STUDIES ON COMMERCIAL BUILDING LIGHTING SYSTEM

A thesis submitted in partial fulfilment
of the requirement for degree of

Master of Engineering in
ILLUMINATION ENGINEERING

Submitted by
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RECOMMENDATION CERTIFICATE

This is to certify that the thesis entitled " STUDIES ON COMMERCIAL BUILDING LIGHTING SYSTEM " submitted by SK TAHSIN SANAM, (Examination Roll No.M4ILN22005, Registration No.154028 of 2020-2021) of this University in partial fulfilment of requirements for the award of degree of Master of Engineering in Illumination Engineering, Electrical Engineering Department, is a bonafide record of the work carried out by him under my guidance and supervision.

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CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a creditable study in the area of Illumination Engineering, carried out and presented by SK TAHSIN SANAM, 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

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of 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 thesis rules and conduct, I have fully cited and referenced all material and results which are not original to this work.

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Date:

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Place:

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Chapter1

Introduction

1.1 General Overview

This Thesis work is a partial study of the methodology and procedure adapted and involved in a proposed lighting design of a commercial building. In this project, artificial lighting is used to complete the commercial building's lighting design. LED lighting fixtures have been considered for the design.

1.2 Objective

The goal of documenting the thesis work is to show how precisely each step of the framework is developed in a computer readable CAD format, culminating in the installation of actual light fixtures into the existing commercial building that is being designed in lighting software called DIALux evo to meet all of the lighting design's requirements.

1.3 Historical Background

Our history of lighting began with the creation of fire out of rocks and woods when sunlight was not available and the usage of sunlight exclusively during the day. Historic homes typically make the most of natural light through wide windows and building orientation. The earliest artificial light source was probably a torch, while the earliest lamps were made from shells or hollow rocks that were filled with fuel like dried grass or wood. Lamps were first used about 4500 BC, and as time went on, their fuel source changed to include kerosene, ethylene, and methane.

The gas light was created in England in the 1790s and imported to America. Since gas was also provided to homes for cooking, these lamps were very popular. The first electric lamps were created in the early 1800s, and light bulbs were created in the 1830s. The arc light was first used in Paris in the 1840s. Early arc lights, often known as 'limelights', were made for theatre lighting by aiming an oxyhydrogen flame at a calcium oxide cylinder.

In 1879, Thomas Edison created the first carbon filament incandescent light bulb, which went on to become the industry standard for decades. Direct current electricity reached citywide levels in the early 1880s, and alternating current in the late 1880s. The standard power mercury vapour light was created in 1901.

In the 1930s and 1940s, fluorescent lighting items first hit the market. It has been more than 50 years since they were first used, and throughout that time they have changed from being largely utilised in large commercial buildings to being the most widely used alternative to incandescent bulbs.

In the 1990s, high intensity discharge lights (HIDs) initially became available. They were first almost exclusively found in car headlights. But as technology advanced, they started to be used more widely in expansive indoor spaces and for outdoor commercial lighting in locations like sports arenas, gymnasiums, and parking lots.

LED lighting products are the newest addition to the market for about 15 years. LEDs are now the preferred choice in a world where energy and resources are getting more expensive and scarcer as a result of their greatly increased energy efficiency.

Long before 21st century, during the evolution of different types of light source, in most of the application areas lighting design was simply just like placing most effective light source where some task is needed to be performed. However, later manufacturers and lighting designers began to think differently, considering things like how lighting can improve human health, save energy, and beautify an area. As a result, a new lighting design strategy has been introduced. Software for designing lights as well as various methods have been created.

Prior to using lighting softwares,the Lumen method was frequently used to determine how many fittings were needed for rectangular arrays. The usage of lighting design software has evolved into industry standard practise in recent years. In most software, choosing the fixtures and analysing the light distribution includes modelling a physical representation of the area to be illuminated. Software will include data on luminaires from various manufacturers. When specific manufacturers' luminaires are not included in the programme, data files for those luminaires can typically be downloaded from the websites of those manufacturers and imported into the lighting software[1].

1.4 Organization of the Thesis Work

The overall thesis consists of nine different chapters and their sub-sections. The contents of all chapters of this thesis work are described as follows,

Chapter 1 provides a brief general introduction.

Chapter 2 elaborates on electromagnetic radiation, the effects of light on humans, Light Emitting Diodes, etc.

Chapter 3 tells us the lighting design requirements in commercial building recommended in National and International standards.

Chapter 4 provides information about the Work-Place used for this thesis.

Chapter 5 describes the methodology adopted and softwares taken in this thesis work.

Chapter 6 provides detailed technical specification of the luminaires and lighting controls, used in designing the commercial building.

Chapter 7 elaborates the complete software simulation to achieve the desired values (i.e., recommended values) of the design parameters considered, as per the National and International standards for each type of room within the commercial building.

Chapter 8 covers the Load Calculation and Bill Of Quantity.

Chapter 9 is the last section of this work which includes the conclusion and future aspect of the lighting design performed here.

Chapter2

EM Radiation, LED Technology and Human Factors

2.1 Light

In general we say, light is a form of energy that makes our surrounding visible to us.

But Technically, visible or invisible electromagnetic radiation of any wavelength is referred to as light.Thus gamma rays, X-rays, microwaves, radio-waves, are also light. The region of the electromagnetic radiation spectrum that the human eye can see is known as the visible light spectrum.

2.1.1 Electromagnetic Radiation

Electromagnetic waves, which are periodic oscillations of the electric fields and magnetic fields, are what make up electromagnetic radiation. Electric and magnetic waves flow orthogonally to one another in a vacuum at a speed of 3×10^8 m/s, resulting in electromagnetic radiation and electromagnetic field, as shown in Figure 2.1[2].

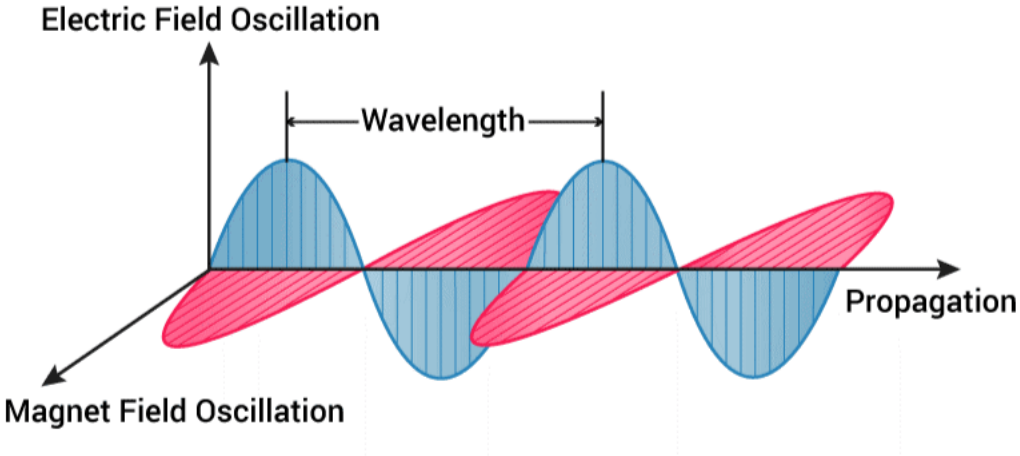


Figure 2.1: **Electromagnetic Field**

2.1.2 Electromagnetic Waves in Electromagnetic Spectrum

In increasing frequency and decreasing wavelength order, radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, gamma rays, and cosmic rays make up the full electromagnetic spectrum. These are the many types of radiation, along with their frequency and wavelength ranges as follows:

Type of Radiation	Frequency Range	Wavelength Range
gamma-rays	$> 3\times10^{19}$ Hz	< 0.01 nm
x-rays	3×10^{16}- 3×10^{19} Hz	0.01 nm - 10 nm
ultraviolet	7.8×10^{14}- 3×10^{16} Hz	10 nm - 380 nm
visible	3.8×10^{14}- 7.8×10^{14} Hz	380 nm - 780 nm
infrared	3×10^{11}- 3.8×10^{14} Hz	780 nm - 0.1 cm
microwaves	3×10^{9}- 3×10^{11} Hz	0.1 cm - 10 cm
radio waves	$< 3\times10^{9}$ Hz	> 10 cm

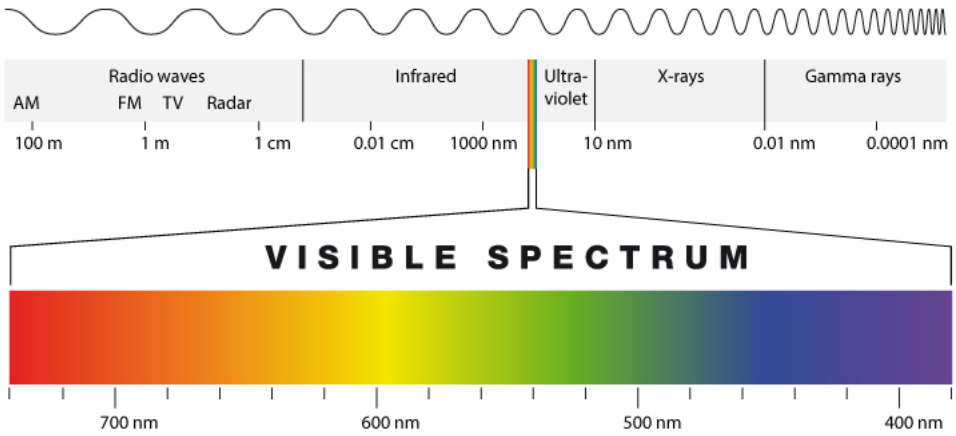
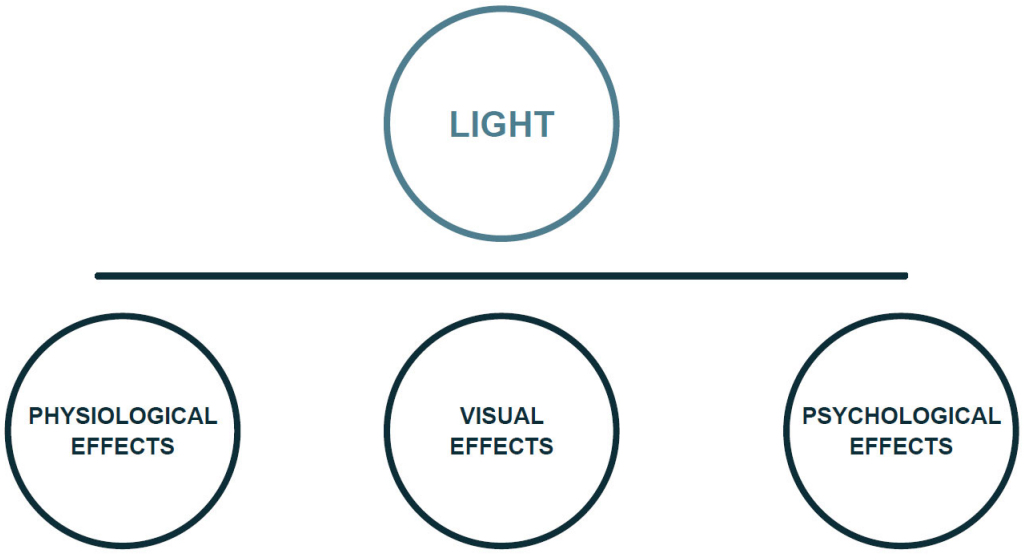


Figure 2.2: **Spectrum of Electromagnetic Radiation**[5]

2.2 Effects of Light on Humans

Light is present all around us, but we rarely think about it on a daily basis. But light serves our fundamental purposes and needs. Here are some of the most crucial points to keep in mind as we think about our general health[3].



2.2.1 Light Effects Our Vision

We should initially keep in mind that light enables us to see and perceive the world around us. While sunlight is prevalent throughout the day, it is not present at night, and artificial light is used in some indoor locations both during the day and at night. Thus, light is crucial, but we should also keep in mind that prolonged exposure to bright sunlight outside and to harsh artificial light with high flicker levels can both damage and strain the eyes which occasionally result in headaches and tiredness.

2.2.2 Light Helps Regulate Our Sleep

Our circadian rhythm or biological clock which impacts our cognition, blood pressure, immune system, metabolism and sleep/wake cycle, is controlled by the body's hormonal response to light wavelengths. We are exposed to blue light through computer screens, mobile phones, tablets and televisions for the most of the time of a day. It's not a problem throughout the day when we need to be focused and productive because blue light tells the body it's time to be awake and attentive. But at night, when it suppresses melatonin and interferes with sleep, it can become a bigger issue. And not getting enough sleep at night not only makes us feel inactive the next day but also has a

detrimental impact on our body fat percentage, brain function, insulin resistance, and can even affect our appetite.

2.2.3 Light Can Improve Our Mental Health

"The human body thrives when the weather is warmer. According to research, the main reason for mood changes comes down to longer days and thus, exposure to more light," says Lowri Dowthwaite, a Lecturer in Psychological Interventions at the University of Central Lancashire.

According to studies, more exposure of our body to the sunlight helps boost a chemical in our brain called serotonin, that makes us feel energetic, keeps us calm, positive and focused. The lack of sunlight is the primary cause of Seasonal Affective Disorder, a form of depression that affects many people at a certain time of the year. Our attitude and mental health can be improved by daily outdoor exercise in the presence of sunlight for at least 20 minutes, which gives us more energy for the rest of the workday. But since we spend a lot of time indoors, proper indoor lighting design is crucial because artificial light also aids in vision, stimulates us, and affects our mood and activity level because our physiological reaction to light depends on the spectrum of colours, intensity, and timing of the light.

2.3 LED Technology

"Light Emitting Diode" or simply "LED", as it is more generally known, is tiny light bulb that fits easily into an electrical circuit. Given their electrical similarities to PN junction diodes, LEDs are really just specific kind of diode. In other words, an LED will allow current to flow in one direction while blocking it in the opposite direction. LEDs therefore don't have filaments that burn out like incandescent lamps do. LEDs are illuminated solely from the motion of electrons in a semiconductor substance. In contrast to incandescent lights, which first convert electrical energy into heat energy, LEDs turn electrical energy straight into light energy. When forward biassed, light-emitting diodes can produce either visible light or invisible infrared light. Remote controls employ LEDs that emit invisible infrared light.

2.3.1 Physics of Light Generation from Light Emitting Diode (LED)

LEDs are just specialised PN junction diodes that produce light through the electro-luminescence phenomena. It is constructed of a pretty thin layer of semiconductor material that has been highly doped.

LEDs only function under conditions of forward bias. The free electrons from the n-side and the holes from the p-side are pushed towards the junction when external voltage is introduced and the Light Emitting Diode (LED) is forward biassed.

Some of the free electrons recombine with the holes in the positive ions when they reach the junction or depletion zone. We are aware that protons have more electrons than positive ions do. Therefore, they are ready to take electrons. As a result, in the depletion zone, free electrons recombine with holes. Similarly, in the depletion zone, holes from the p-side recombine with electrons.

