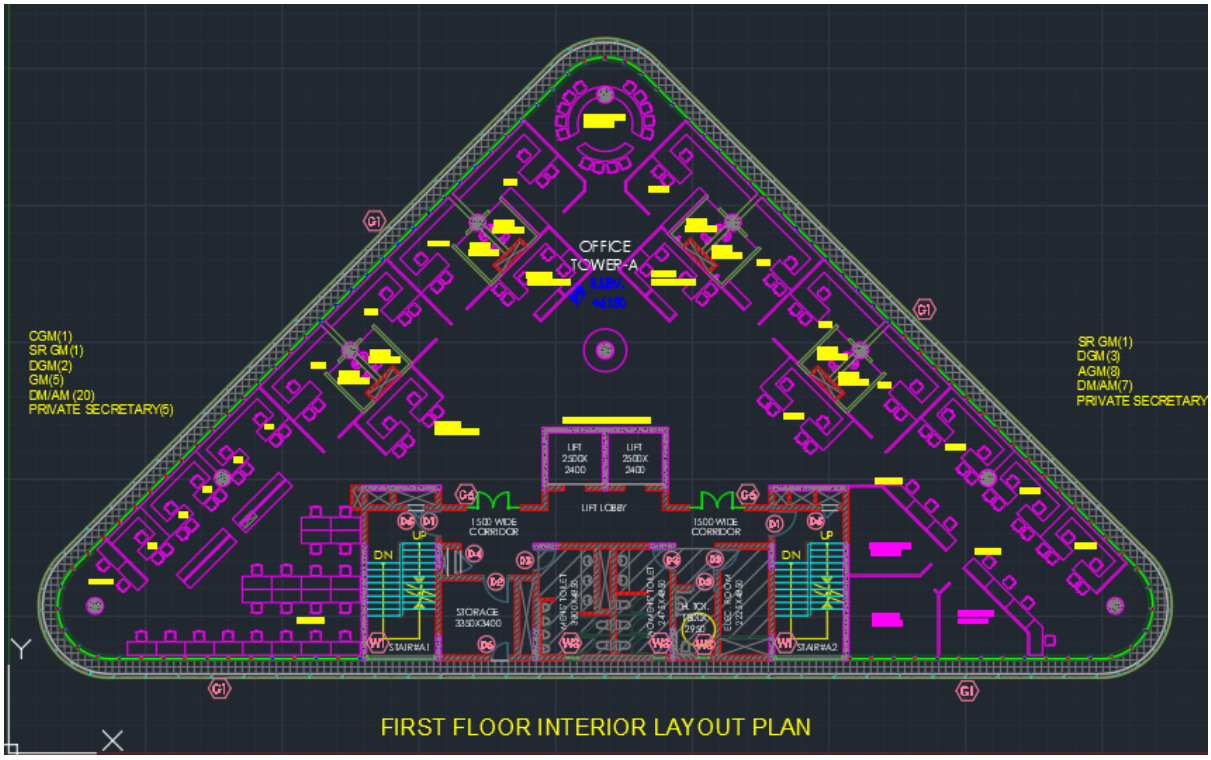
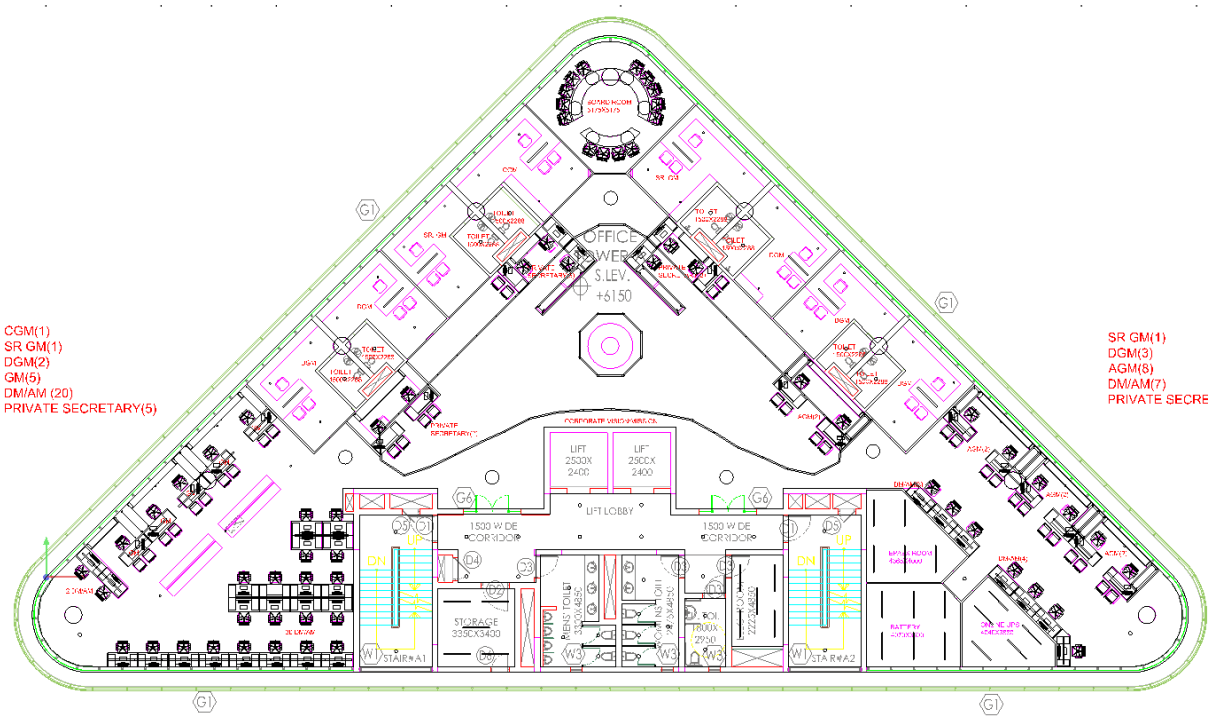


Fig 5.13: AutoCAD layout for First Floor of GRIDCO Building

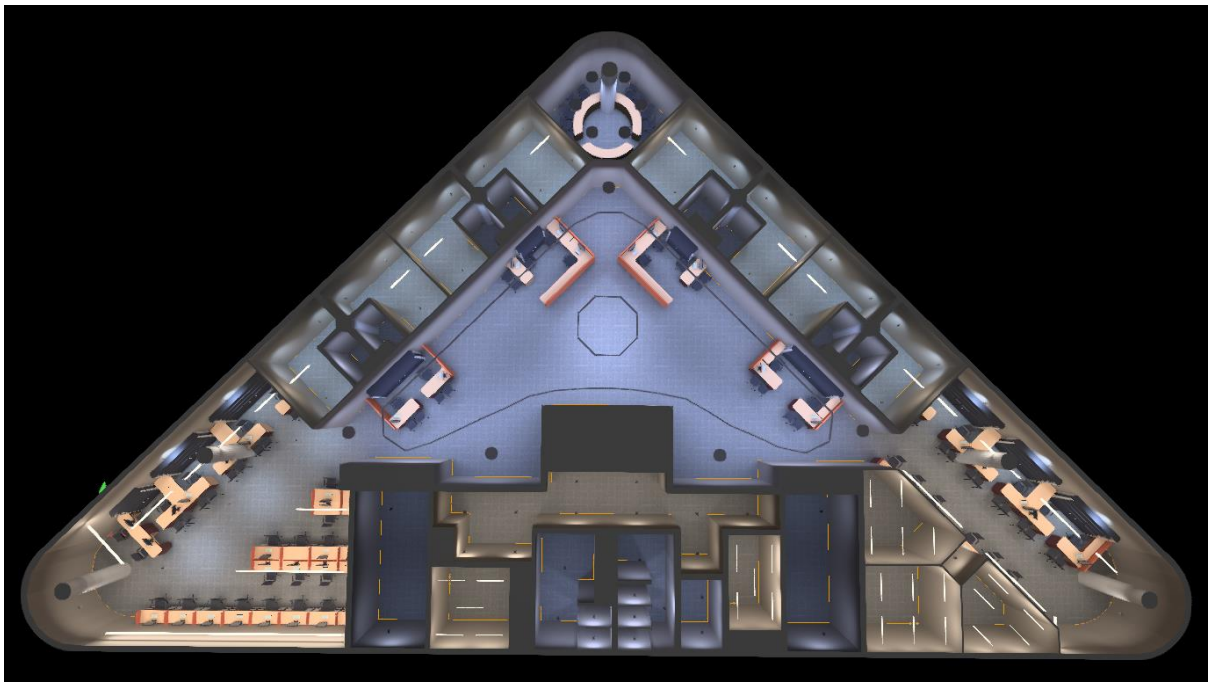
5.3.2.1. Open Workstation and Lobby: The open workstation consists of a handful number of cubicles and some personal desks like GMs' desks, AGMs' desks, Private Secretary's desk etc. As the structure and shape of the open work-station area is kind of different and unique, so a couple of luminaires channels were formed to give the lighting fixture arrangements an aesthetic appearance. The area is mostly illuminated using suspended linear LED channel.

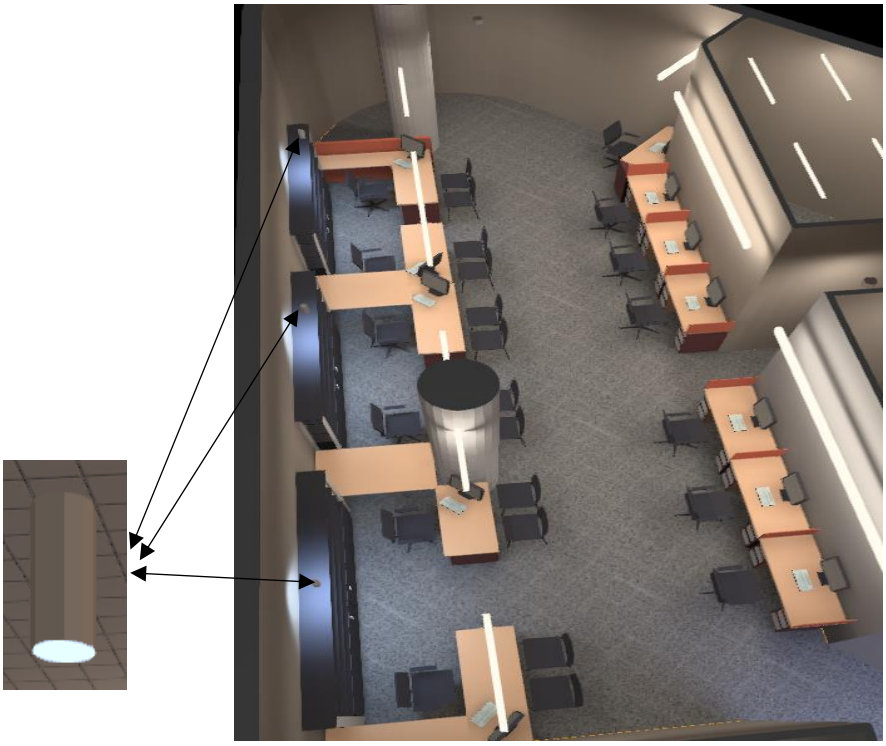
5.3.2.1.1. DIALux Design: After importing the first floor dwg file in DIALux, the open workstation area is drawn according to the layout with height of the room given as 3.6 m as specified. Some texture has been considered on the walls and floor (keeping the reflectance same as before) to generate an aesthetic look of the area.

Floor Plan:

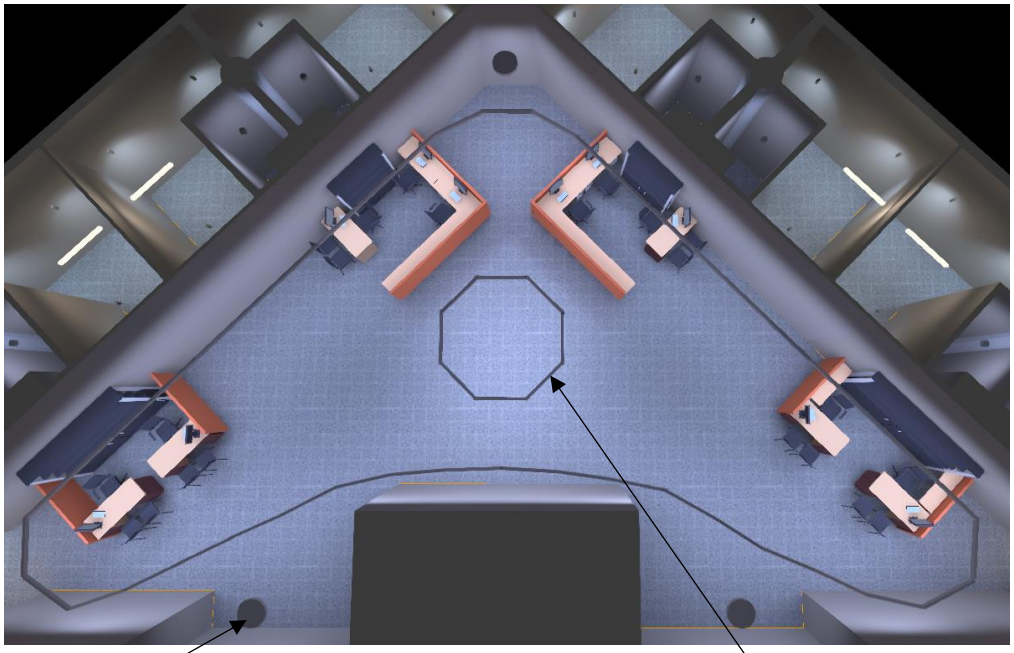


3D Rendering:





b. Vertica Luminaire



c. Orbit Ring

a. Stylus Linear LED Channel

5.3.2.1.2. Luminaires Characteristics:

a. Stylus LED linear Channel (LM43-491-XXX-57-WC, LM43-321-XXX-40-WC)

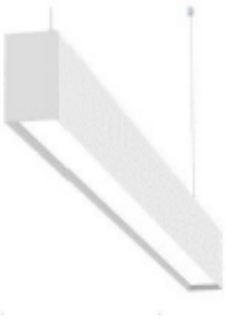


Fig 5.14: Stylus Luminaire [**10**]

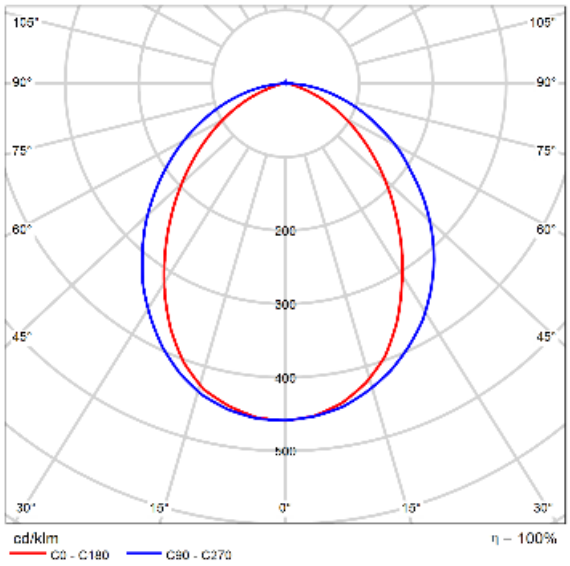


Fig 5.15: Polar LDC of Stylus Luminaire

Type	LED Linear Channel (WC), LED Linear profile (WX)
Mount Type	Suspended
Housing	White powder coated finish extruded aluminium housing
Diffuser	Special translucent satin finish colour LED PMMA Diffuser
System Lumen Output	**LM43-491-XXX-57-WC/WX** - 3300 Lumens, **LM43-321-XXX-40-WC** - 1900 Lumens
Power	**LM43-491-XXX-57-WC/WX** – 30 W, **LM43-321-XXX-40-WC** - 20 W
CCT	**LM43-491-XXX-57-WC/WX** – 5700K, **LM43-321-XXX-40-WC** - 4000K
CRI	84 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.95
THD	<10%

Table 5.7: Characteristics of **Stylus LED** (**LM43-491-XXX-57-WC**)

b. Vertica - LD30-201-60W-40-PS

Fig 5.16: Vertica Luminaire [**10**]

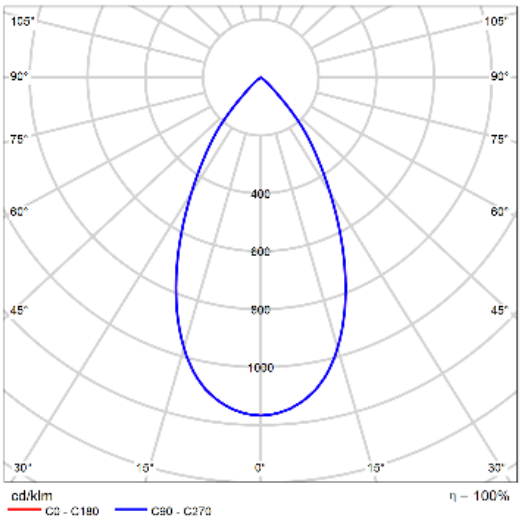


Fig 5.17: Polar LDC of Vertica Luminaire

Type	integral Round LED Downlight
Mount Type	Suspended
Optics	superior optics clubbed with variety of beam angles (36 and 60 degree) to create the right play of light
System Lumen Output	2000 Lumens
Power	20 W
CCT	4000K
CRI	84 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.95
THD	<10%

Table 5.8: Characteristics of **Vertica** (**LD30-201-60W-40-PS**)

c. Orbit Ring - LM230R-621-XX57-XW (Refer 5.7.1.2.2)

d. Halo Plus - LD99-281-XXX57PMBL (Refer 5.7.1.2.2)

5.3.2.1.3. Results:

The lighting simulation of the open workstation produces the following result –

Results on considered Calculation surface 1—

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
open work-station desk Perpendicular illuminance Height: 0.801 m	397 lx	285 lx	462 lx	0.72	0.62	CG1