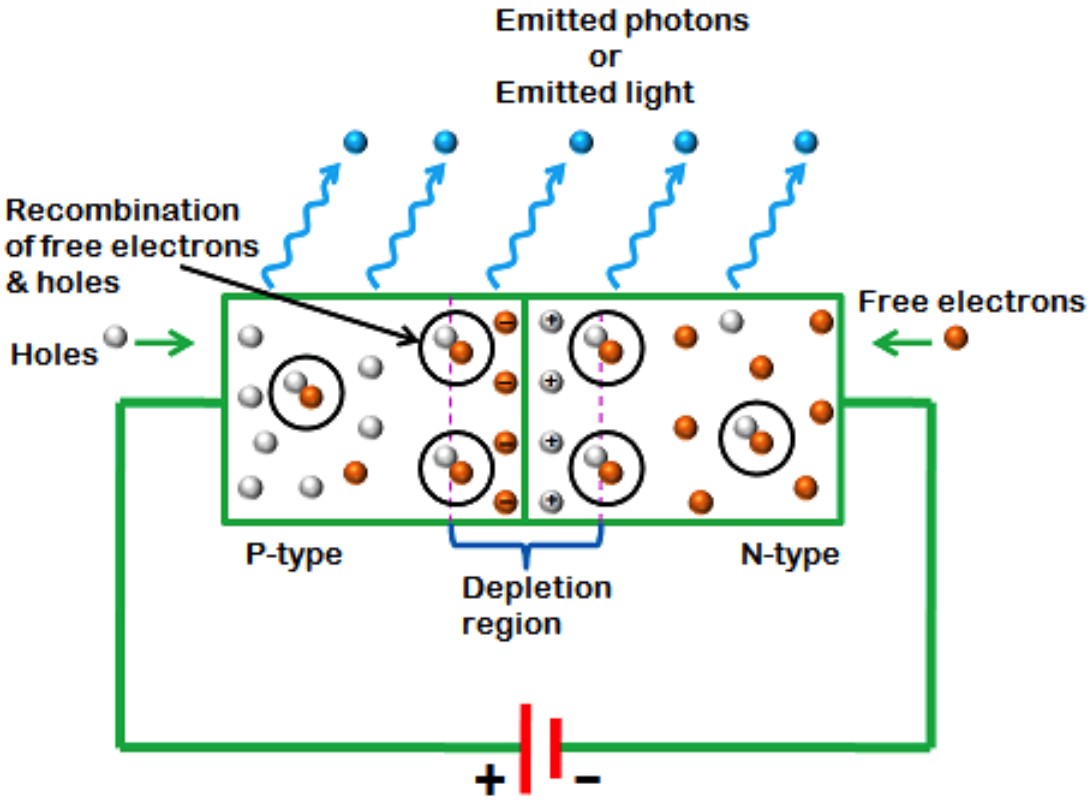


Figure 2.3: **Mechanism of Light Generation in Light Emitting Diode**

The width of the depletion region shrinks as a result of free electrons and holes recombining there. More charge carriers will therefore traverse the p-n junction as a result.

Before they recombine at the depletion zone, some charge carriers from the p-side and n-side will pass through the p-n junction. For example, some free electrons from an n-type semiconductor may traverse the p-n junction and recombines with holes in an adjacent p-type semiconductor. In a manner similar to this, holes from p-type semiconductor cross the p-n junction and recombines with free electrons in n-type semiconductor[6].

Recombination therefore occurs in the depletion zone as well as in p-type and n-type semiconductor.

Before they recombine with holes in the valence band, the free electrons in the conduction band release energy in the form of light.

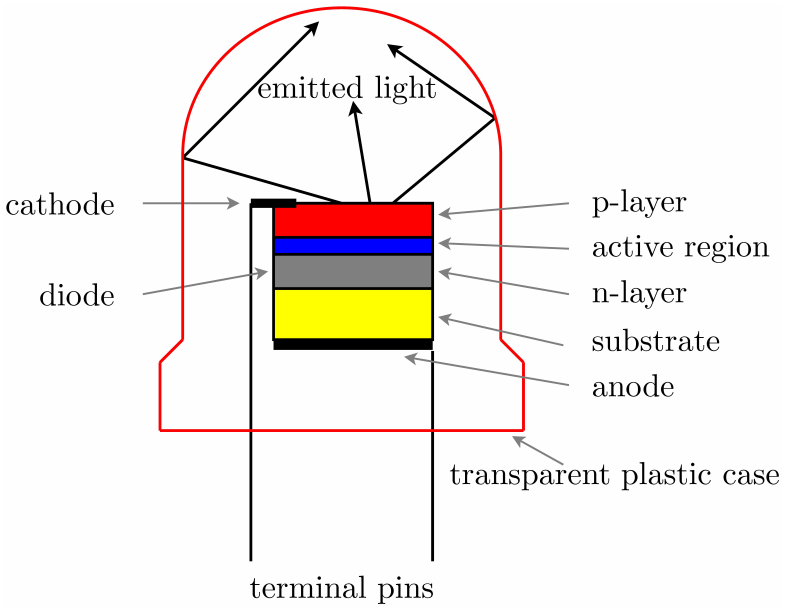


Figure 2.4: **Fabricated LED**

In silicon and germanium diodes, majority of the energy is dissipated in the form of heat and emitted light is very small.

However, the photons that are released in substances like gallium arsenide and gallium phosphide have enough energy to produce bright visible light[4].

2.4 Advantages of LED Lighting

Industrial and commercial organisations interested in lowering their energy consumption and expenditures can profit greatly from LED lighting. LED lights provide the following benefits:

2.4.1 Long Lifespan

LEDs don't burn out or fail like incandescent lighting; instead, they just get less bright over time. Depending on the calibre of the bulb or fixture, excellent LEDs are estimated to last 30,000–50,000 hours or even longer. A standard incandescent bulb lasts only 1,000 hours; a comparable compact fluorescent bulb lasts 8,000 to 10,000 hours. With a longer operational life, LEDs can minimise labour expenses for changing bulbs in commercial settings, resulting in a lighting system that requires less maintenance.

2.4.2 Energy Efficiency

LED lighting uses roughly 50% less energy than conventional incandescent, fluorescent, and halogen choices, which results in significant energy cost reductions, especially for rooms where lights are left ON for lengthy periods of time. Unlike conventional bulbs, which emit light and heat in all directions, LEDs focus light in a specified direction (because LEDs are mounted on a flat surface, they emit light hemispherically rather than spherically). Stating more precisely, LED emits light for just 180 degrees, but all other types of light emit light 360 degrees surrounding the source.The issue is that we're illuminating the room rather than the ceiling. This directional lighting capabilities cuts down on light and energy waste. Saving money is closely associated with these increases in energy efficiency.

2.4.3 Improved Safety

Safety is perhaps the most overlooked advantage of LED lighting. When it comes to lights, the number one hazard is the emission of heat. More than 90% of the energy used to power conventional bulbs like incandescents is converted straight into heat. Thus, approximately 10% or even less of the energy consumed by incandescent lamps is actually transformed to visible light; the bulk is instead converted to infrared (IR) or radiated heat. Burn hazards for humans and materials are presented by excessive heat and ultraviolet radiation (UV). . Nearly all of the light that LEDs emit is visible light, with almost no IR or UV emissions. This feature is one of the reasons why medical professionals are considering LEDs as a possible treatment for Seasonal Affective Disorder (SAD), a condition that affects a lot of individuals throughout the winter months.

Furthermore, because LEDs utilise less energy, they can function well in low-voltage electrical systems. In the case of a problem, these are typically significantly safer.

2.4.4 Friendly with Environment

The environmental problems associated with conventional lighting sources like fluorescent or mercury vapour lamps are not present with LEDs. Both of these conventional approaches require particular care when the product has reached the end of its useful life since they both contain mercury inside the lightbulb. With LEDs, none of these factors are necessary.

2.4.5 Instant Lighting and Capacity to Withstand Repeated Switching

LEDs nearly instantly reach full brightness when turned ON. Unlike metal halide lights, there is no warm-up period. Consider how a fluorescent light often flickers and takes two or three seconds to completely illuminate. The more frequently traditional light sources are turned on and off, the shorter their lifespan becomes, but LEDs are unaffected by frequent switching. Their longevity or efficiency are not affected in any way. Since LEDs are unaffected by turning on and off, they can be quickly cycled for applications that need sensors that often transition from on to off and back again, such as flashing light displays.