Results on considered Calculation surface 2—

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
private secretary desk Perpendicular illuminance Height: 0.801 m	418 lx	384 lx	445 lx	0.92	0.86	CG3

General result on for the whole open workstation area—

Building 1 · Storey 1 · Open Work-Station and Lobby (Light scene 1)

Summary

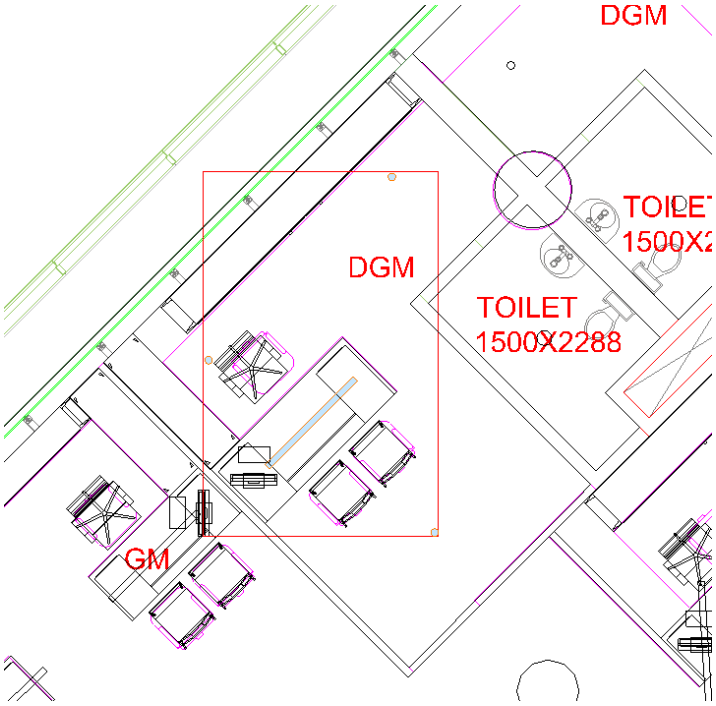
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	354 lx	≥ 300 lx	✓	WP24
	g_1	0.023	-	-	WP24
Consumption values	Consumption	410 kWh/a	max. 13400 kWh/a	✓	
Room	Lighting power density	6.43 W/m²	-	-	
		1.82 W/m²/100 lx	-	-	

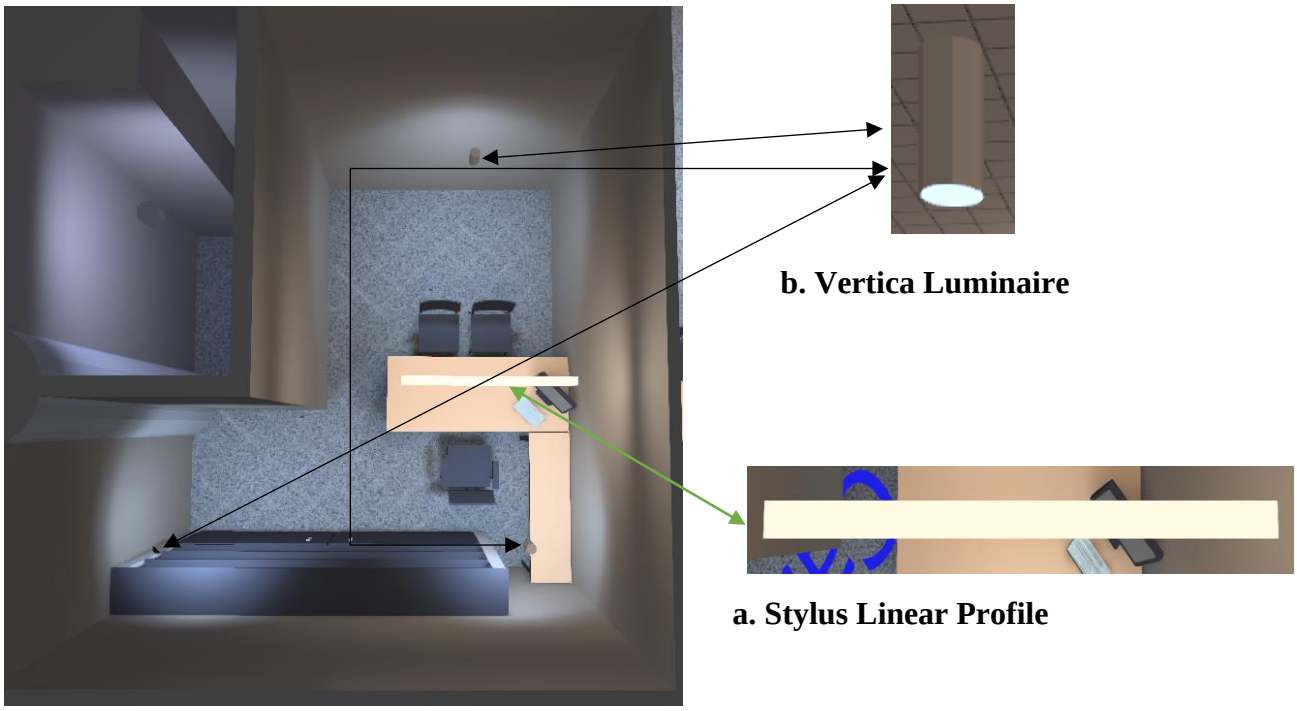
5.3.2.2. DGM's Cabin: The DGM's cabins located at first floor of the building have been illuminated using suspended Linear LED profile and LED COB Downlight luminaires.

5.3.2.2.1. DIALux Design: After importing the first floor dwg file in DIALux, the DGM's cabin area is drawn according to the layout with height of the room given as 3.6 m as specified. Some texture has been considered on the walls and floor (keeping the reflectance same as before).

Floor Plan:



3D Rendering:



b. Vertica Luminaire

a. Stylus Linear Profile

5.3.2.2.2. Luminaires Characteristics:

a. **Stylus LED linear Profile - LM43-491-XXX-57-WX (Refer 5.7.2.1.2)**

b. **Vertica - LD30-201-60W-40-PS (Refer 5.7.2.1.2)**

5.3.2.2.3. Results:

Results on considered Calculation surface 1—

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
DGM desk Perpendicular illuminance Height: 0.801 m	349 lx	279 lx	451 lx	0.80	0.62	CG4

General result on for the DGM's Cabin—

Building 1 · Storey 1 · DGM Cabin (Light scene 1)

Summary

Results

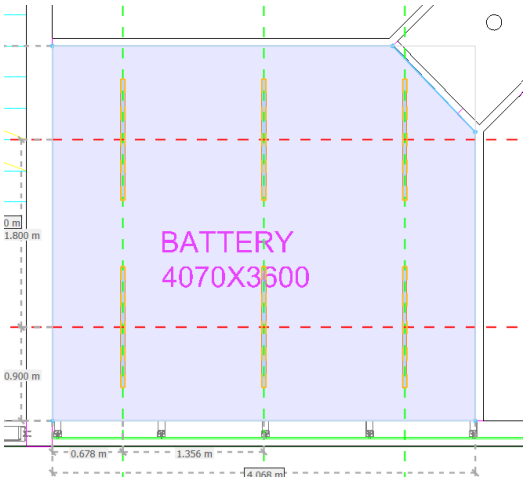
	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	330 lx	≥ 300 lx	✓	WP13
	g_1	0.027	-	-	WP13
Consumption values	Consumption	15 kWh/a	max. 500 kWh/a	✓	
Room	Lighting power density	7.01 W/m²	-	-	
		2.12 W/m²/100 lx	-	-	

5.3.2.3. Battery Room:

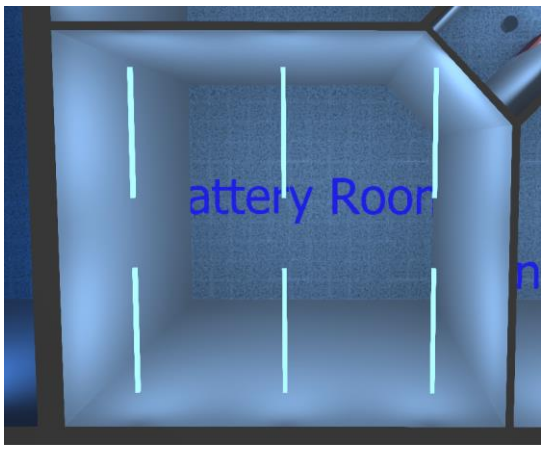
The Battery room located at the first floor of the building has been illuminated using LED Batten type lighting fixtures.

5.3.2.3.1. DIALux Design: After importing the first floor dwg file in DIALux, the Battery room is drawn according to the layout with height of the room given as 3.6 m as specified. The luminaires were mounted at a height of 3.6 m from floor as the luminaires are surface mounting type.

Floor Plan-



3D Rendering-



5.3.2.3.2. Luminaire Characteristics: The characteristics of the luminaire used (**Trim Neo LED Batten - LL20-221-XXX-65NE3)** is given in the section **5.7.1.4.2.**

5.3.2.3.3. Result: The lighting simulation of the battery room area produces the following result –

Building 1 · Storey 1 · Battery Room (Light scene 1)

Summary

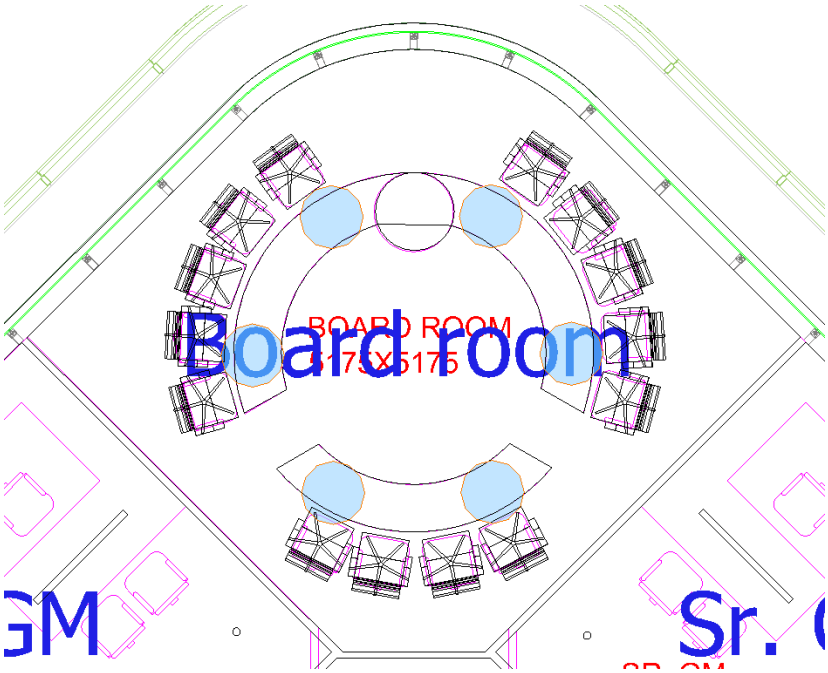
Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	229 lx	≥ 200 lx	✓	WP1
	g_1	0.69	-	-	WP1
Consumption values	Consumption	20 kWh/a	max. 550 kWh/a	✓	
Room	Lighting power density	8.38 W/m²	-	-	
		3.66 W/m²/100 lx	-	-	

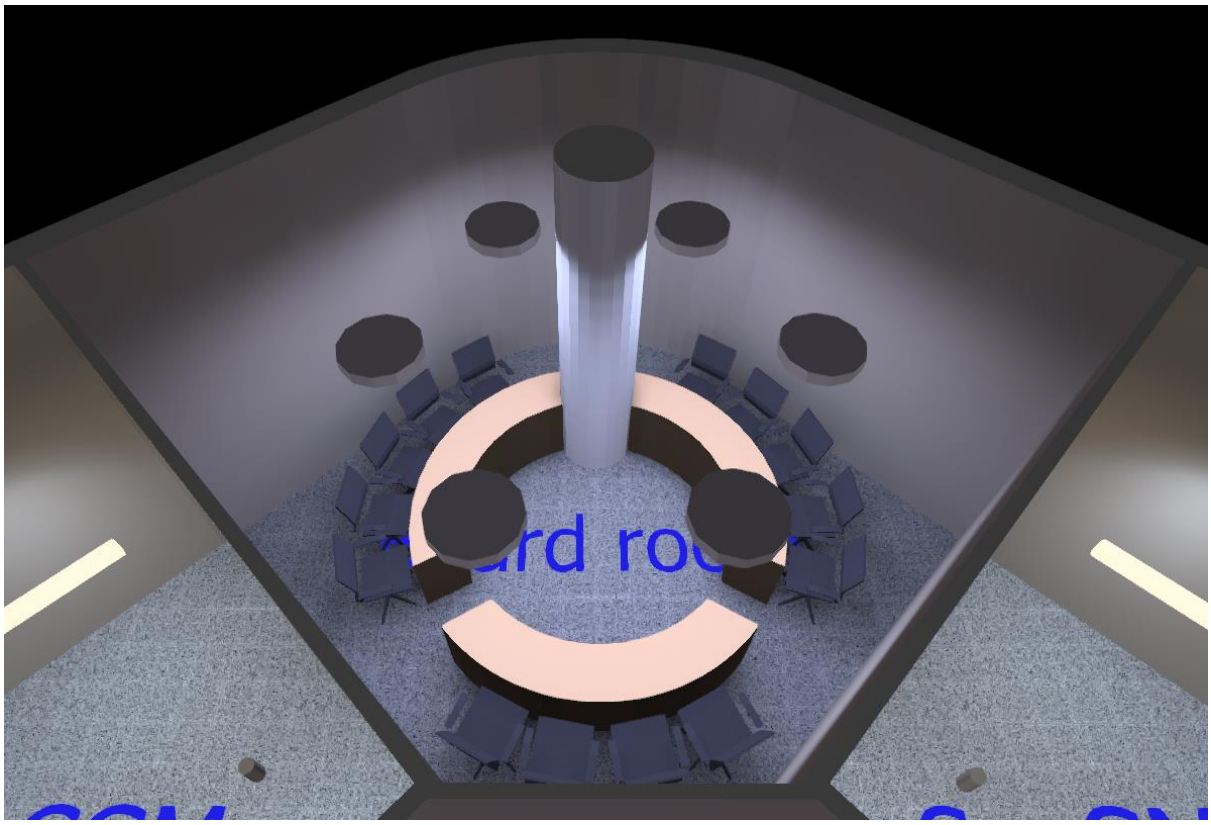
5.3.2.4. Board Room 1: The Board room located at the first floor of the building has been illuminated using LED hanging decorative type lighting fixtures.

5.3.2.3.1. DIALux Design: After importing the first floor dwg file in DIALux, the Board room is drawn according to the layout with height of the room given as 3.6 m as specified. The suspended luminaires were mounted at a height of 3 m from floor. Since the shape of the task plane (meeting desk) is circle, so circular arrangement of the luminaires is considered.

Floor Plan-



3D Rendering-



5.3.2.3.2. Luminaires Characteristics: The characteristics of the luminaire used (**Orbit Ring - LM230R-621-XX57-XW)** is given in the section **5.7.1.2.2.**

5.3.2.3.3. Result: The lighting simulation of the Board room 1 produces the following result –

Results on considered Calculation surface 1—

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
borad room desk Perpendicular illuminance Height: 0.800 m	424 lx	398 lx	451 lx	0.94	0.88	CG2

General result on for the Board Room 1—

Building 1 · Storey 1 · Board room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	307 lx	≥ 300 lx	✓	WP8
	g_1	0.35	-	-	WP8
Consumption values	Consumption	35 kWh/a	max. 900 kWh/a	✓	
Room	Lighting power density	8.32 W/m²	-	-	
		2.71 W/m²/100 lx	-	-	

5.3.3. Second Floor Room:

The second floor also consists of open work-station, other cabins, storage, electrical rooms, toilets which are more or less identical as compared to first floor. The significant room in second floor is the Board room 2 which is discussed below. The AutoCAD layout of second floor is –