2.4.6 Exceptional Design Flexibility

LEDs are really tiny. They can therefore be applied to just about any situation, according to this. Keep in mind that they were initially intended to serve as an indication light in a circuit board. A conventional bulb can be made by grouping them together. A line or series of LED lights, similar to a string of holiday lights, can be made by connecting many of them together. Consider the possibilities this affords us for lighting in our facility. Since LED lights can be made so small, we can use them to illuminate anything from a shop floor to a stadium used for professional football.

2.4.7 Being Able to Function in Both Hot and Cold Environments

A wide variety of operating temperatures don't significantly degrade the performance of LEDs. Cold weather is not friendly to traditional illumination sources. Lighting sources, in particular fluorescent lights, require a higher voltage to start and lose some of their brightness when the temperature drops. However, LED lights perform around 5% better in colder temperatures. For illumination needs in freezers, cold storage areas, or refrigerated display cases, LED lights are a superior option. They are the ideal option to illuminate building perimeters, and lights used for outdoor signs because of their efficiency in cold weather.

2.4.8 Ability to Dim

Nearly any power level, from 5% to 100%, is effective for LED performance. When dimmed, some lighting sources, such as metal halide, operate less effectively. Sometimes we are unable to dim them at all. For LED lights, the opposite is true. An LED light performs better when its electricity isn't used at maximum capacity. Other advantages also follow from this characteristic. It lengthens the bulb's lifespan and results in us consuming less energy, which lowers our energy bills. It's vital to remember that when employing LEDs, we cannot utilise conventional lighting dimming equipment. Hardware designed specifically for their technology is required.

2.4.9 Outstanding Colour Rendering Index (CRI)

According to an ideal light source, a light's CRI rating indicates how well it can reveal objects' true colours (natural light). In general, a high CRI is a desired quality. When it comes to CRI, LEDs typically receive very high (excellent) ratings.

2.4.10 Wide Range of Correlated Color Temperature (CCT)

The term 'Correlated Color Temperature' or CCT, refers to a measurement of a lamp's lit-up colour look. Based on the colour of the light output, a colour temperature is assigned to each bulb. There is a large variety of correlated colour temperature (CCT) values for LEDs. They come with a range of options, including a warm yellowish glow, a cool white light and others.

Chapter3

Lighting for Commercial Building

3.1 Goals of Commercial Lighting

One of the best and simplest ways to enhance the work environment is lighting. The main purpose of the lighting in the office is to facilitate work. The difficulty is that office lighting designs must be unified and efficiently illuminate a variety of places that share a single roof, including the reception area, open office space, and individual offices of various sizes. It must uphold and convey the company's image. Energy regulations, energy prices, and lighting system efficiency are all things that must be taken into consideration. Additionally, flexibility must be built in to allow for simple adjustments as the business expands and its lighting requirements alter. These are the considerations that should be made when designing[15]:

- Establish a unified setting that improves the office staff's sense of well-being and productivity.
- Make a flexible lighting design that enables workers to do activities in comfort, successfully, and safely.
- Each section of the office should have ambient, task, accent, and decorative lighting that is integrated and balanced.
- Ensure a smooth transition from one area to another.
- Create a lighting design that balances energy efficiency and illumination quality for long-term employee comfort.
- Integrate and manage daylight to raise employee satisfaction and save energy usage.
- Be sure to include energy codes and efficiency.

3.2 Different Layers of Commercial Lighting

The four types of lighting that are frequently utilised in commercial lighting are general lighting, task lighting, accent lighting, and decorative lighting. Combining and balancing different lighting kinds adds visual interest to the area and makes it look more appealing, exciting, and welcoming.

3.2.1 General Lighting

The primary source of illumination in a room is general lighting. As the light levels from other fixtures can be decreased, especially when using LED sources, this uniform, base level of illumination can easily become the focus of energy savings.

For purposes of orientation, general tasks, and contrast ratio adjustment, it should provide the area with general illumination. Employee comfort is increased by diffused general illumination, which promotes wellbeing. This can be accomplished easily by positioning recessed fixtures in overlapping positions with reflectors, baffles, and lensed trims.

Wall washing and perimeter lighting assist define rooms, while vertical lighting gives the impression that the space is larger. Vertical lighting produces a comfortable, welcoming atmosphere. For visual comfort, spaciousness, as well as visual and directional signals, it is crucial that vertical surfaces are lighted. Vertical brightness facilitates orienting, aids in the definition of spaces, and contributes to the appearance of a larger, more welcoming room[7].

Figure 3.1: **General Lighting**

3.2.2 Task Lighting

A focused, localised and greater intensity of illumination is provided by task lighting when it is utilised to illuminate a space for a particular purpose. Energy-efficient sources are vital to use in order to save running expenses and ensure that a place functions properly.

In offices, conference rooms, especially on counter tops, task lighting performs best when added to general lighting. Effective work lighting should reduce glare from the lamp or surfaces while eliminating shadows on the specific lighted area. The brightness of the surrounding regions can be increased, decreased or both to easily regulate glare, which hinders office productivity.

Between 500 and 2000 lux of light are advised for task areas. The difference in brightness or contrast between the task area and the surrounding area must be considered when lighting a task area. A great contrast is produced with a task lighting to general illumination ratio of 3 to 1. The most adaptable aspect of task lighting is typically the quantity of light needed on the task or luminance, which can be adjusted to make up for poor contrast levels. The best approach for office areas is to make use of the task luminaires' strategic placement and the normally low ambient light level. By using this combination, the ideal working conditions are met, and energy is saved because high-level illumination is only used where it is required. Task lighting improves the quality of light for particular tasks while reducing dependency on overhead lighting.

Figure 3.2: **Task Lighting[9]**

3.2.3 Accent Lighting

Using one or more focused or point light sources, accent lighting enhances the visual appeal of a design and places a striking emphasis on shapes, textures, finishes, and colours. Unwanted shadows and distracting glare may result from this light's unclear direction.

The trick is to make this illumination more focused and intense than the ambient light in the area. For directional control and accent lighting that is very effective, consider track fixtures, recessed housings with adjustable trims, and concealed adjustable illumination with point source bulbs. To emphasise an object's best qualities, they are simple to target accurately. Using accent lighting incorrectly often results in accentuating everything while underscoring nothing; always remember that there is such a thing as too much lighting. The IESNA suggests a 5:1 ratio of accent lighting to ambient light to make objects stand out and produce a noticeable visual impression. There should be between 150 and 500 footcandles of light for accent lighting.

Figure 3.3: **Accent Lighting[10]**

3.2.4 Decorative Lighting

In addition to adding to the lighting layers in a commercial environment, decorative lighting also improves the appearance of the area as a design feature. Pendants, sconces, chandeliers, table and floor lamps, and cylinders are examples of decorative lighting. In addition to contributing to the overall lighting scheme, decorative lighting should enhance and add visual appeal to the space.

Pendants need to be 8–10 feet above the finished floor in order to be visible, but not so low as to be distracting. Pendant lights exhibited above desks and counters should be suspended 36–48 inches above the horizontal plane; this is low enough to give task and/or accent lighting and add some sparkle, but not so high as to interfere with people using the area.

It helps to generate a sense of human scale, especially in a big space, to hang wall sconces and wall-mounted cylinders at a distance of around 5 feet.

Using decorative lighting to enhance a space's decor, beauty, and style also helps to reinforce the concept and style of the area and is a significant representation of the company's brand. A welcoming and comfortable atmosphere can also be enhanced by decorative lighting[8].