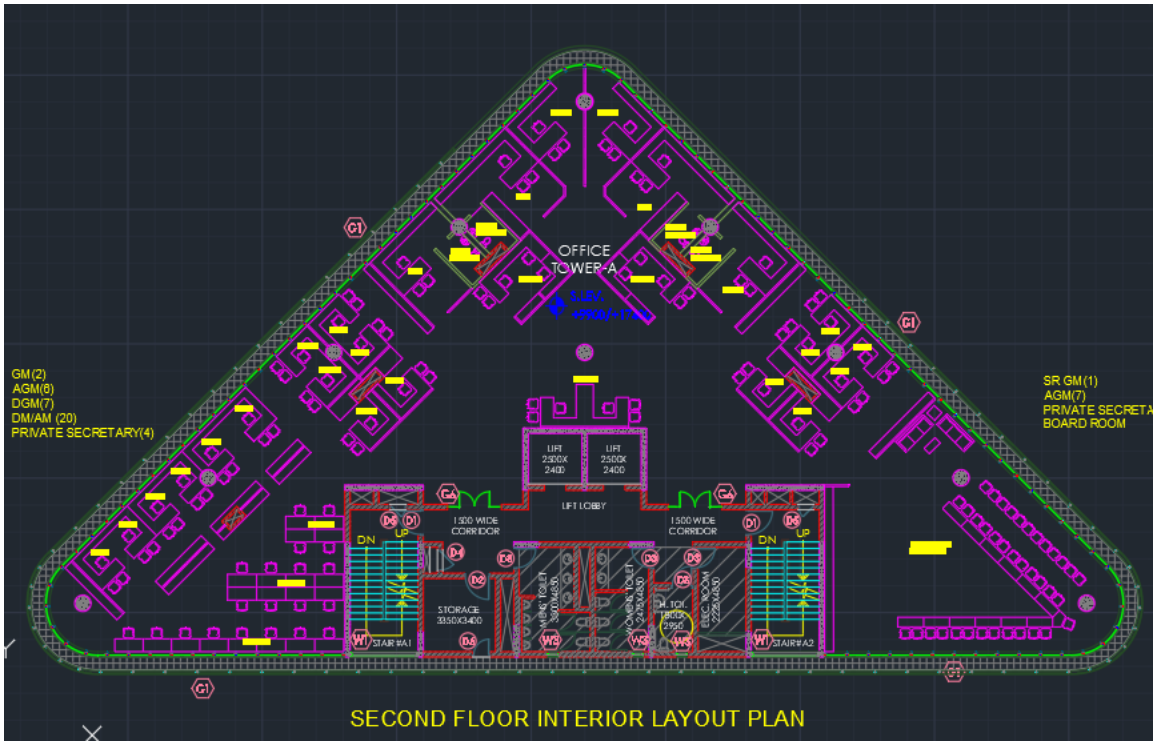
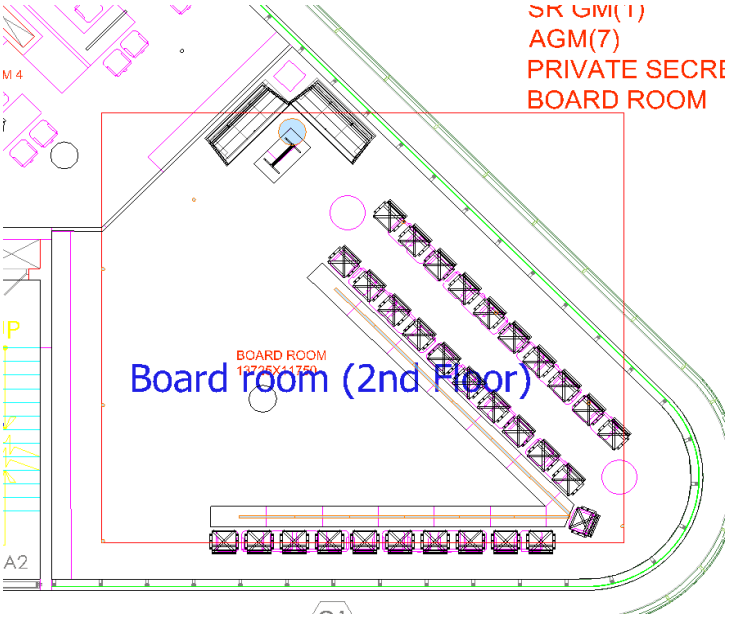


Fig 5.18: AutoCAD layout of second floor

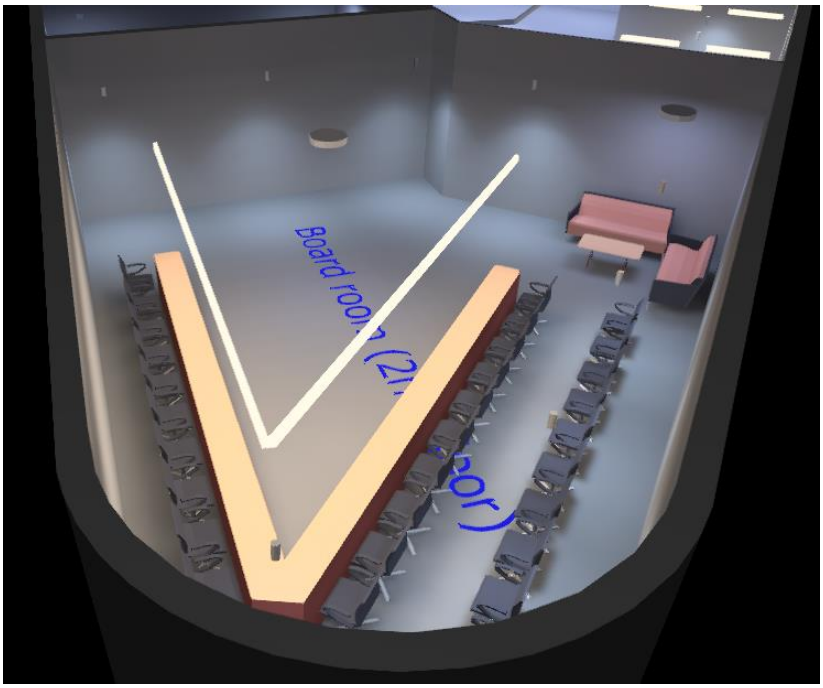
5.3.3.1. Board Room 2: The Board room 2 located at the second floor of the building has been illuminated using LED suspended linear channel lighting fixtures.

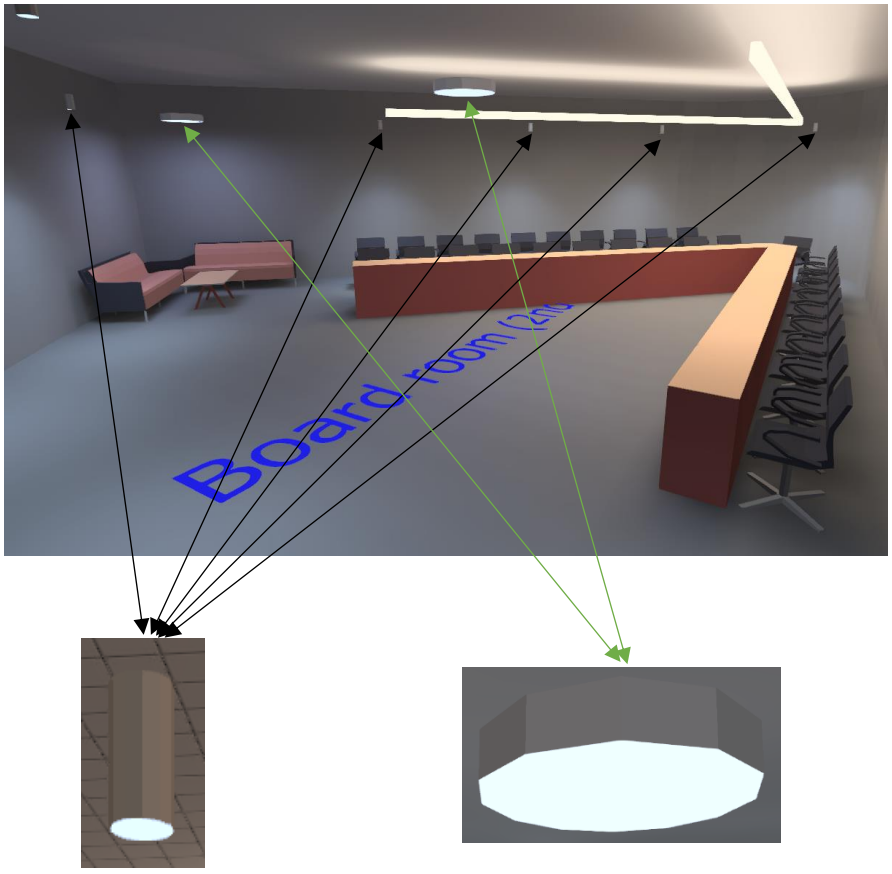
5.3.3.1.1. DIALux Design: After importing the second floor dwg file in DIALux, the Board room 2 is drawn according to the layout with height of the room given as 3.6 m as specified. The suspended luminaires were mounted at a height of 3 m from floor. According to the shape of board room desk, the LED linear channel has been designed.

Floor Plan-



3D Rendering-





b. Vertica Luminaire **c. Orbit Ring**

5.3.3.1.2. Luminaires Characteristics:

a. The characteristics of the luminaire used (**Stylus LED linear Channel - LM43-491-XXX-57-WC)** is given in the section **5.7.2.1.2.**

b. The characteristics of the luminaire used (**Vertica - LD30-201-60W-40-PS**) is given in the section **5.7.2.1.2.**

c. The characteristics of the luminaire used (**Orbit Ring - LM230R-621-XX57-XW)** is given in the section **5.7.1.2.2.**

5.3.3.1.3. Results: The lighting simulation of the Board room 2 produces the following result –

Results on considered Calculation surface 1—

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
board room desk Perpendicular illuminance Height: 0.800 m	509 lx	257 lx	636 lx	0.50	0.40	CG2

General result on for the Board Room 2—

Building 1 · Storey 1 · Board room (2nd Floor) (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	339 lx	≥ 200 lx	✓	WP18
	g_1	0.26	-	-	WP18
Consumption values	Consumption	97 kWh/a	max. 3900 kWh/a	✓	
Room	Lighting power density	5.34 W/m²	-	-	
		1.57 W/m²/100 lx	-	-	

5.3.4. Third Floor room:

The second floor also consists of open work-station, other cabins, storage, electrical rooms, toilets which are more or less identical as compared to first floor. The significant room in third floor is the Managing Director's cabin which is discussed below. The AutoCAD layout of third floor is –

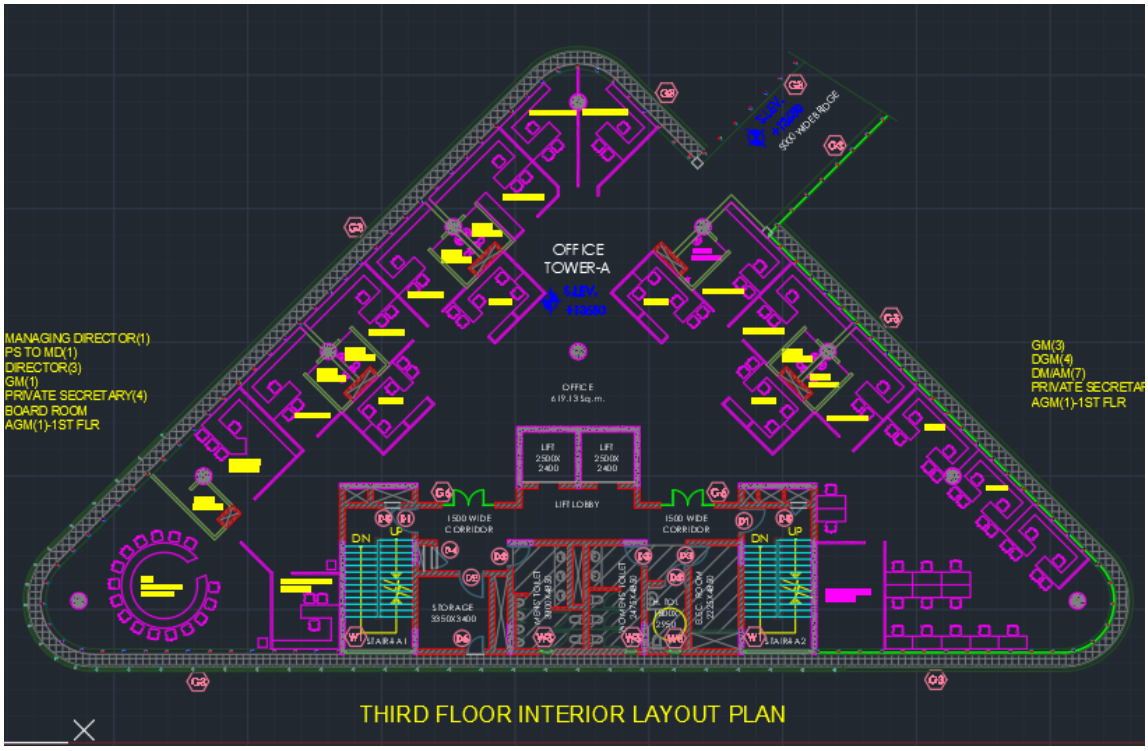
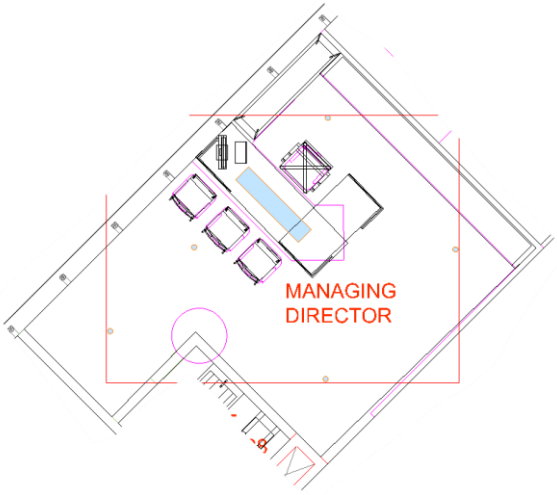


Fig 5.19: AutoCAD layout of third floor

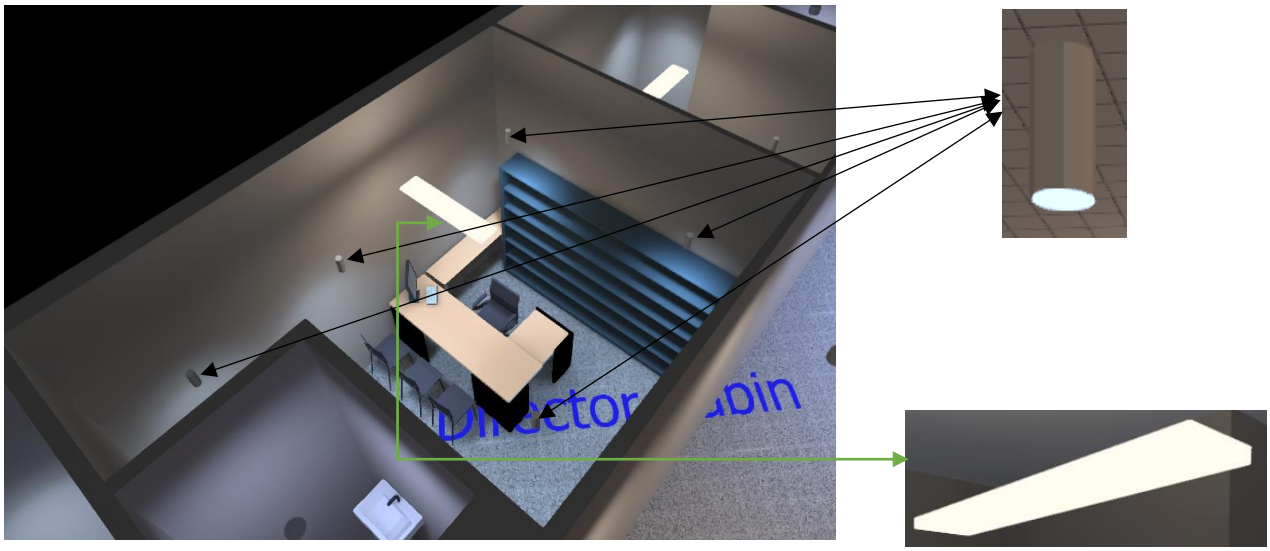
5.3.4.1. Managing Director Cabin: The Managing Director's cabin located at the third floor of the building has been illuminated using LED suspended linear channel and downlight type lighting fixtures.

5.3.3.1.1. DIALux Design: After importing the third floor dwg file in DIALux, the Managing Director's cabin is drawn according to the layout with height of the room given as 3.6 m as specified. The suspended luminaires were mounted at a height of 3 m from floor. As the position of the Managing Director is one of the most significant posts, so for this kind of rooms, 4ft x 1ft LED suspended linear profile is suggested above the task plane.