Figure 3.4: **Decorative Lighting**

3.3 Commercial Lighting Design Considerations

- The size and shape of the area.
- Movement patterns inside the area.
- The intended use of each room: each room is nearly usually used for a certain job, some of which require more light than others.
- The height and shape of the ceiling: whether or not light will reflect off these surfaces and add to the ambient light level in the space.
- Wall colour: Because darker walls absorb more light, additional lighting may be needed. A company's image will be better reflected by a bright, airy office than by a dark one.
- Artwork and highlight areas: deciding which works and locations will be emphasised helps decide the required amount of accent lights.
- Luminaire families: Recessed downlights used as wall washers and adjustable accent lights belong to the same family of luminaires, and they should have the same aperture size, trim finish, and lamp kinds. To avoid bringing the lighting system into focus, complement these selections with same or comparable finishing fixtures.
- Light source colour characteristics: Correlated Colour Temperature and Colour Rendering Index are the two units of measurement used to define the colour characteristics of a light source. Not all sources of light are created equally. While two white light sources may appear to be the same, they can portray colours differently or give the room a different vibe. The space will be evenly and consistently lit if the lamps are the same Correlated Colour Temperature and have the same, or very comparable, Colour Rendering Indices.

3.4 National and International Standards and Recommendations

Lighting designs are carried out using a variety of criteria and parameters. Different International and Indian standards serve as a guide and as recommendations for the lighting design requirements. Europian Standard EN 12464-1:2011; Indian Standards IS 3646 Part- 1 (1992) and ECBC 2017 provide the national recommendations for commercial lighting design that are the most widely adopted.

3.4.1 IS 3646 Part- 1 (1992)

This Indian Standard (Part 1) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Illuminating Engineering and Luminaires Sectional Committee had been approved by the Electrotechnical Division Council[11].

In clause 4.2.2.2 of IS 3646 part 1 (1992), the recommended illumination which includes type of interior or activity, range of service illuminance in lux, quality class of direct glare limitation and remarks for commercial lighting have been stated which follows:

It is stated in SL No. 17 of clause 4.2.2.2 of IS 3646 part 1 (1992), that sets illumination standards for General offices, Deep plan general offices, Computer work stations, Conference rooms, executive offices, Computer and data preparation rooms, Filing rooms shown in Figure 3.5:

IS 3646 (Part 1) : 1992

Table 1 (*continued*)

Type of Interior or Activity	Range of Service Illuminance in Lux	Quality Class of Direct Glare Limitation	Remarks
17 COMMERCE			
17.1 Offices			
17.1.1 General offices	300-500-750	1	
17.1.2 Deep plan general offices	500-750-1 000	1	
17.1.3 Computer work stations	300-500-750	1	
17.1.4 Conference rooms, executive offices	300-500-750	1	
17.1.5 Computer and data preparation rooms	300-500-750	1	
17.1.6 Filing rooms	200-300-500	1	
17.2 Drawing Offices			
17.2.1 General	300-500-750	1	
17.2.2 Drawing boards	500-750-1 000	1	
17.2.3 Computer aided design and drafting	—	—	Special lighting is required
17.2.4 Print rooms	200-300-500	1	
17.3 Banks and Building Societies			
17.3.1 Counter, office area	300-500-750	1	
17.3.2 Public area	200-300-500	1	
23 GENERAL BUILDING AREAS			
23.1 Entrance			
23.1.1 Entrance halls, lobbies, waiting rooms	150-200-300	2	
23.1.2 Enquiry desks	300-500-750	2	Localized lighting may be appropriate
23.1.3 Gatehouses	150-200-300	2	
23.2 Circulation Areas			
23.2.1 Lifts	50-100-150	—	
23.2.2 Corridors, passageways, stairs	50-100-150	2	
23.2.3 Escalators, travellators	100-150-200	—	

Figure 3.5: **IS 3646 part 1 (1992) Recommended Illumination Table**

3.4.2 ECBC 2017

The name ECBC 2017 implies Energy Conservation Building Code 2017. There are two methods defined by ECBC 2017 that define Lighting Power Density (LPD) for each building type[12]. The methods are:

a) Building Area Method
b) Space Function Method

a) Building Area Method

Determination of interior lighting power allowance (watts) by the building area method shall be in accordance with the following:

- Determine the allowed Lighting Power Density (LPD) for each appropriate building area type.
- Calculate the gross lighted carpet area for each building area type.
- The interior lighting power allowance is 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.

The recommended Lighting Power Density (LPD) values for office building are:

Building Type	LPD (W/m^2)
Office Building	9.50

Table 3.1: Interior Lighting Power for ECBC Buildings – Building Area Method

Building Type	LPD (W/m^2)
Office Building	7.60

Table 3.2: Interior Lighting Power for ECBC + Buildings – Building Area Method

Building Type	LPD (W/m^2)
Office Building	5.0

Table 3.3: Interior Lighting Power for SuperECBC Buildings – Building Area Method

b) Space Function Method

Determination of interior lighting power allowance (watts) by the space function method shall be in accordance with the following:

- Determine the appropriate building type and the allowed Lighting Power Density (LPD)
- For each space, enclosed by partitions 80% or greater than ceiling height, determine the gross carpet area by measuring to the face of the partition wall. Include the area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.
- The interior lighting power allowance is the sum of the lighting power allowances for all spaces. 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.

The recommended Lighting Power Density (LPD) values for conference/meeting room, restroom, storage room, corridor, lobby are:

Common Space Types	LPD (W/m^2)
Restroom	7.70
Storage	6.80
Conference/Meeting	11.5
Corridor	7.10
Lobby	9.10

Table 3.4: Interior Lighting Power for ECBC Buildings – Space Function Method

Common Space Types	LPD (W/m^2)
Restroom	6.10
Storage	5.40
Conference/Meeting	9.20
Corridor	3.60
Lobby	7.30

Table 3.5: Interior Lighting Power for ECBC + Buildings – Space Function Method

Common Space Types	LPD (W/m^2)
Restroom	3.80
Storage	3.40
Conference/Meeting	5.70
Corridor	2.30
Lobby	4.60

Table 3.6: Interior Lighting Power for SuperECBC Buildings – Space Function Method

3.4.3 EN 12464-1:2002 (E) and EN 12464-1:2011

This European Standard specifies lighting requirements for indoor work places, which meet the needs for visual comfort and performance. All usual visual tasks are considered, including Display Screen Equipment (DSE).

This standard neither provides specific solutions, nor restricts the designers freedom from exploring new techniques nor restricts the use of innovative equipment[13].

As mentioned in EN 12464-1:2002 (E),

The illuminance of immediate surrounding areas shall be related to the illuminance of the task area and should provide a well-balanced luminance distribution in the field of view.

Large spatial variations in illuminances around the task area may lead to visual stress and discomfort.

The illuminance of the immediate surrounding areas may be lower than the task illuminance but shall be not less than the values given in Table.

Task illuminances lx	**Illuminances of immediate surrounding areas** lx
≥ 750	500
500	300
300	200
≤ 200	E_{task}
Uniformity≥ 0.7	Uniformity≥ 0.5

Table 3.7: Uniformities and relationship of illuminances of immediate surrounding areas to task area

As specified in section 6.3 of EN 12464-1:2011, task and activity sectors' lighting needs:

Ref. no.	Type of task/activity area	$\bar{E}_{m,r}$ lx	$\bar{E}_{m,u}$ lx	U_o
6.26.1	Filing, copying, etc.	300	500	0,40
6.26.2	Writing, typing, reading, data processing	500	1 000	0,60
6.26.3	Technical drawing	750	1 500	0,70
6.26.4	CAD work stations	500	1 000	0,60
6.26.5.1	Conference and meeting rooms	500	1 000	0,60
6.26.5.2	Conference table	500	1 000	0,60
6.26.6	Reception desk	300	750	0,60
6.26.7	Archiving	200	300	0,40

Column 1 lists the reference number for each task or activity area.