Floor Plan-



3D Rendering-



a. On-Air Luminaire

5.3.3.1.2. Luminaires Characteristics:

a. On-Air - LM44-701-XXX-57-WX

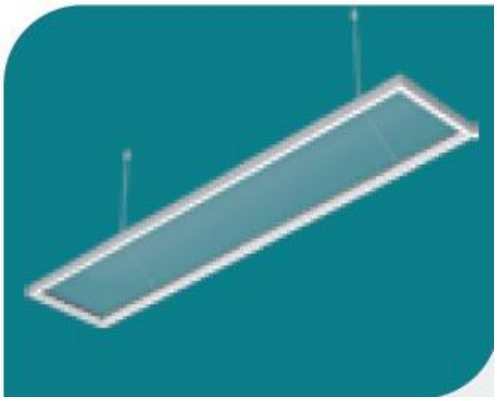


Fig 5.20: On-Air Luminaire [**10**] Luminaire

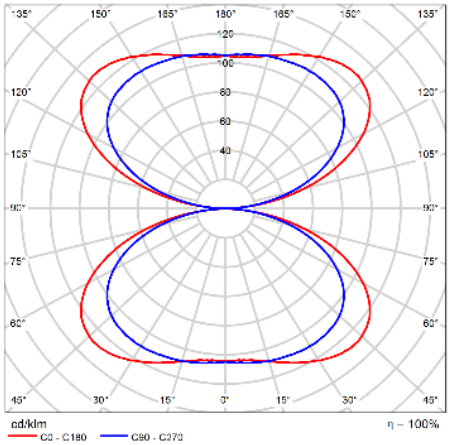


Fig 5.21: Polar LDC of On-Air

Type	Up-Down 4 ft x 1 ft high efficiency integrated LED Linear profile
Mount Type	Suspended
Housing	White Matt Powder Coated extruded aluminium Housing
Diffuser	Reflector+ Light guide plate+ Diffuser
System Lumen Output	3800 Lumens
Power	38 W
CCT	5700K
CRI	>80 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	2 KV
IP Rating	IP 20
Power Factor	0.95
THD	<10%

Table 5.9: Characteristics of **On-Air (LM44-701-XXX-57-WX)**

b. The characteristics of the luminaire used (**Vertica - LD30-201-60W-40-PS**) is given in the section **5.7.2.1.2.**

5.3.3.1.3. Result: The lighting simulation of the Managing Director's cabin produces the following result –

Results on considered Calculation surface 1—

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
managing director desk Perpendicular illuminance Height: 0.800 m	319 lx	271 lx	361 lx	0.85	0.75	CG1

General result on for the Managing Director's cabin—

Building 1 · Storey 1 · Managing Director Cabin (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Workplane	$\bar{E}_{perpendicular}$	364 lx	≥ 200 lx	✓	WP28
	g_1	0.030	-	-	WP28
Consumption values	Consumption	23 kWh/a	max. 700 kWh/a	✓	
Room	Lighting power density	7.05 W/m²	-	-	
		1.94 W/m²/100 lx	-	-	

5.4. <u>Lighting Layouts of different floors:</u> After achieving the desired average illuminance values and overall uniformity values by lighting simulation in DIALux, the luminaires layout is exported as a dwg file which can be imported in AutoCAD. There in AutoCAD, the luminaire layout is placed on the original imported layout to generate lighting layout as shown below-

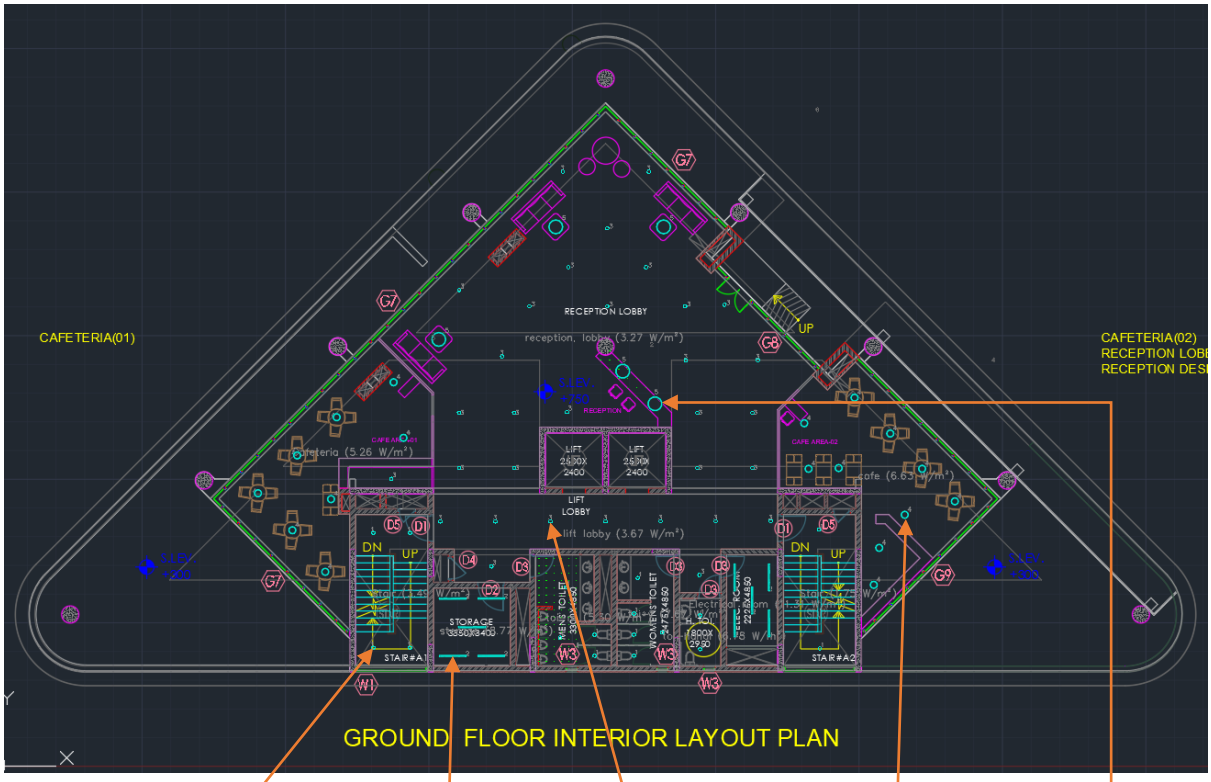
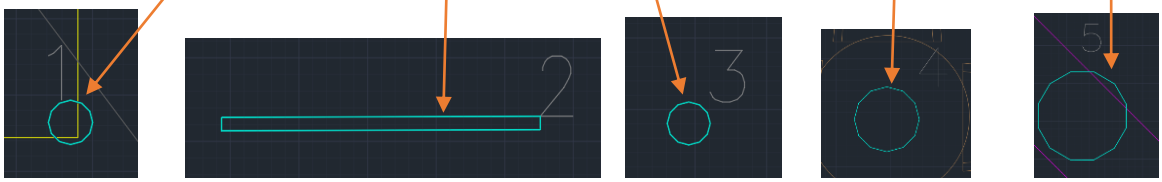


Fig 5.22: Lighting Layout of Ground Floor of GRIDCO Building



Luminaire list (Building 1, Storey 1)

Index	Manufacturer	Article name	Item number	Fitting	Luminous flux	Light loss factor	Connected load	Quantity
1	LD06-221XXX-57SMG1			2x	1800 lm	0.85	18 W	17
2	Wipro Lighting	TrimLED Neo – 4FT LED Batten	LL20-221-XXX-65NE3	1x LED	2001 lm	0.85	20 W	10
3	Wipro Lighting	Pendent mounted LED Downlighter	LD99-281-XXX57PMBL	1x LED	1800 lm	0.85	18 W	32
4			LM56-301-XXX-40-WH	1x	2555 lm	0.85	30.5 W	18
5	LM230R-621-XX57-XW Decorative Suspended Light			1x	2400 lm	0.85	35 W	5

Fig 5.23: Legends for Lighting Layout of ground floor

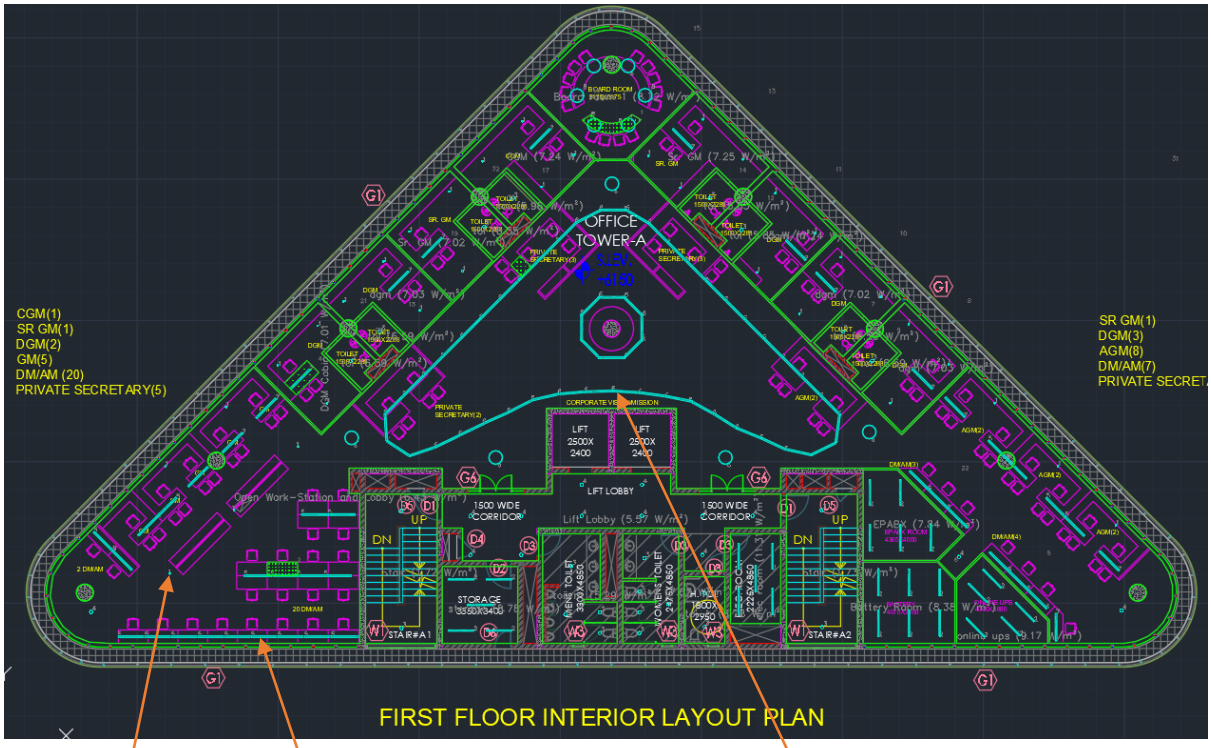
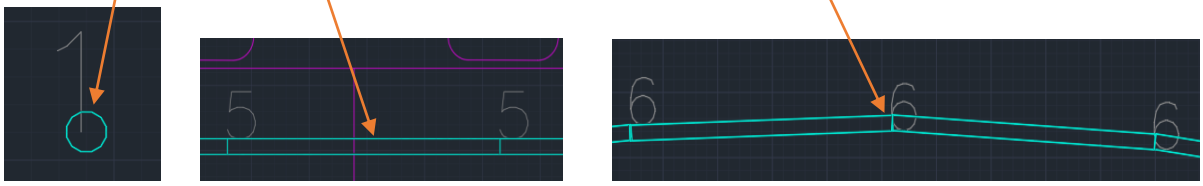


Fig 5.24: Lighting Layout of First Floor of GRIDCO Building



Luminaire list (Building 1, Storey 1)

Index	Manufacturer	Article name	Item number	Fitting	Luminous flux	Light loss factor	Connected load	Quantity
1	Wipro Lighting	LD30-201-60W-40-PS 20W-4000K/60deg		1x LED_Downight 20W/60	2000 lm	0.85	20 W	34
2	Wipro Lighting	TrimLED Neo - 4FT LED Batten	LL20-221-XXX-65NE3	1x LED	2001 lm	0.85	20 W	26
3	LD06-221XXX-57SMG1			2x	1800 lm	0.85	18 W	23
4	Wipro Lighting	Pendent mounted LED Downlighter	LD99-281-XXX57PMBL	1x LED	1800 lm	0.85	18 W	14
5	Wipro Lighting	StylusLED Up Down Light luminaire	LM43-491-XXX-57-WC	1x LEDs	3300 lm	0.85	30 W	29
6	LM43-321-XXX-40-WX			1x 49	1900 lm	0.85	20 W	51
7	Wipro Lighting	StylusLED Up Down Light luminaire	LM43-491-XXX-57-WX	1x LEDs	3300 lm	0.85	30 W	14
8	LM230R-621-XX57-XW Decorative Suspended Light			1x	2400 lm	0.85	35 W	11

Fig 5.25: Legends for Lighting Layout of first floor

5.5. <u>Preparing BOQ:</u> BOQ stands for Bill of Quantities. Sometimes clients ask for BOQ for an easier understanding of the products with their list prices. This BOQ usually consists of the list of luminaires used in design along with their specifications, quantities and unit price. A sample of the BOQ of GRIDCO building is shown below-

	A	B	C	D	E	F	G	H	I	J	K	L	M
1				Wipro Lighting BOQ - GRIDCO Building, Bhubaneswar									
2	Sl No.	Product Code	Specification	Image	d Floor (Qty)	1st Floor (Qty)	2nd Floor (Qty)	3rd Floor (Qty)	4th Floor (Qty)	5th Floor (Qty)	Total (Qty)	Unit Rate (Rs.)	Total Price (Rs.)
3		LM56-301-XXX-40-WH	Supply of suspended Round LED Downlight with pressure die cast Aluminium housing and high transmitive PMMA diffuser having 300mm Cutout Dia, with power consumption Maximum upto 30 W having system lumen output of Minimum 2555 Lumen. LED chip life of 50,000 burning hours at L70 – Minimum tested for 10K hours for complaince of TM21 projection. The LED used shall have CCT of 4000K, CRI of 100 Ra. The LEDs used in the product shall be of reputed make like Nichia, Japan / Cree, USA / Bridgelux, USA / Lumiled USA / Osram Germany. Luminaire driver should be Isolated and multistage constant current APFC type. Driver should be BIS registered with Input voltage range of 150V to 270V (nominal rated voltage – 240V) with minimum 2 KV surge protection, PF >0.95, THD <15%; IP 20;. Similar to Wipro Make **Coral LED (LM56)** or equivalent Philips / Trilux make. Manufacturer should have In-House NABL accredited LAB.		18	0				0	18	########	#########
4		LD06-221XXX-57SMG1	Supply of Surface mounted Round LED Downlight with pressure die cast Aluminium housing and high transmitive PS diffuser having 150mm Cutout Dia, with power consumption Maximum upto 18 W having system lumen output of Minimum 1800 Lumen. LED chip life of 50,000 burning hours at L70 – Minimum tested for 10K hours for complaince of TM21 projection. The LED used shall have CCT of 5700K, CRI of 80 Ra. The LEDs used in the product shall be of reputed make like Nichia, Japan / Cree, USA / Bridgelux, USA / Lumiled USA / Osram Germany. Luminaire driver should be Isolated and multistage constant current APFC type. Driver should be BIS registered with Input voltage range of 90V to 265V (nominal rated voltage – 240V) with minimum 2 KV surge protection, PF >0.90, THD <10%; IP 40;. Similar to Wipro Make **Mollis LED (LD06)** or equivalent Philips / Trilux make. Manufacturer should have In-House NABL accredited LAB. Manufacturer need to submit Following Certificates – 1) LM79 Test		15	23	19	23	17	4	101	########	#########
		LM230R-621-XX57-XW	Supply of Suspended Round LED Downlight with pressure die cast Aluminium housing and high transmitive PMMA diffuser having 600mm Cutout Dia, with power consumption Maximum upto 35 W having system lumen output of Minimum 2400 Lumen. LED chip life of 50,000 burning hours at L70 – Minimum tested for 10K hours for complaince of TM21 projection. The LED used shall have CCT of 5700K, CRI of 100 Ra. The LEDs used in the product shall be of reputed make like Nichia, Japan / Cree, USA / Bridgelux, USA / Lumiled USA / Osram Germany. Luminaire driver should be Isolated and multistage constant current APFC type. Driver should be BIS registered with Input voltage range of 150V to 270V (		5	11	7	11	11	0	45	########	#########

Fig 5.26: BOQ for GRIDCO Building Indoor Lighting Design

CHAPTER 6

SOME OTHER COMPUTER AIDED INDOOR LIGHTING DESIGNS

6.1. <u>Cable Mills Factory, Howrah</u>: For the renovation of Cable Mills Factory at Gloster Limited Mill in Bauria, Howrah, we, the C&I team of Wipro lighting were sent an AutoCAD layout of the renovated mill.

The requirements of the client were –

- Machine positions must be shown in the design.
- Average lux level between two machines must be minimum 250 Lux.