Column 2 lists those tasks or activities areas, for which specific requirements are given. If the particular task or activity is not listed, the values given for a similar, comparable situation should be adopted. Task or activity areas can also be a room, e.g. a corridor or resting room.

Column 3 gives the minimum maintained illuminance $E_{m,r}$ on the reference surface for the interior (area) in which the task or activity from Column 2 is performed.

Column 4 gives the upper maintained illuminance $E_{m,u}$ on the reference surface for the interior (area) in which the task or activity from Column 2 is performed.

Column 5 gives the minimum illuminance uniformity U_o on the reference surface for the maintained illuminance E_m[14].

Chapter4

Case Studies

4.1 About the Work Place

This design report provides a summary of the numerous rooms and areas that make up the proposed commercial building's roof. The various rooms and areas are separated into four blocks. According to the function of each specific space or room, a virtual name is assigned to that space or room.

4.2 Details of the Rooms Considered in this Case Studies

Room Name	**Block**	**Area(m^2)**	**Height(m)**
Conference Room (6 Person)	A	14.34	3.45
Co-working Space	A	359.83	3.45
Creative Space	A	9.15	3.45
IT Lounge, Pantry& Wide Corridor	joining A & B	164.36	3.45
AV Studio	B	22.64	3.45
Deep Plan Meeting Room (4 Person)	B	9.78	3.45
Meeeting Room (2 Person)	B	8.95	3.45
Open Meeting Space (4-6 Person)	C	10.33	2.4
Collab	C	25.74	3.45
Waiting Lounge with Wide Corridor	D	98.57	3.45
Wellness Room	D	14.89	3.45
Store Room	D	6.08	3.45

4.3 Classifications of the Various Rooms and Places

4.3.1 Office Reception and Waiting Area

When clients and visitors enter the space, they frequently establish their initial impression of the company. Lighting must enhance the design, offer a secure transition from the external to the interior, and project a powerful corporate identity. The task area for the receptionist and the area where guests are waiting typically require lighting in two different locations. The receptionist's face should be lit carefully to give off an inviting appearance. While providing adequate illumination for routine tasks, the waiting area's lighting should be peaceful.

4.3.2 Corridors

The office's corridors must be illuminated for extended, if not continuous, periods of time. To save energy, lighting must be at least one-fifth as bright as the surrounding areas. When moving into and out of the hallways, this level is safe for navigation and won't affect eye adaptation. Lighting up the walls and ceilings can make the area appear bigger and more airy.

4.3.3 Conference Rooms

The conference room performs a variety of tasks, including brainstorming meetings, video and power point presentations, and other activities. As a result, the lighting plan must take these many uses into account. The lighting in these areas must be planned to provide the most flexibility and comfort for the eyes. To adjust the illumination level for visual presentations, the general lighting in the space must be dimmable and set at a convenient, navigable level. It is necessary to give adequate illumination on the persons seated at the table as well as the proper task lighting for reading and writing.

4.3.4 Open Plan Office Space and Office Lounge Area

Offices with open floor plans are lively places where many different tasks are carried out as well as where brilliant ideas and innovation can be produced in a well-equipped workplace lounge area. The ambient lighting level in the open-plan office must be functional, comfortable, and consistent with the overall lighting scheme. The distribution characteristics and overall brightness of the ambient lighting will be significantly influenced by the furniture utilised in the space. Therefore, the task lighting in the area will deliver the greater illuminance levels required at task sites. In order to prevent hot spots and glare, the lighting should be dispersed evenly. Given that workstations are temporary, it is crucial to maintain the open lighting plan relatively adaptable.

4.3.5 Private Office Space

Private offices are used for both individual work and as meeting rooms for groups. With suitable task lighting above the desk and other work surfaces, the ambient light in the space should be adequate for movement and discussion. By spotlighting artwork or other work-related materials while also creating simple light patterns, accent lighting can provide diversity and appeal to a space. Track heads or recessed housings with changeable angles can be used to accomplish this. The design and style of the luminaire should enhance the room's architectural and interior design features.

4.3.6 Wellness Room

In many workplaces, this area is important but frequently disregarded. A wellness room is a quiet space where an employee can retreat if they are stressed or feeling ill, or if a nursing mother needs to pump. In the public areas of the office, it might offer a necessary separation from other people.

The wellness room's ambient lighting should provide the user a homey feeling. As a result, it ought to be a warm, secure, and safe place. Therefore, wellness lighting should increase productivity while also enhancing one's well-being and behaviour.

4.3.7 Store Room

Smaller room storage lighting is frequently disregarded, overlooked, or given less consideration in the home or office. However, there is a strong argument in favour of efficient lighting in closets and storage areas, which can make a room appear and feel bigger, better, and more organised. When we need things quickly, we must have access to them quickly.

The general guideline for lighting a tiny, little used storage area is to concentrate on a balance between functionality and aesthetics. The main source of lighting in a store is often ambient light. Although individuals rarely spend much time in these areas, excessive lighting is usually not a problem. Nevertheless, there should be enough light. It would depend on the size and configuration of the space how much light was needed.

Chapter5

Design Methodology Adapted

5.1 Introduction

The steps needed for lighting design are covered in this chapter. The building layout is created by the architect in a computer-readable format, ideally CAD. There are doors, windows, and other detailed aspects present in the layout. Additionally, whether true or false, it specifies the types of ceilings and the height of the floors. Understanding the ceiling is essential. The remainder of this chapter will expand on this concept.

5.2 Application Software with Step-by-Step Lighting Design

In this case study lighting design, two softwares are utilised. They are:

- AUTOCAD 2021: CAD drawing software.
- DIALux evo 10.1: Lighting design software.

The CAD file is opened on the AUTOCAD software shown in the figure:

It is carefully examined, and any specific information (sectional diagrams, objects, etc.) and relevant notes are produced regarding the measures (such as in millimetres, feet, etc.). As needed by the user, the layers of a CAD drawing can be turned ON or OFF. The file is in.dwg format.

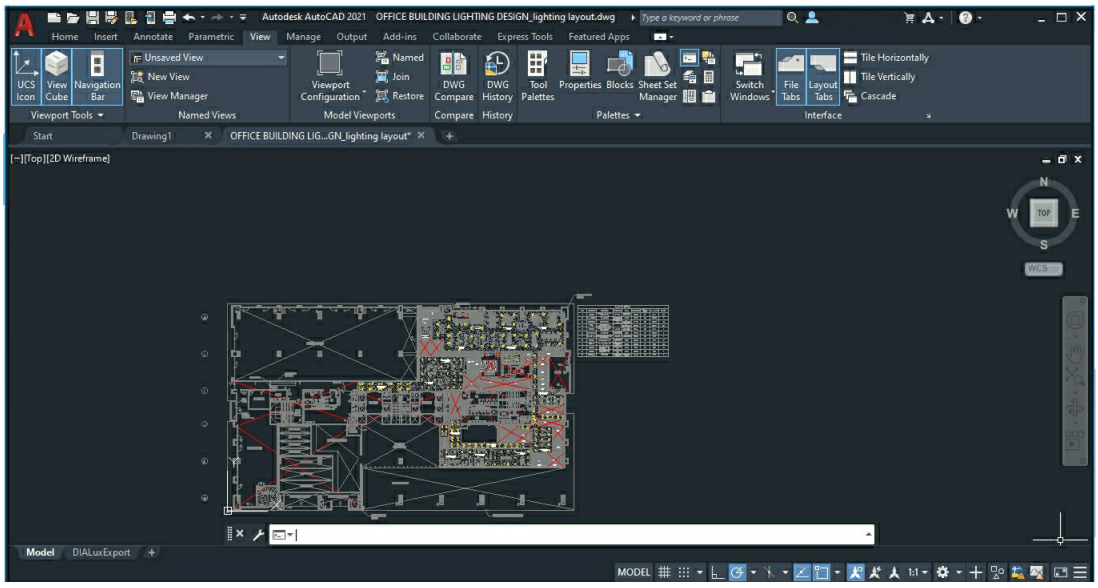


Figure 5.1: **Opening the CAD drawing in AUTOCAD 2021**

After this the CAD drawing file is imported by specifying respective unit of measurement (such as in millimetre, in feet etc.) into DIALux evo going to tab 'New Interior Project', which is shown in the next figure:

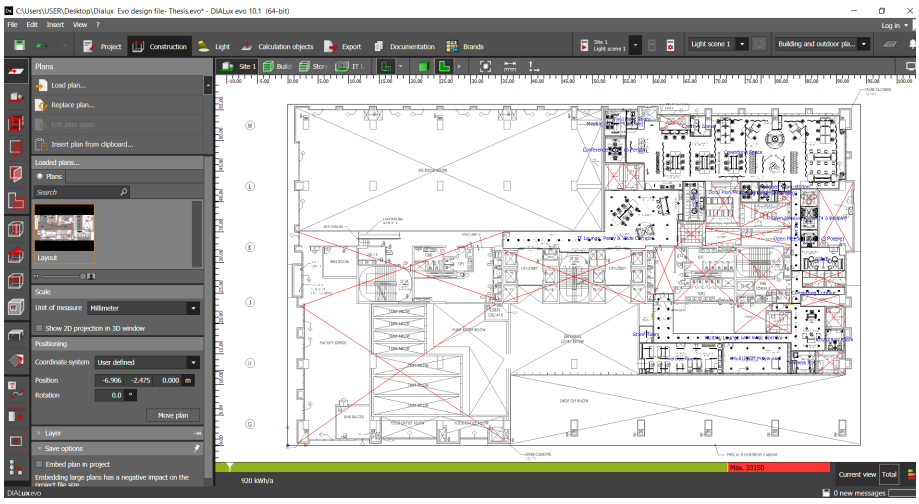


Figure 5.2: **Imported CAD drawing into DIALux evo 10.1**

By just saving this DIALux evo file, a.dlx file format will be produced. This .ies files corresponding to the luminaires intended to be used in the simulation must be imported to DIALux evo. The simulated result file is saved in pdf format.

5.3 Design Parameters to be Achieved in This Case Study

- Maintained Average Illuminance (E_m)
- Overall Uniformity (U_o)
- Lighting Power Density (LPD)

Chapter6

Specifics about The Used Luminaire

6.1 Luminaire Details (as in August, 2022)

Depending on the needs of the application, many types of luminaires are employed in this case study; some are pendant-style, some are ceiling-recessed, and some are other sorts. The following is a list of their precise details.

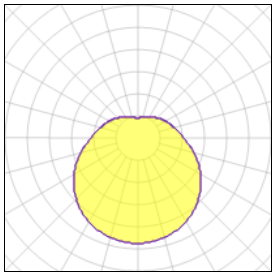
Product data sheet

ALPHABET OF LIGHT W/C CIRCOLARE 90
1306000A
ARTEMIDE

IP 20

ALPHABET OF LIGHT W/C CIRCOLARE 90

Light output 1 (integrated)



Lamp type	LED	CCT	3000 K
Nominal lamp power	55 W	CRI	80
Total flux	6040 lm	LOR	100%
Luminous efficacy	110 lm/W	ULOR	31%
		Total power	55 W

Mounting mode

Ceiling mounted

Shape and measurements

Length: 35.41 in
Width: 35.42 in
Height: 1.97 in

Adjustability

Fixed

Electric

System power: 55 W

Protection

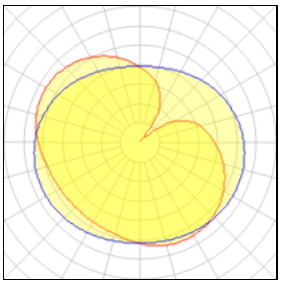
IP: 20

Product data sheet

MICONOS SUSPENSION
A031000
ARTEMIDE

IP 20

Light output 1



1 x General service incandescent lamp

Nominal lamp power	15 W	Socket	E27
Lamp flux	1522 lm	LOR	90%
Luminous efficacy	91 lm/W	ULOR	42%
CCT	2700 K	Total flux	1372 lm
CRI	80	Total power	15 W

Mounting mode

Pendant

Shape and measurements

Length: 11.81 in
Width: 11.90 in
Height: 13.52 in

Adjustability

Fixed

Electric

System power: 15 W

Protection

IP: 20

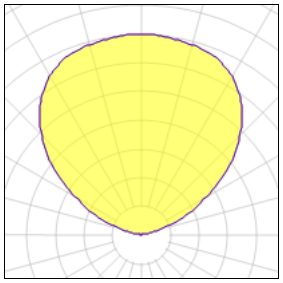
Product data sheet

NEUTRON 1 FIXED ROUND FLOOR LED SIDE
07.9525/PW LED/1W/111°
FLOS

IP 67

Adjustable recessed luminaire for ceilings or in ground applications, for LEDs or 12 volt halogen QR-CBC 35 lamps. Die-cast aluminum recessed housing, high corrosionresistance. 6mm tempered protection glass. Silicone seals. Stainless steel closing ring with fixing screws. PG9 cable gland with pre-wired 1 metre power loom. Finishes: matt black (04), grey (72), stainless steel (55), stainless steel dark copper (PB), stainless steel gold (PG), stainless steel black (PN).

Light output 1



1 x LED

Nominal lamp power	1 W	LOR	48%
Lamp flux	53 lm	ULOR	48%
Luminous efficacy	25 lm/W	Total flux	25 lm
CCT	3000 K	Total power	1 W
CRI	79		

Mounting mode

Floor recessed

Shape and measurements

Height: 4.73 in
Diameter: 4.92 in

Adjustability

Fixed

Electric

System power: 1 W

Protection

IP: 67

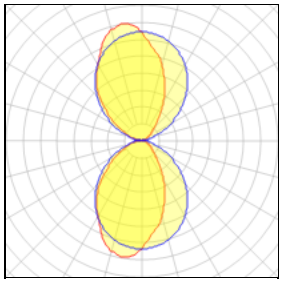
Product data sheet

TIGHT LIGHT
F0011009 2X9W TOP LED
FLOS

IP 20

Direct/indirect light wall lamp. Body in painted extruded aluminium. Lateral friezes in pressofused aluminium turned up to 45º on digital control for perfect mating with the lamp body. Diffusers in injection printed PMMA with photo-engraved finish. Injection printed wall attachment in PA66. Multi-voltage power pack integrated in the body.

Light output 1



1 x LED

Nominal lamp power	20 W	LOR	50%
Lamp flux	1282 lm	ULOR	25%
Luminous efficacy	64 lm/W	Total flux	641 lm
CCT	3000 K	Total power	20 W
CRI	80		

Mounting mode

Wall mounted

Shape and measurements

Length: 6.30 in
Width: 3.94 in
Height: 5.12 in

Adjustability

Fixed

Electric

System power: 20 W
Appliance Class: I

Protection

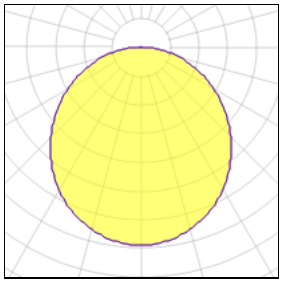
IP: 20

Product data sheet

BASIC SUPERFLAT - G7
BG7OSE-830H-D300-U
LIGHTNET

LED pendant luminaire. Direct-indirect or direct-only light distribution. Tiered luminaire body made of aluminium profile with only 18mm visible frame. Surface white, silver, graphite, black, champagne or copper coated. Further surface options see Lightnet-Surface-Collection or RAL of your choice. Microprismatic screen with optimized glare reduction especially for workplaces. Satin opal diffuser for general lighting with maximum transmittance and homogeneous lighting. Converter integrated into luminaire housing, optionally switchable or dimmable (1-10V, DALI, Touch-Dim, Casambi). Colour temperatures 2200K, 2700K, 3000K, 3500K, 4000K or 6500K. Binning initial ≤ MacAdam 3. Colour rendering CRI>80 or CRI>90. Height-adjustable central cord suspension with transparent power supply cable or rod suspension. On request: Integration of emergency lighting components, sensor technology.