6.1.1. DIALux Design:

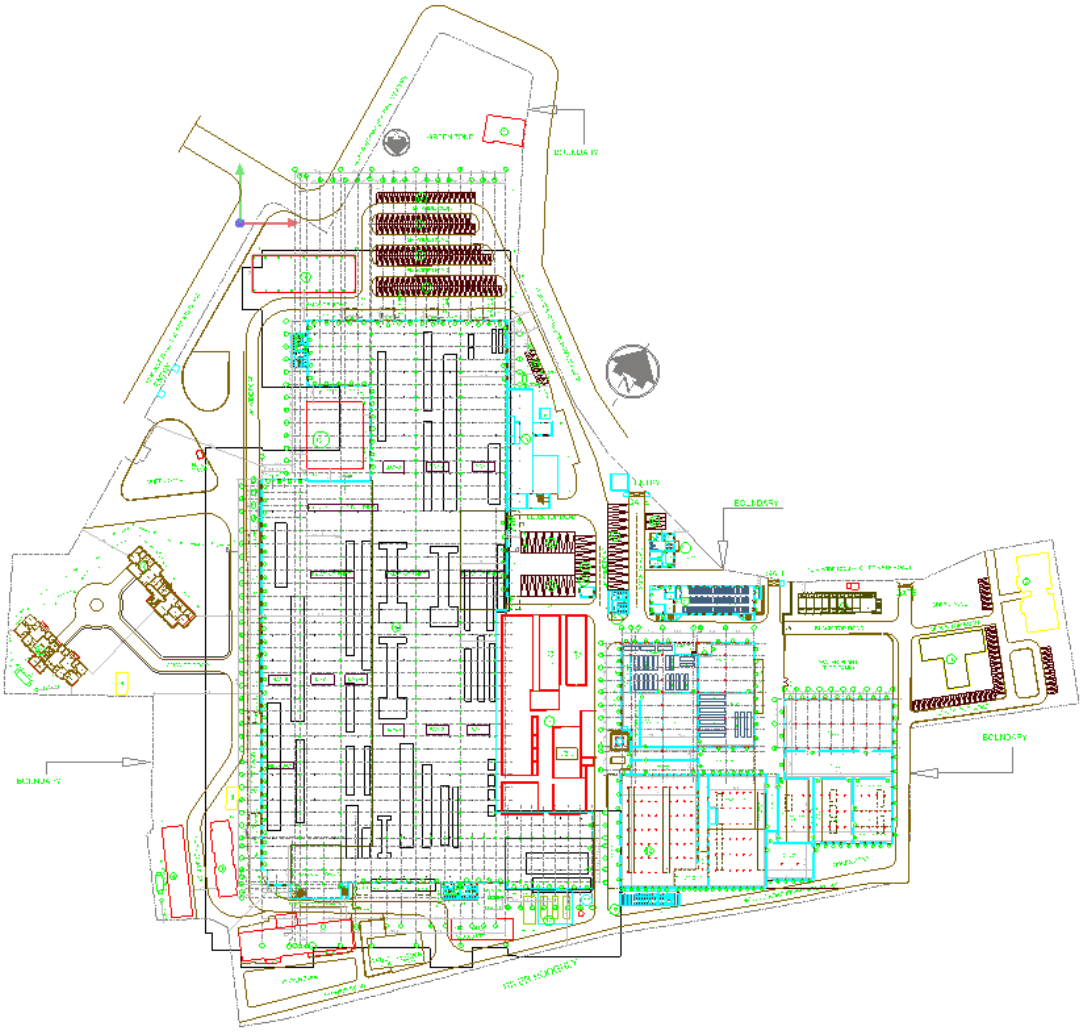


Fig 6.1: Floor plan of the design

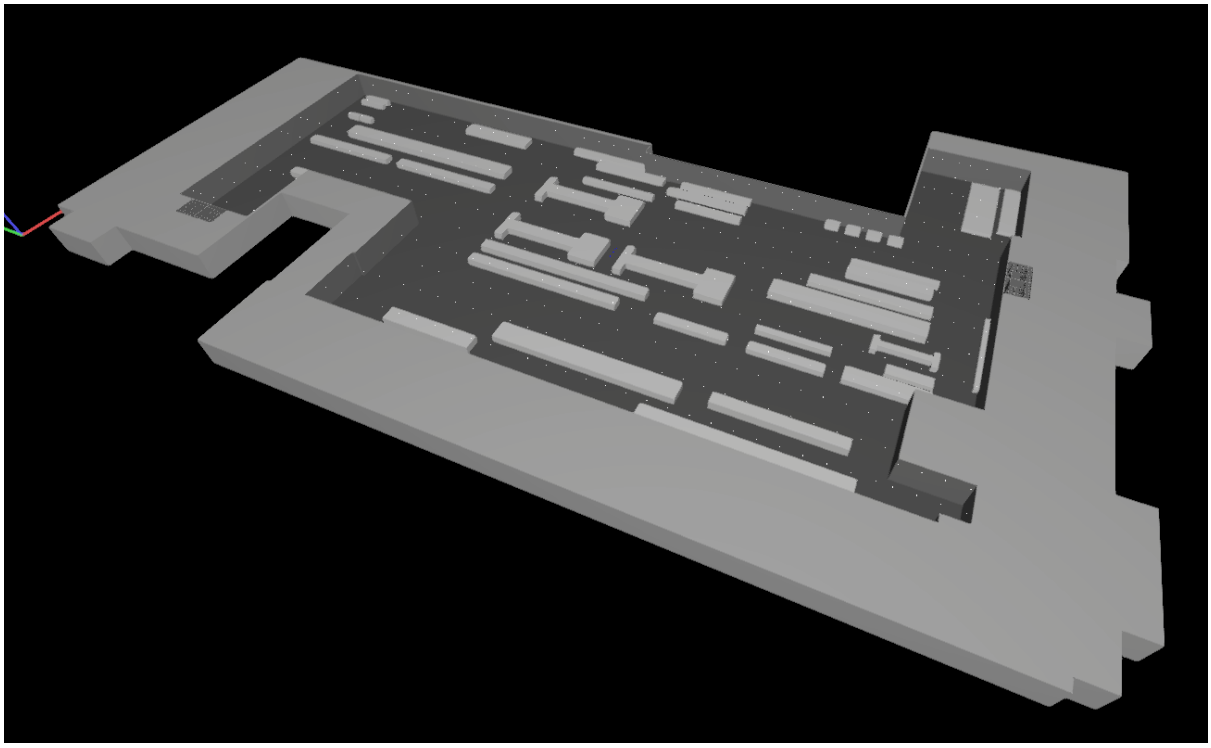


Fig 6.2: 3D Rendering of Factory area with machines as extrusion volumes

6.1.2. Luminaires:

Luminaire list

Φ_{total}	P_{total}	Luminous efficacy
11406060 lm	95328.0 W	119.7 lm/W

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
96	LD06-221XXX-57SMG1			18.0 W	1818 lm	101.0 lm/W
468	WIPRO ENTERPRISES (P) LTD	LH21-252-060-57-X1	UNO HIGHBAY LIGHT LUMINAIRE	200.0 W	23999 lm	120.0 lm/W

6.1.2. Results:

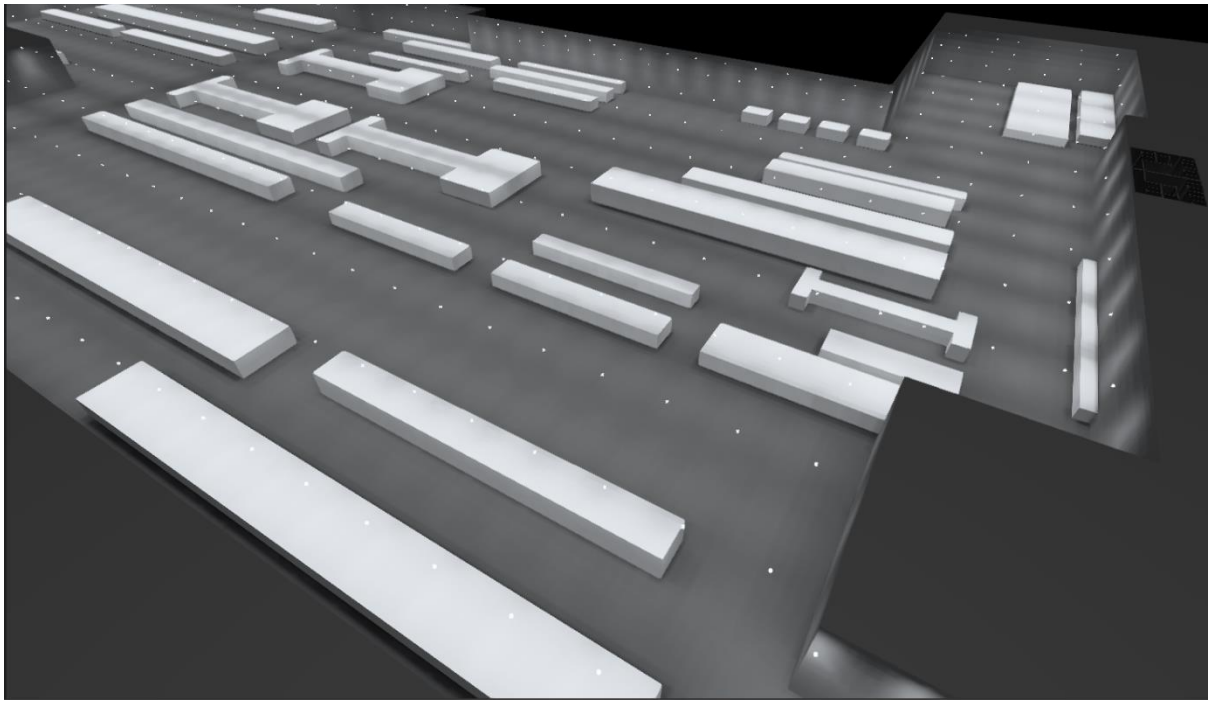


Fig 6.3: 3D Rendering of Factory area with machines as extrusion volumes

Building 1 · Storey 1 · workstation area (Light scene 1)

Calculation objects

Work planes

Properties	Ē (Target)	E_{min}	E_{max}	g_1	g_2	Index
Workplane (workstation area) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	232 lx (≥ 200 lx) ✓	0.068 lx	480 lx	0.000	0.000	WP1

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
area b/w mc 2 Perpendicular illuminance Height: 0.800 m	305 lx	162 lx	430 lx	0.53	0.38	CG1
area b/w mc 1 Perpendicular illuminance Height: 0.800 m	273 lx	111 lx	376 lx	0.41	0.30	CG2
area b/w mc 3 Perpendicular illuminance Height: 0.800 m	290 lx	177 lx	375 lx	0.61	0.47	CG3
area b/w mc 4 Perpendicular illuminance Height: 0.800 m	356 lx	187 lx	462 lx	0.53	0.40	CG4

6.2. <u>Bazaar Kolkata Warehouse:</u> Another AutoCAD layout of Bazaar Kolkata warehouse at Dankuni was given to us by Coing Consulting company to proceed with the lighting design.

6.2.1. DIALux Design:

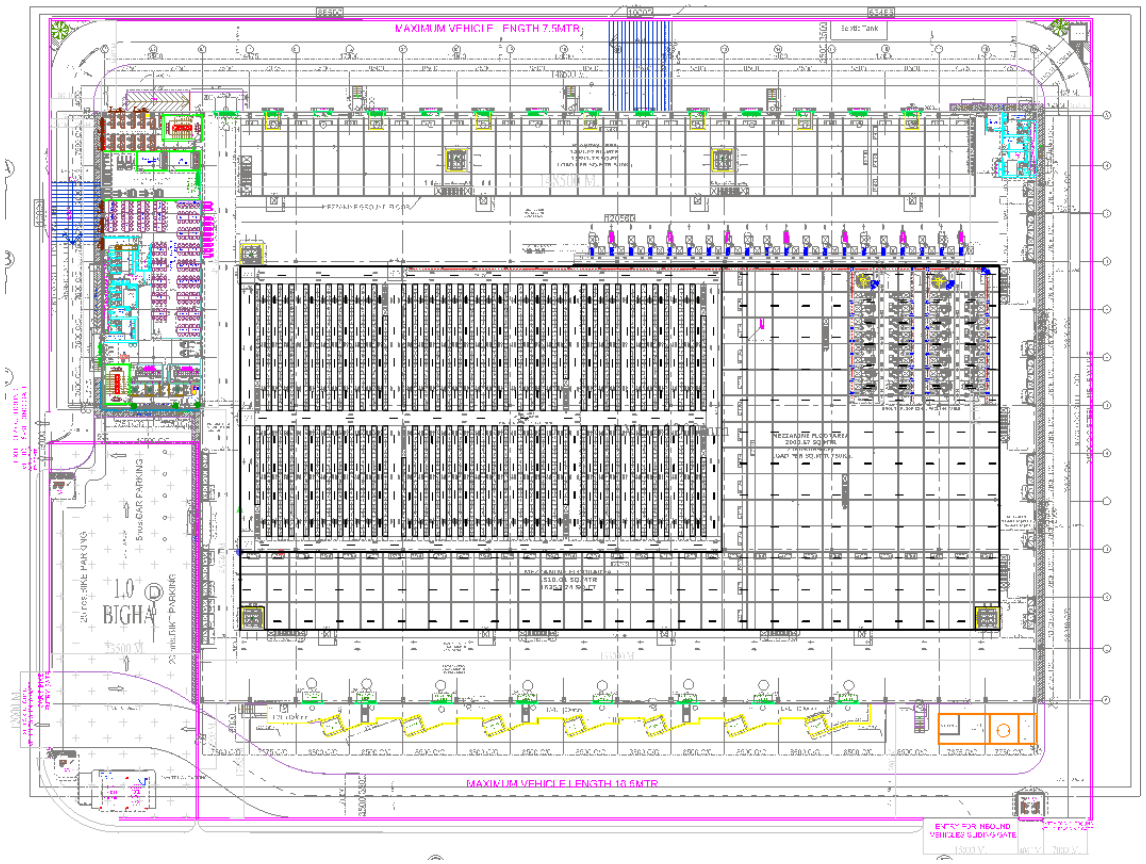


Fig 6.4: Floor plan of the design

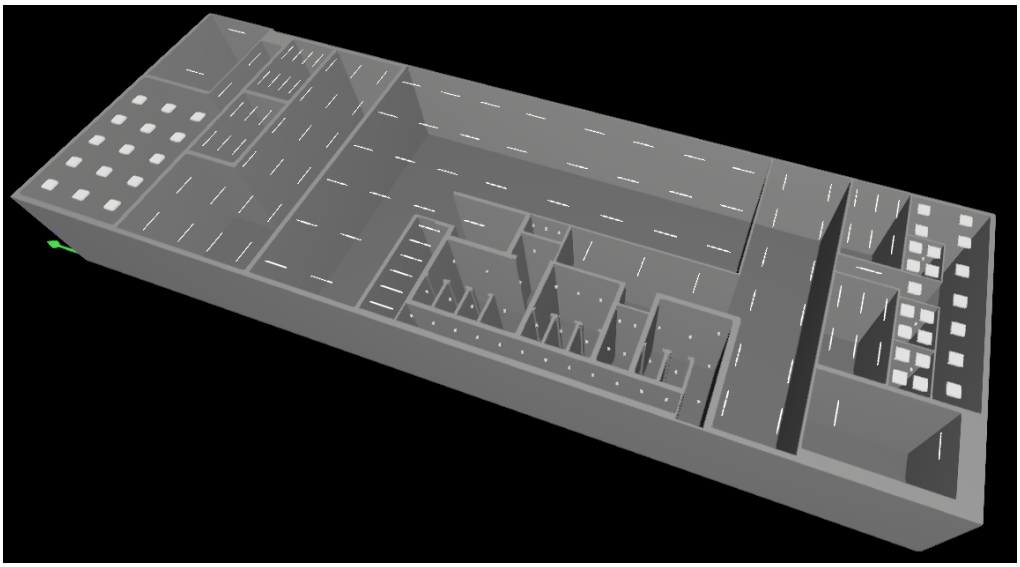


Fig 6.5: 3D rendering of Office area

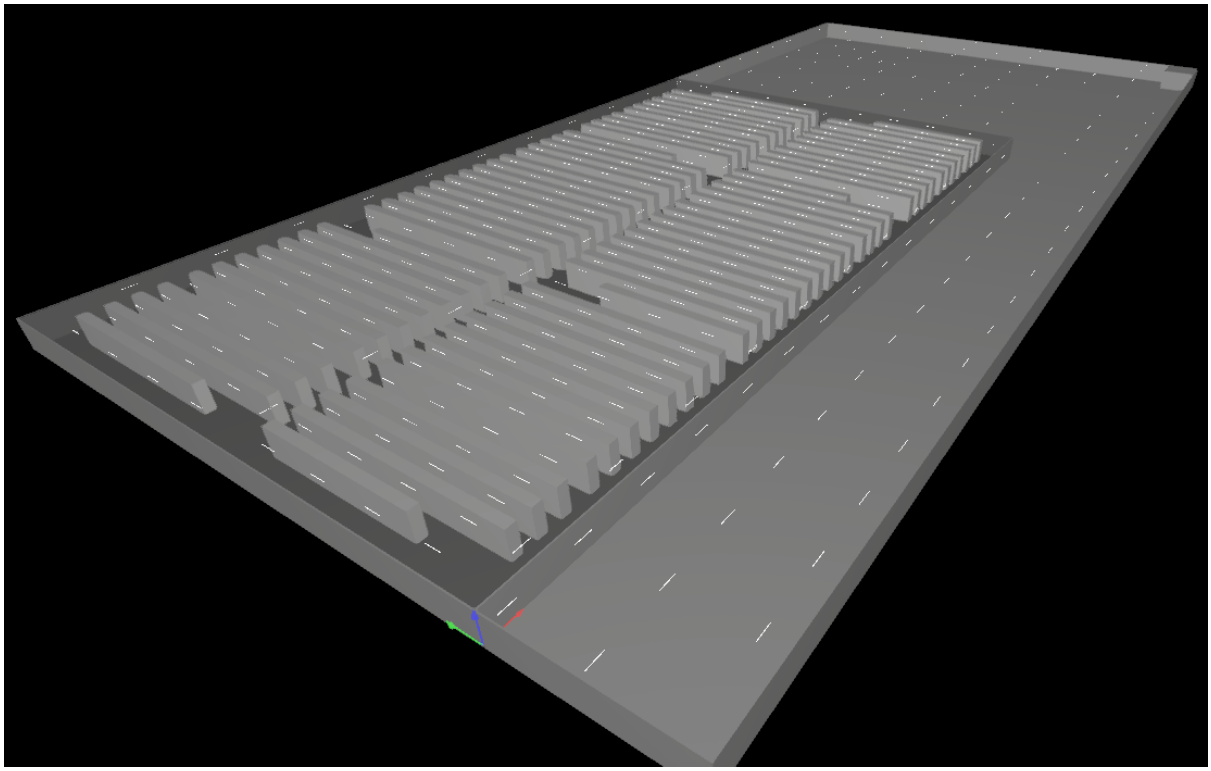


Fig 6.6: 3D Rendering of warehouse Shelf and Packaging area

6.2.2. Luminaires:

6.2.2.1. Warehouse Area:

Building 3

Luminaire list

Φ_{total}	P_{total}	Luminous efficacy
4054986 lm	32448.0 W	125.0 lm/W

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1014	Wipro Lighting	LL24-501-XXX-57-HE	Batten Type LED Luminaire - 4FT LED Batten	32.0 W	3999 lm	125.0 lm/W

6.2.2.2. Office Area:

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
44	LD06-221XXX-57SMG1			18.0 W	1800 lm	100.0 lm/W
				18.0 W	1800 lm (100 %)	-
22	Wipro Lighting	CRCO10S038HP57GL1	LED 2X2 Luminaire suitable for Surcafe on	36.0 W	3600 lm	100.0 lm/W
16	Wipro Lighting	CRCO10S038HP57GL1	LED 2X2 Luminaire suitable for Surcafe on	36.0 W	3600 lm	100.0 lm/W
				36.0 W	3600 lm (100 %)	-
34	Wipro Lighting	LL24R-541-XXX-57-CD	Batten Type LED Luminaire - 4FT LED Batten with reflector	40.0 W	3999 lm	100.0 lm/W
				40.0 W	3999 lm (100 %)	-

6.2.3. Results:

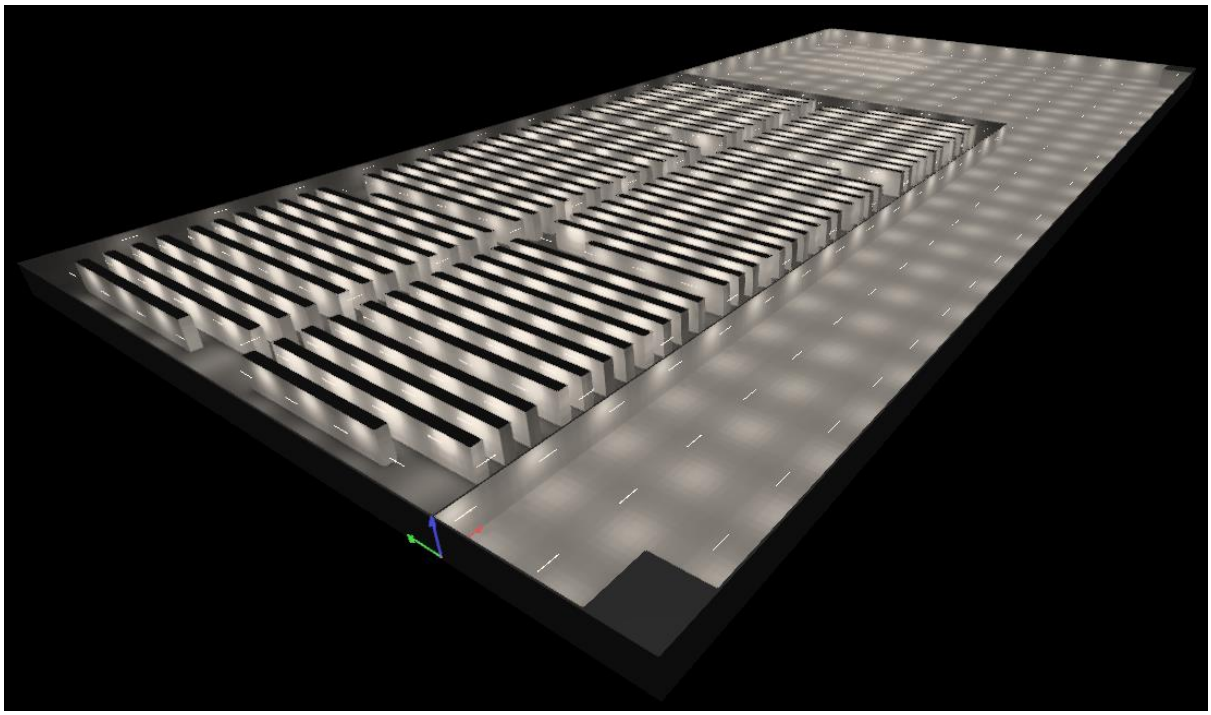


Fig 6.7: 3D Rendering of warehouse Shelf and Packaging area after simulation

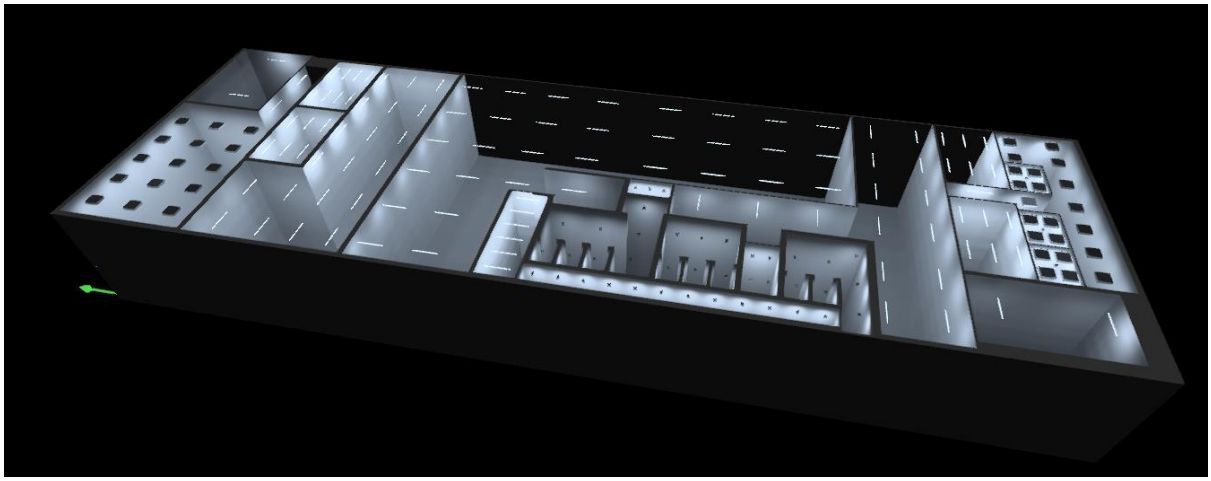


Fig 6.8: 3D Rendering of Office area after simulation

Building 3 · Ground Floor

Calculation objects

Work planes

Properties	Ē (Target)	E_{min}	E_{max}	g_1	g_2	Index
Workplane (warehouse rack area) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	159 lx (≥ 150 lx) ✓	11.5 lx	529 lx	0.072	0.022	WP22
Workplane (mezzanine packing table area & corridor) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	164 lx (≥ 150 lx) ✓	48.3 lx	462 lx	0.29	0.10	WP24

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
area in-b/w racks Perpendicular illuminance Height: 0.000 m	221 lx	122 lx	319 lx	0.55	0.38	CG3
area in-b/w racks Perpendicular illuminance Height: 0.000 m	237 lx	126 lx	321 lx	0.53	0.39	CG4
rack area corridor Perpendicular illuminance Height: 0.800 m	179 lx	71.0 lx	391 lx	0.40	0.18	CG5
packing table Perpendicular illuminance Height: 0.800 m	325 lx	233 lx	395 lx	0.72	0.59	CG10

CHAPTER 7

COMPUTER AIDED FAÇADE LIGHTING DESIGN

7.1. Introduction: Light encourages night-time public life in urban environments. Businesses, restaurants, and cultural institutions profit from a vibrant nightlife. Impressive facade lighting aids in orienting and makes buildings noticeable in urban areas. The uniform illumination of facades serves to draw attention to landmarks and provides them a serene presence in the urban environment. With facades, grazing light wall-washing is great for showcasing the delicate textures of wood and natural stone to produce eye-catching reliefs.

The main entry gate of the High Court of Orissa is such as architectural entity. So, it needs to be illuminated in an eye-catching way. So, a façade lighting design of this gate has been proposed and installed by Wipro Commercial & Institutional team.

7.2. Available Data: The client of this project provided some pictures of this gate and the dimensions related to the gate.

- Diameter of the wide pillars is 1 m.
- Distance from one pillar to the other is 4 m.
- Height of the pillars is 4 m.
- Height of the side walls is 2.2 m.

Some pictures of the gate are attached below –

Fig 7.1: Front view of the gate

Fig 7.2: Front view of the gate from road

Fig 7.3: Side view of the gate

7.3. <u>DIALux Design:</u> Since, no AutoCAD layout has been provided, so we have to improvise the structure into the 2D picture below –

7.3.1. Structure in DIALux Evo: After considering a rectangular floor element, extrusion volumes were taken to build the structure of the gate.

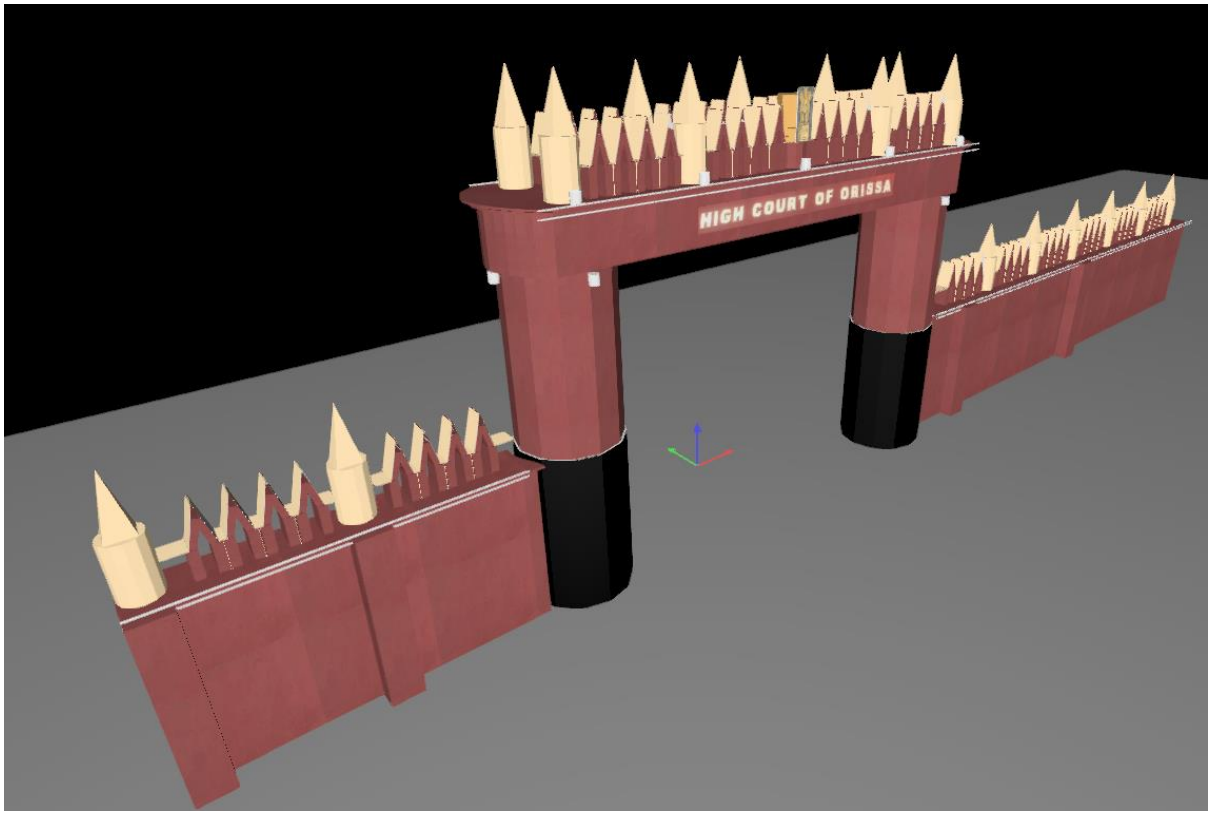


Fig 7.4: Structure of the gate developed in DIALux Evo

The textures and colours applied on the gate were considered so that the façade lighting installation can be visualise virtually.

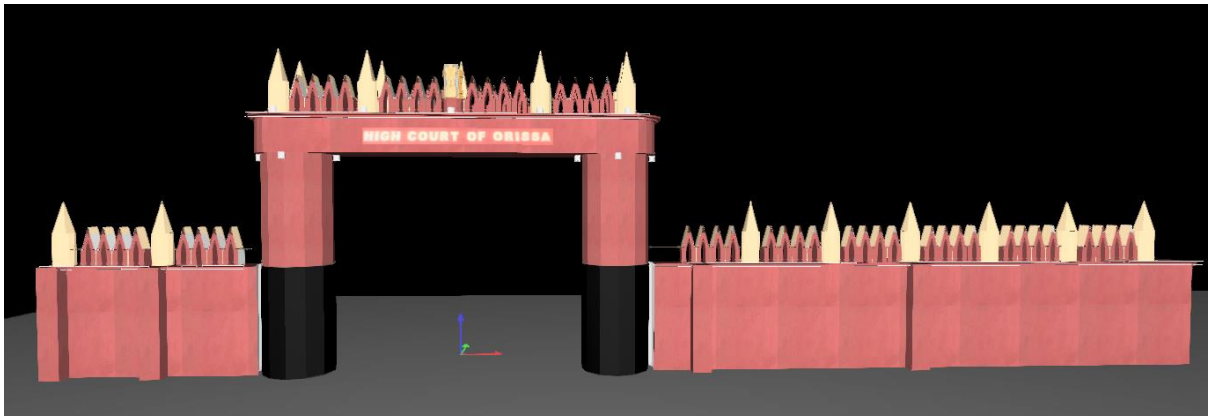


Fig 7.5: Front view of the gate in DIALux Evo

7.3.2. Luminaires positions: On the walls as well as on the gate, strips of LED luminaires have been considered both at upward and downward direction to highlight architectural structures of the gate.
The mounting heights of LED strip lights at main entrance and at the walls are 4 m and 1.7 m respectively.

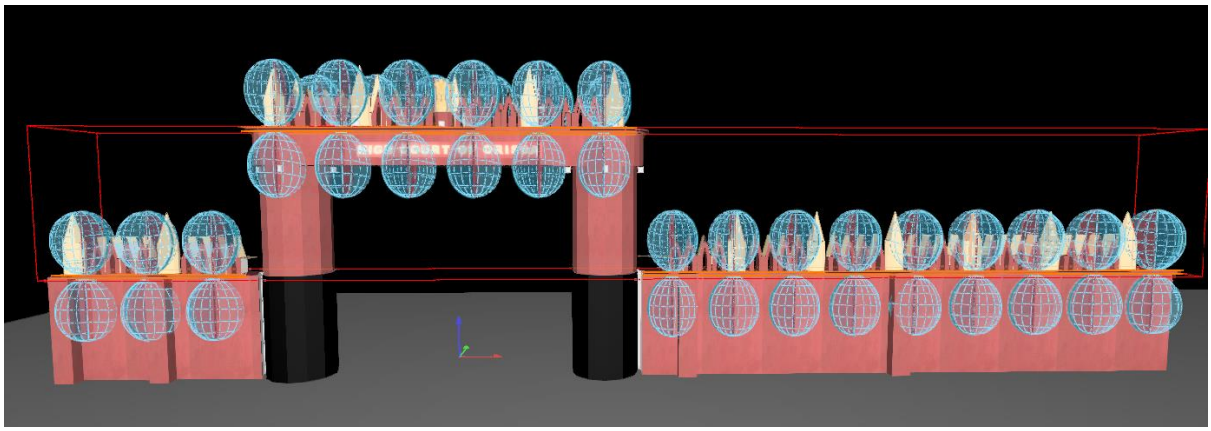


Fig 7.6: Depicts the positions of the LED strip lights

IP 67 rated LED Bush lights of nominal wattage have been considered to highlight the ‘Ashoka Stambh’ at the centre top of the gate and the pointy-head structures on the top of the gate and on the walls. The luminaires were mounted at 4 m in the upward direction and at 3.4 m in downward direction to create an aesthetic appearance.

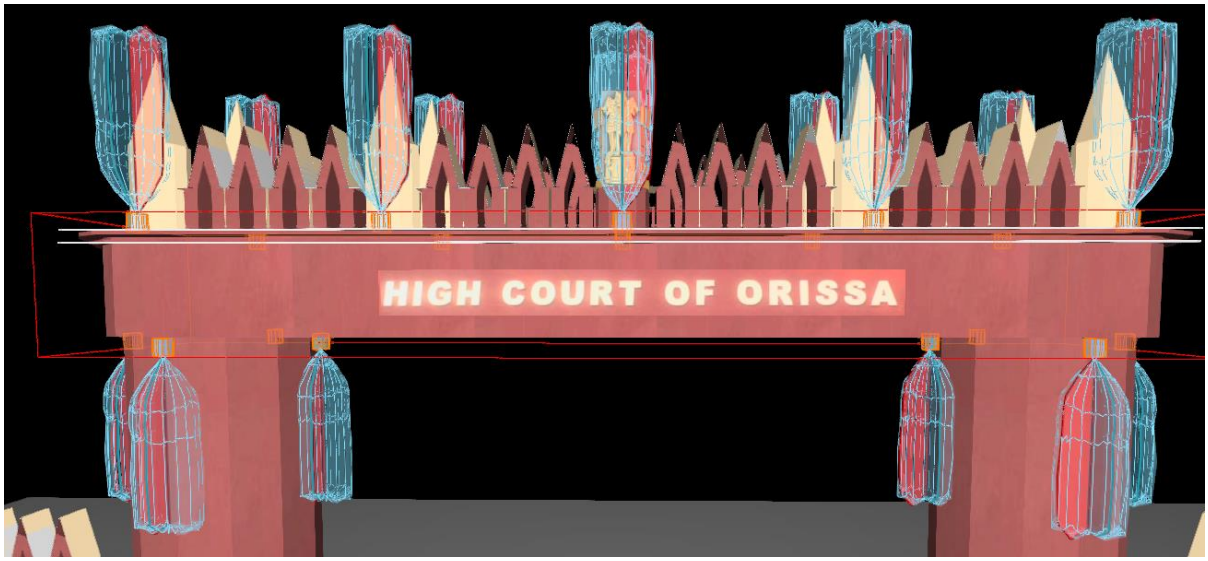


Fig 8.7: depicts the positions of the LED Bush lights

7.3.3. Luminaires Characteristics:

Luminaire list

Φ_{total}	P_{total}	Luminous efficacy
35543 lm	572.0 W	62.1 lm/W

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
42	Wipro	LS27-005-120-WW-50-1mtr		10.0 W	616 lm	61.6 lm/W
19	Wipro Lighting	LF05-600-036-27-XX	IP67 LED Bush Light (8W) Luminaire with 36 Deg beam angle	8.0 W	509 lm	63.7 lm/W

a. ARCUS Flexi Strip Light - LS27-005-120-WW-50

Fig 7.8: ARCUS **Flexi Strip Light** Luminaire [**10**]

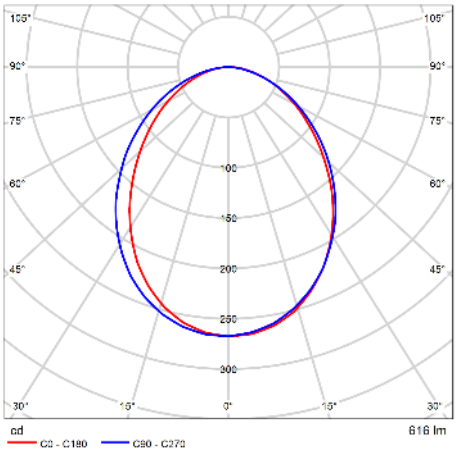


Fig 7.9: Polar LDC of **ARCUS Flexi Strip Light** Luminaire

Type	Flexible LED strip light, 1 m length, homogeneous and light spot free illumination.
Mount Type	Surface/ Wall
Housing	frosted encapsulated
System Lumen Output	616 Lumens/m
Power	10 W/m
CCT	3000K
CRI	>80 Ra
Voltage Range	100 V-300 V
Rated Voltage	240 V
Surge Protection	3 KV
IP Rating	IP 68
Power Factor	>0.9
THD	<20%

Table 7.1: Characteristics of **ARCUS Flexi Strip Light (LS27-005-120-WW-50)**

b. Gardenia - LF05-600-036-27-XX

Fig 7.10: **Gardenia** Luminaire
Luminaire [**10**]

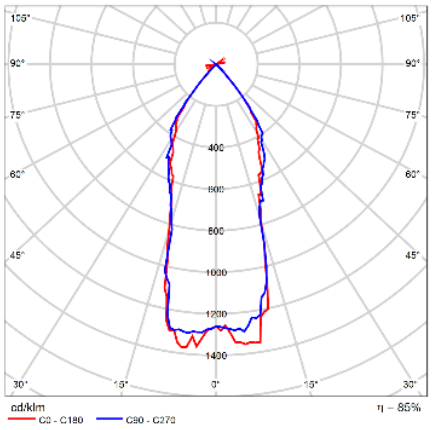


Fig 7.11: Polar LDC of **Gardenia**

Type	Compact LED Bush light
Mount Type	Ground
Housing	polyester coated aluminium housed
System Lumen Output	509 Lumens
Power	8 W
CCT	2700K
CRI	80 Ra
Voltage Range	150 V-270 V
Rated Voltage	240 V
Surge Protection	3 KV
IP Rating	IP 67
Power Factor	>0.9
THD	<20%

Table 7.2: Characteristics of **Gardenia Bush Light** (**LF05-600-036-27-XX)**

7.4. Results: The following images depict the outcome after the lighting simulation of the developed structure in DIALux Evo 10.0.

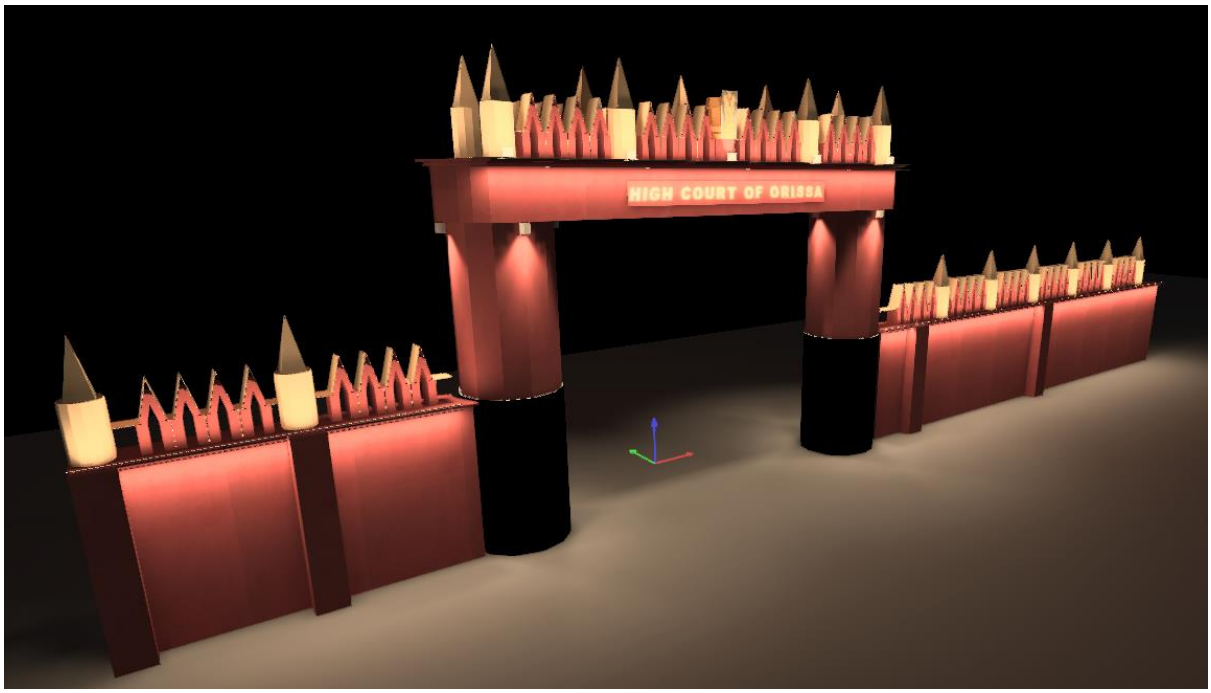


Fig 7.12: Simulated design of the gate

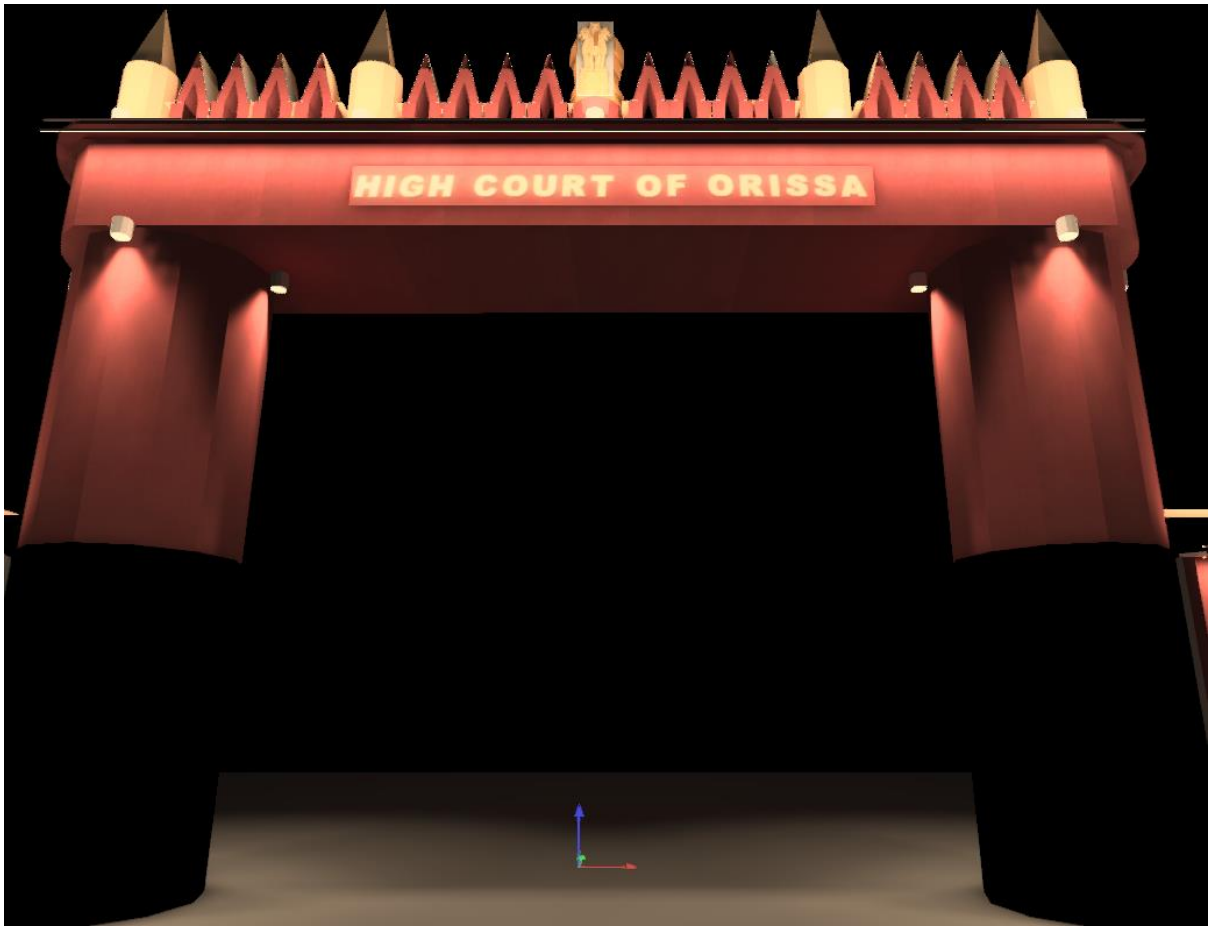


Fig 7.13: Simulated design of the gate (Front view)

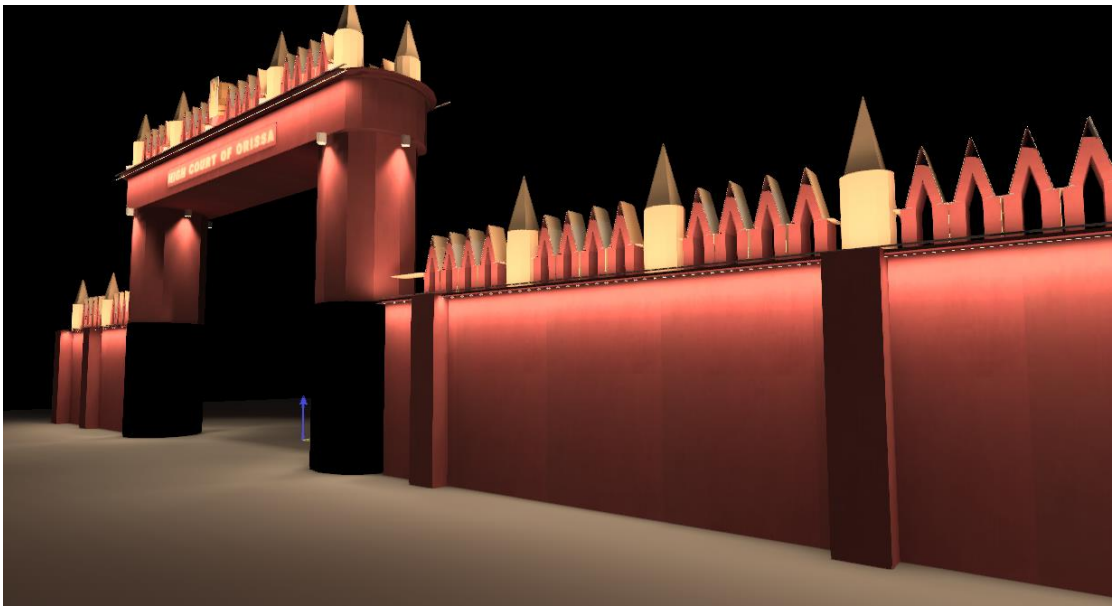


Fig 7.14: Simulated design of the gate (Side view)

7.5. <u>Installation of the lighting fixture:</u> After completion of the design, the report as along with some images of the developed façade lighting design were submitted to the client. After receiving the approval from the client, our Wipro C&I team visited the site to inspect the installation of the lighting fixtures. Below are some images after the completion of lighting installation.

Fig 7.15: Picture taken after lighting installation (Front View)

Fig 7.16: Picture taken after lighting installation (Right wall)

Fig 7.16: Picture taken after lighting installation (Side View)

CHAPTER 8

SOME OTHER COMPUTER AIDED FACADE LIGHTING DESIGNS

8.1. <u>IOCL Dhakuria:</u> The Façade Lighting project of this building was assigned to us by CPWD department.

Fig 8.1: Realtime image of IOCL Dhakuria

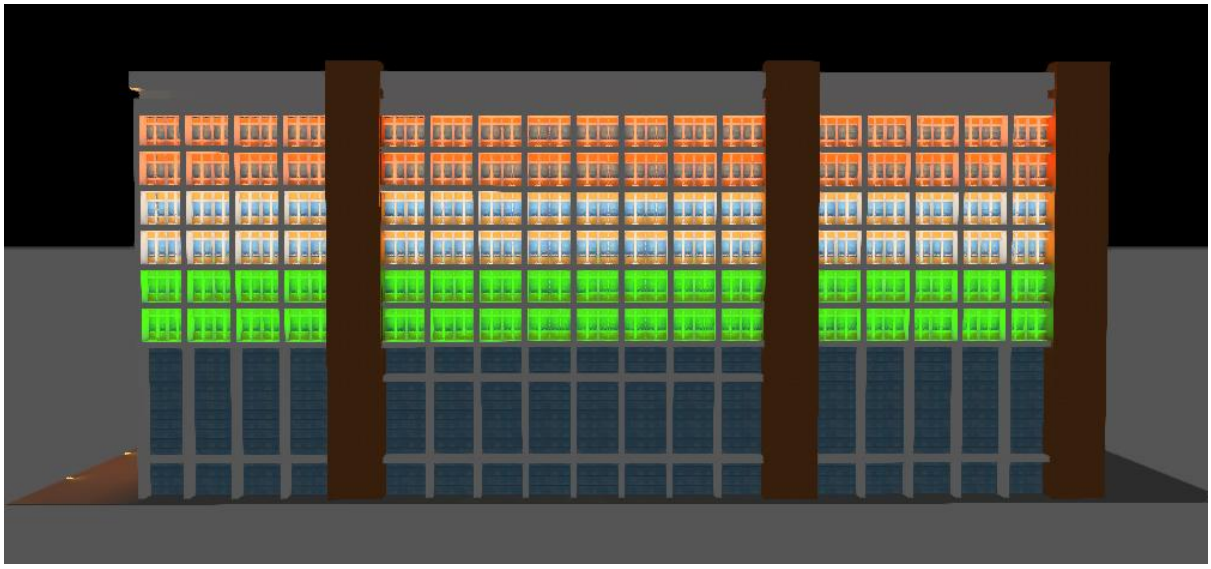


Fig 8.2: Façade lighting design (Indian Flag combination) of IOCL Dhakuria simulated in DIALux Evo

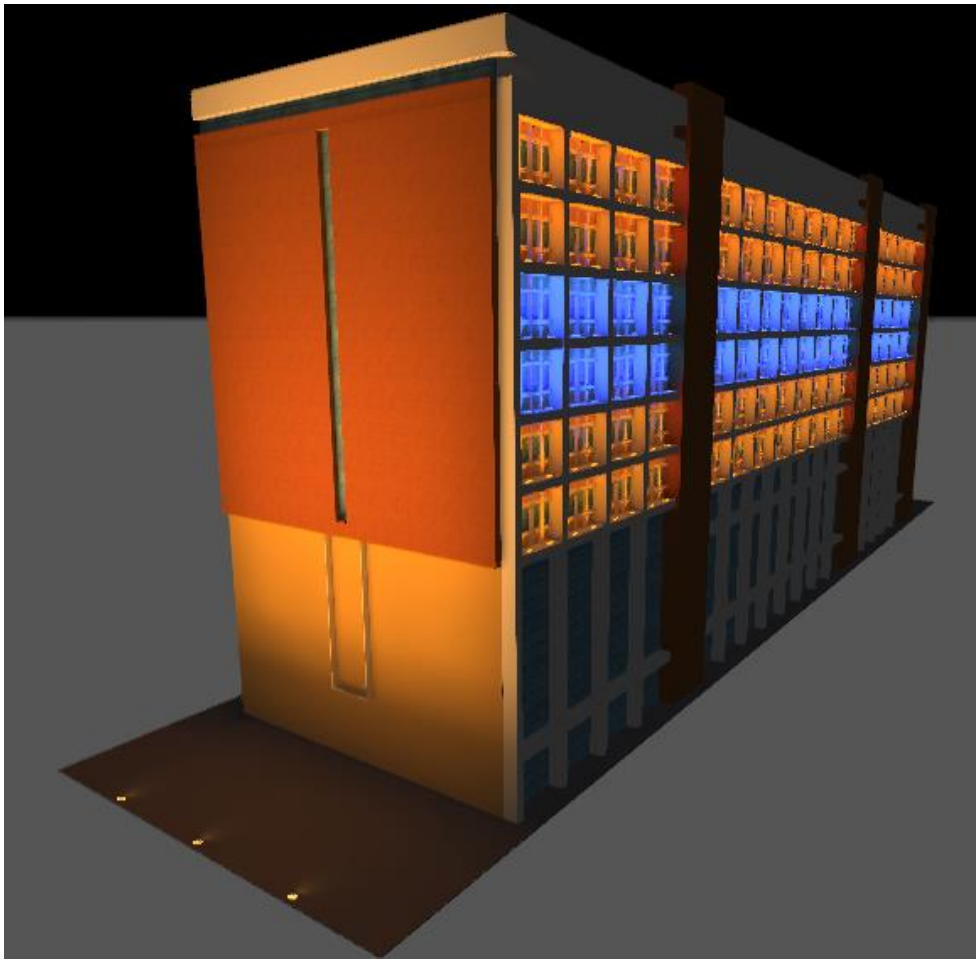


Fig 8.3: Façade lighting design (IOCL logo combination) of IOCL Dhakuria simulated in DIALux Evo

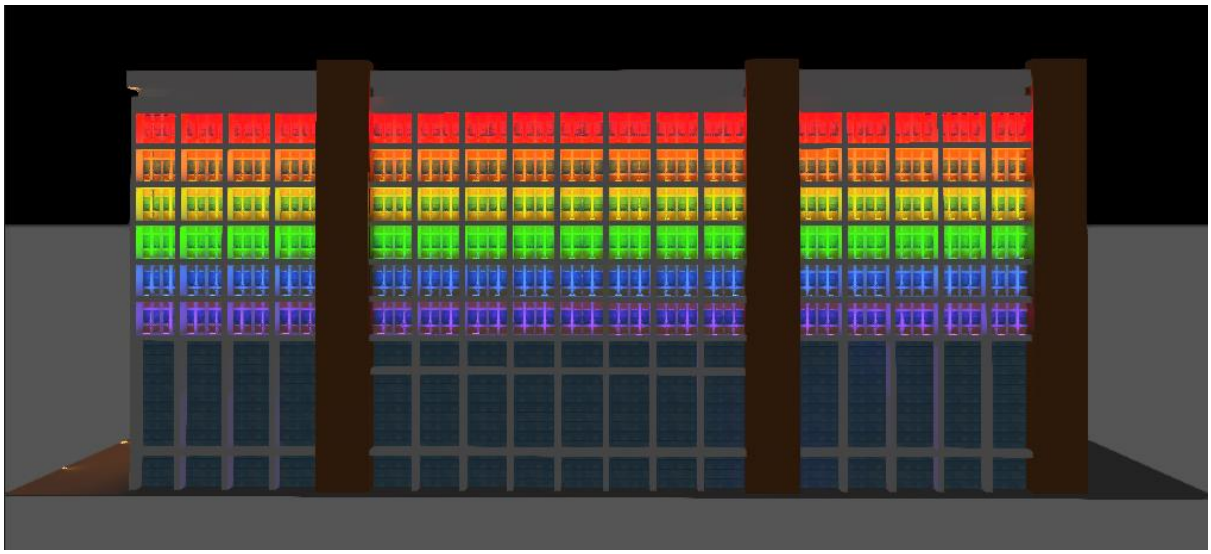


Fig 8.4: Façade lighting design (VIBGYOR combination) of IOCL Dhakuria simulated in DIALux Evo

8.2. <u>HMV Building, Orissa:</u> We got this Façade lighting design project of Heavy Motor Vehicle Training Institute (located in Sundargarh district of Orissa) from ACME Consultants.

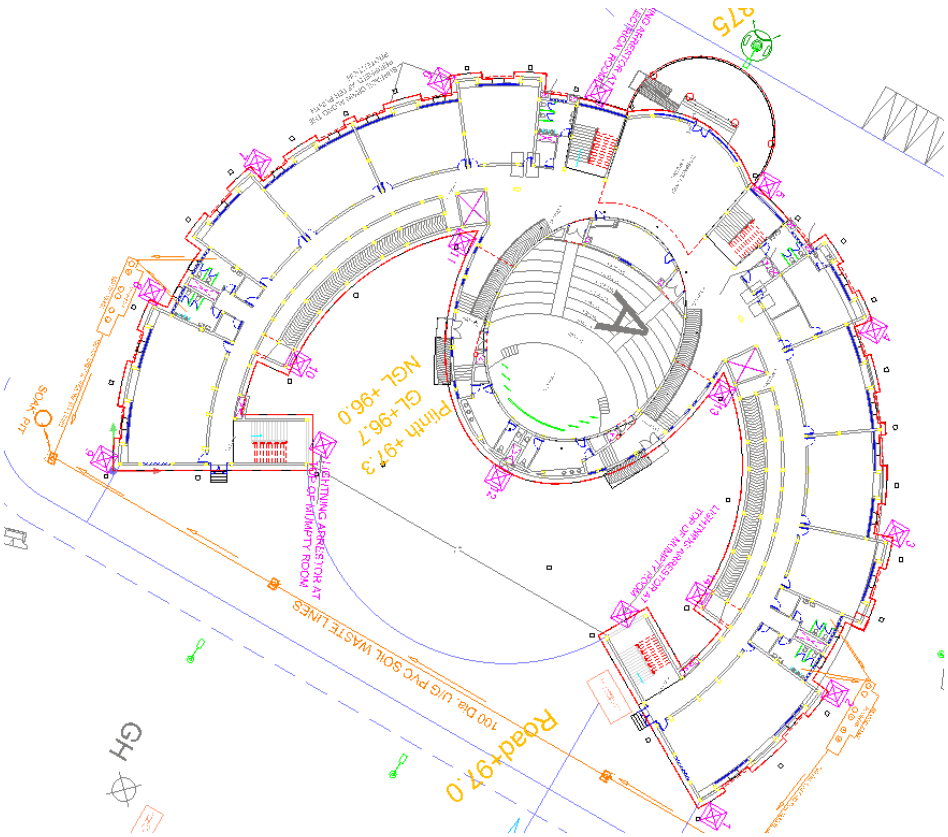


Fig 8.5: Floor Plan of HMV building

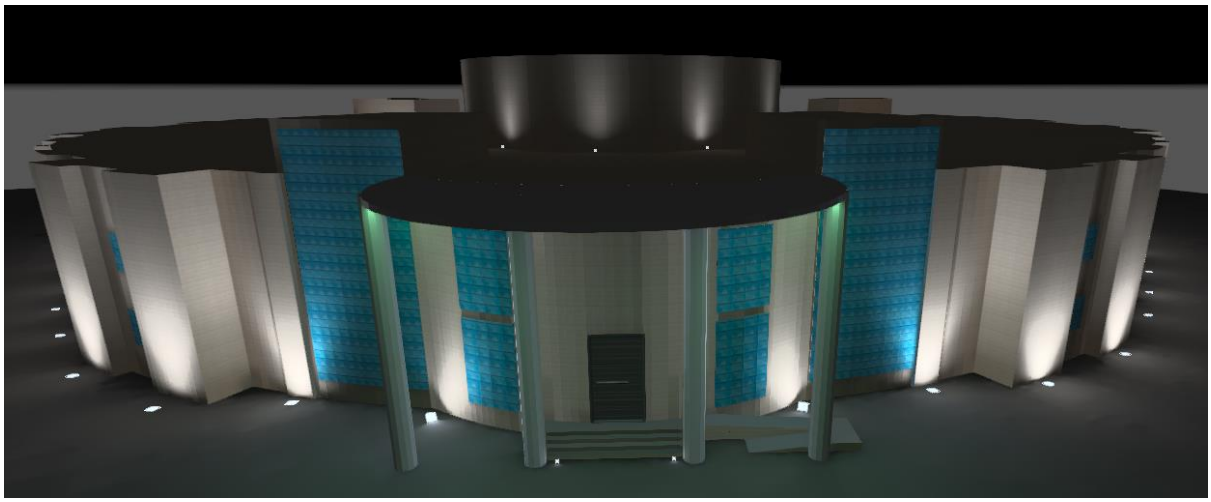


Fig 8.6: Façade lighting design of HMV Administrator Building-1

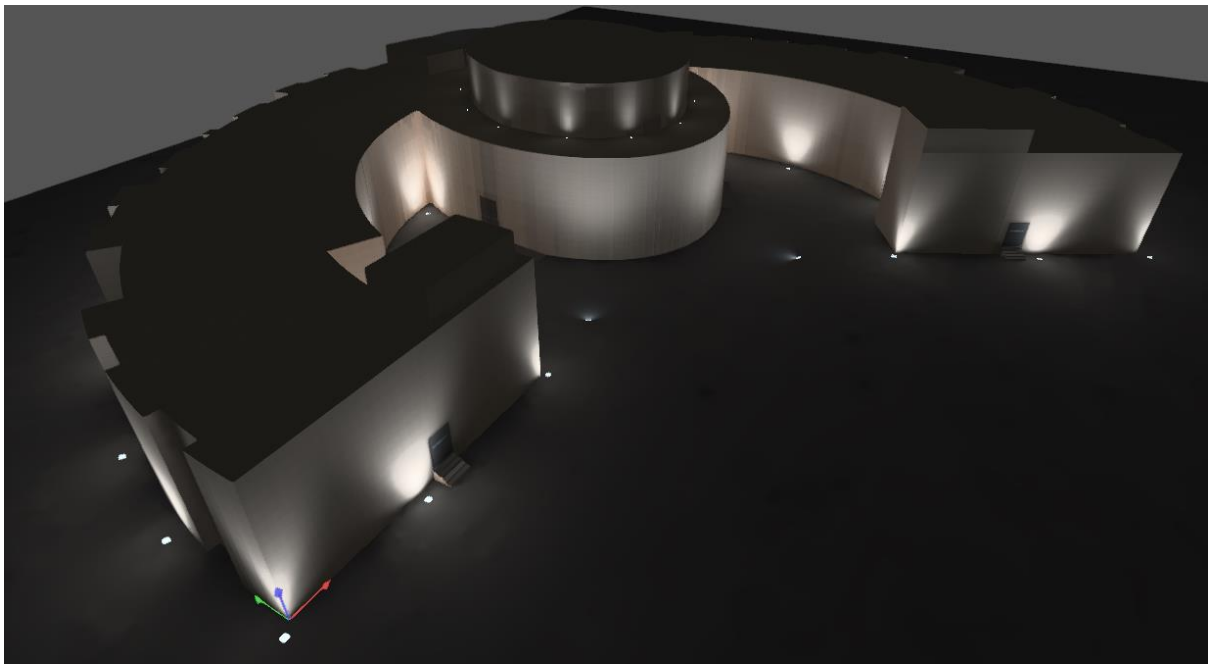


Fig 8.7: Façade lighting design of HMV Administrator Building-2

CHAPTER 9

CONCLUSION AND FUTURE SCOPE

9.1. Conclusion:

Now-a-days, LED luminaires are being used in majority of the workspaces for its advantages over other types of lamps. for the same lumen package, LED luminaires offer lower power consumption compared to conventional luminaires, hence LED luminaires provide energy efficient lighting solution compared to other light sources. Although the original cost of LED luminaires may be considerable, over time, the cost can be easily recovered due to their low operating costs.

For recreational office workspace, along with the traditional 2x2 LED panel, other types of suspended, decorative luminaires with a wide range of CCT are equally effective for different purposes. So, more emphasis is being given to implement unique lighting designs and fixtures. Here, in this project by using mostly the decorative type of luminaires, how an office space can be effectively illuminated has been presented.

Outdoor façade lighting defines beauty of the city, economic efficiency, safety and security. The outdoor luminaires consume more power and gives out more lumen output compared to indoor. So, the lighting design should be designed in such a way that the energy consumption of flood lights for particular area has to be optimized and light pollution problems has to be minimized.

In this project 1 m long LED strip light has been used for the façade lighting of Orissa High Court gate. For façade lighting, RGB luminaires i.e. with variable CCT can also be implemented for difference light distribution at different occasions.

9.2. Future Scope:

With so many of us spending the majority of our waking hours at work, the nature of work has changed. More than ever, workplaces must be flexible and empowering, and lighting is essential for synchronising our circadian rhythms with the cycles of natural day and night.

Human Centric Lighting (HCL) from Wipro Lighting aims at creating a perfect synchrony of the Mind, Body & Light to craft workspaces that enhance employee wellbeing & productivity and make light work 'just right' for us. inSync^{TM} lighting works in harmony with the earth's natural lighting cycle and can be programmed to mimic the daylight –

- Low light levels and low Correlated Colour Temperatures (CCT) in morning.
- High light levels and high CCTs at midday.
- Low light levels and low CCTs during evening.
- Extremely low light levels and a low CCT at night. [Fig 10.1, Fig 10.2] **[11]**

LiFi is high speed bi-directional networked and mobile communication of data using light. LiFi uses a number of light bulbs to create a wireless network and provides a user experience that is remarkably similar to that of Wi-Fi. LiFi can work indoors, outdoors, with the lights dimmed and is not strictly line-of-sight technology. Pure LiFi's technology is also LED agnostic, which means it works with many off-the-shelf LED's. **[12]**

In addition to these technologies, we need to use solar power to be implemented in lighting system. All-in-one solar streetlights make solar solutions more efficient and easy to adapt. No longer you have the bulky solar photo voltaic (PV) panel and lead acid battery box mounted on the poles along with the street light. **[13]**

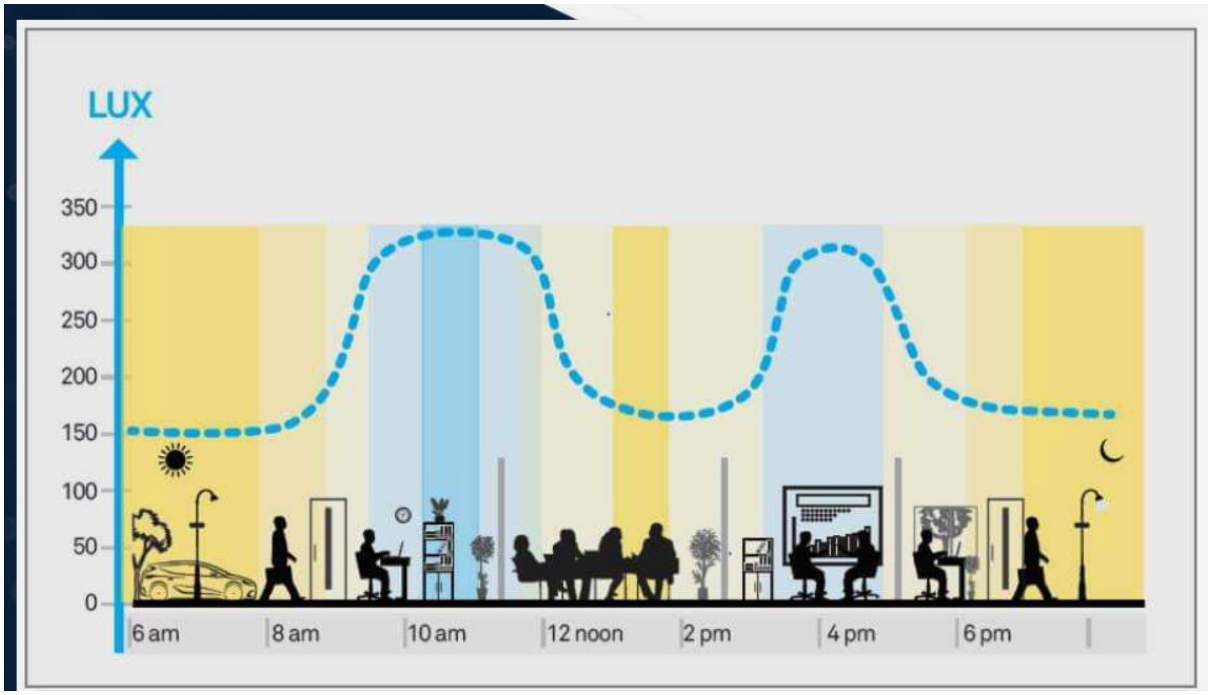


Fig 9.1: Light Intensity by Human Centric Lighting at day time **[12]**

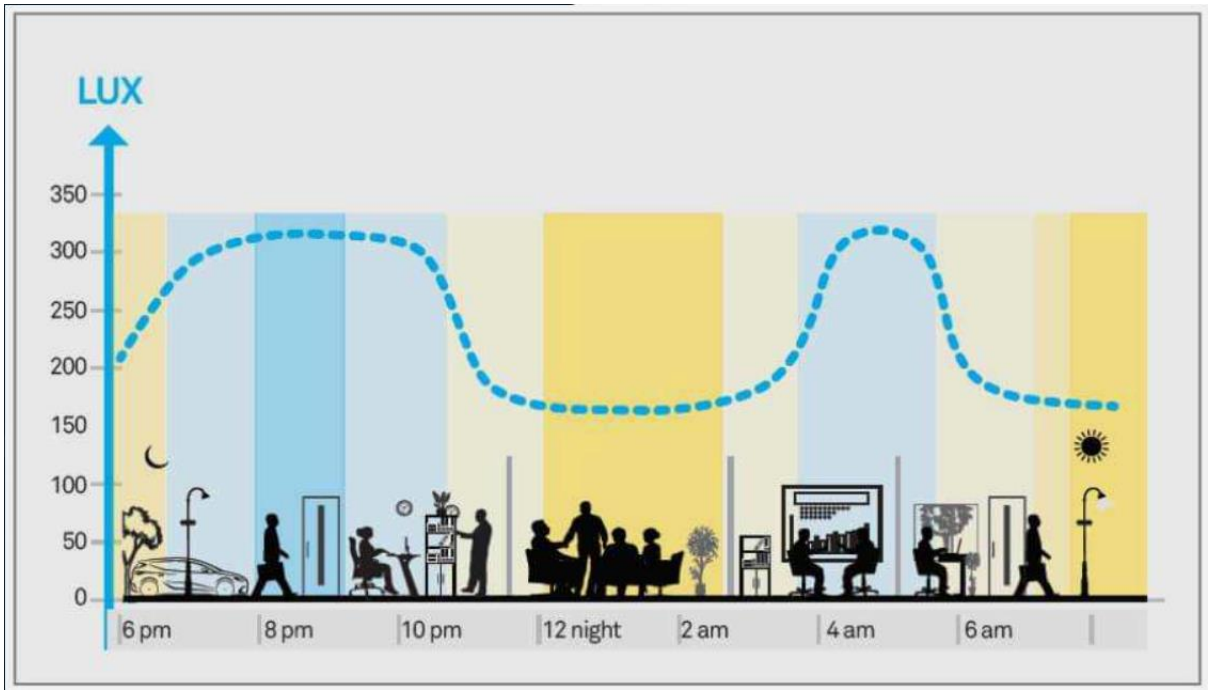


Fig 9.2: Light Intensity by Human Centric Lighting at night-time **[12]**

REFERENCES

1. https://www.wiprolighting.com/media/images/lighting-scenarios-image/image_path/3-1564562705.jpg

2. https://www.wiprolighting.com/media/images/lighting-scenarios-image/image_path/1-1539688602.jpg

3. IS 3646-1 (1992): Code of practice for interior illumination, Part 1: General requirements and recommendations for welding interiors

4. SP 72 (2010): National Lighting Code 2010 [ETD 24: Illumination Engineering and Luminaries]

5. Energy Conservation Building Code (ECBC), Bureau of Energy Efficiency, Ministry of Power, Government of India, New Delhi, India, 2017.

6. https://aisha-a.medium.com/indoor-lighting-design-using-dialux-4-13-efb1cdf49cd8

7. https://issuu.com/designinglighting/docs/feb_2021/s/11739771

8. IS: 1944 (Parts I and II) - 1970: Indian Standard Code of practice for lighting of public thoroughfares.

9. https://www.wiprolighting.com/products/cleanray/trim-neo-led

10. Wipro COMMERCIAL & INSTITUTIONAL LIGHTING RANGE- Price List 2021

11. https://www.wiprolighting.com/human-centric-lighting-insynctm

12. https://www.wiprolighting.com/li-fi-technology

13. https://www.wiprolighting.com/solar