Light output 1 (integrated)



Lamp type	LED	CCT	3000 K
Nominal lamp power	11 W	CRI	82
Total flux	1244 lm	LOR	100%
Luminous efficacy	113 lm/W	Total power	11 W

Mounting mode

Pendant

Shape and measurements

Height: 11.81 in
Diameter: 11.81 in

Adjustability

Height adjustable

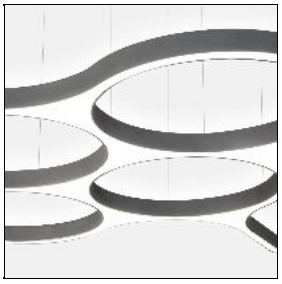
Electric

System power: 11 W

Protection

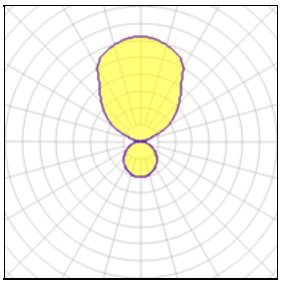
Product data sheet

RINGO STAR CLUSTER SUSPENDED - P3
RP3OSE-830E-C1
LIGHTNET



LED pendant light system. Direct-indirect or direct-only light distribution. Lighting system with various combinations of the different X, Y and circular modules, each module available as stand-alone luminaire. A connector and a cord-holder have to be ordered separately for each joint. Furthermore entirely compatible with all Liquid Line G3/P3 modules. Luminaire body made of aluminium profile with 60mm width. Surface white, silver, graphite, black, champagne or copper coated. Further surface options see Lightnet-Surface-Collection or RAL of your choice. Optionally internal acoustically highly effective broadband absorber for reducing the reverberation time, 4 options (Green Moss, Yellow Felt, Graphite Felt or White Perforated). Satin opal diffuser for general lighting. Converter integrated into luminaire housing, optionally switchable or dimmable (1-10V, DALI, Touch-Dim, Casambi). Colour temperatures 2200K, 2700K, 3000K, 3500K, 4000K or 6500K. Binning initial ≤ MacAdam 3. Colour rendering CRI>80 or CRI>90. Ceiling rose with transparent power supply cable has to be ordered separately for each complete light structure.

Light output 1 (integrated)



Lamp type	LED	CCT	3000 K
Nominal lamp power	16 W	CRI	82
Total flux	1403 lm	LOR	100%
Luminous efficacy	88 lm/W	ULOR	70%
		Total power	16 W

Mounting mode

Pendant

Shape and measurements

Length: 8.86 in
Width: 2.36 in
Height: 3.94 in

Adjustability

Height adjustable

Electric

System power: 16 W

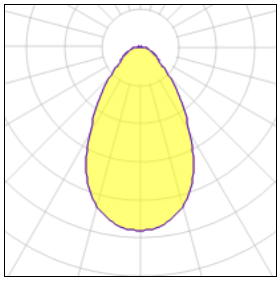
Protection

Product data sheet

LUXSPACE, RECESSED DN571B PSE-E 1XLED12S/830 F SG-O
DN570B
PHILIPS

LuxSpace recessed – high efficiency, visual comfort and a stylish design Customers are looking to optimize all their resources, and that means not just their running costs (energy, etc.) but also their human resources. Energy savings are therefore a priority, but they must not have an adverse effect on the well-being of employees, who need a pleasant environment in order to be more productive, or on customers, who want to enjoy their shopping experience. LuxSpace provides the perfect combination of efficiency, light comfort and design, without compromising on lighting performance (color rendering and color uniformity). It offers a wide choice of options for creating the desired ambience, no matter the application. For office applications LuxSpace supports the general feeling of health and wellbeing having dedicated Tunable White products

Light output 1



1 x General service incandescent lamp

Nominal lamp power		LOR	100%
Lamp flux	1050 lm	Total flux	1050 lm
Luminous efficacy	89 lm/W	Total power	11.8 W
CCT	3000 K		
CRI	99		

Mounting mode

Ceiling recessed

Shape and measurements

Height: 4.76 in
Diameter: 8.43 in

Electric

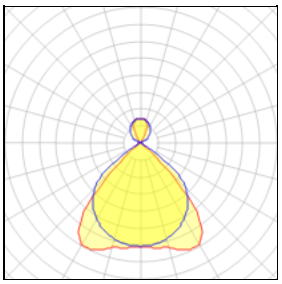
System power: 11.8 W

Product data sheet

CELINO TPS680/682 TPS682 1XTL5-28W HFP C8
TPS680
PHILIPS

Celino – light beam. Celino is a complete luminaire range that reflects the market trend towards miniaturization and architectural integration, while delivering a significant advance in optical performance. Celino features Philips' aluminum micro optic with 3D lamellae, which ensures optimum visual comfort and efficiency in compliance with the latest office-lighting norm (EN 12464-1). Made of natural anodized aluminum, the housing of Celino is a mere 71 mm wide and has die-cast-aluminum end caps. The design allows multiple luminaires to be connected in a line arrangement. Celino is available as a full range – suspended, surface-mounted, free-standing, recessed and wall-mounted, with a choice of TL5, TL5 Eco or LED light sources – for maximum freedom in application.

Light output 1



1 x General service incandescent lamp

Nominal lamp power		LOR	73%
Lamp flux	2625 lm	ULOR	11%
Luminous efficacy	62 lm/W	Total flux	1912 lm
CCT	3500 K	Total power	31 W
CRI	80		

Mounting mode

Pendant

Shape and measurements

Length: 48.03 in
Width: 2.80 in
Height: 2.99 in

Electric

System power: 31 W

Chapter7

Proposed Lighting Design

7.1 Lighting Simulation for Commercial Building

Problem Statement: The Workspace is a designed to have Movable Office Furniture; giving employees the freedom to change the layout of the space in minutes. Hence, the lighting for the space should be flexible enough to meet the requirements, irrespective of the furniture layouts. The design should be able to adapt to the needs of the future workspace layouts as-well.

Requirements that must be addressed for the design;

- The Exposed Ceiling is White with 60% Reflection Factor.
- The Walls are White with 70% Reflection Factor (Textures / Wall Art can be used).
- The Floors are Carpeted (Dark Grey) with 15% Reflection Factor (Textures for Floors can be used).
- Maintenance Factor has to be 0.9.
- The True Ceiling height is 3.45 Meter.
- Mounting Height of Light Fixtures in Exposed Ceiling Areas to be considered at 2.4 Meter.

7.2 Lighting Design of Several Types of Room in a Commercial Building Used as Case Study

As a Commercial Building has many different sorts of areas and rooms. They are classified as follows:

- Conference Room (6 Person)
- Co-working Space
- Creative Space
- IT Lounge, Pantry & Wide Corridor
- AV Studio
- Deep Plan Meeting Room (4 Person)
- Meeting Room (2 Person)
- Open Meeting Space (4-6 Person)
- Collab
- Waiting Lounge with Wide Corridor
- Wellness Room
- Store Room

Figure 7.1: **3D View of The Commercial Layout's Lighting Design**

Figure 7.2: **2D View of The Commercial Layout's Lighting Design**

7.2.1 Lighting Design of 'Conference Room (6 Person)'

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011, in Conference Room

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o)=0.60.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

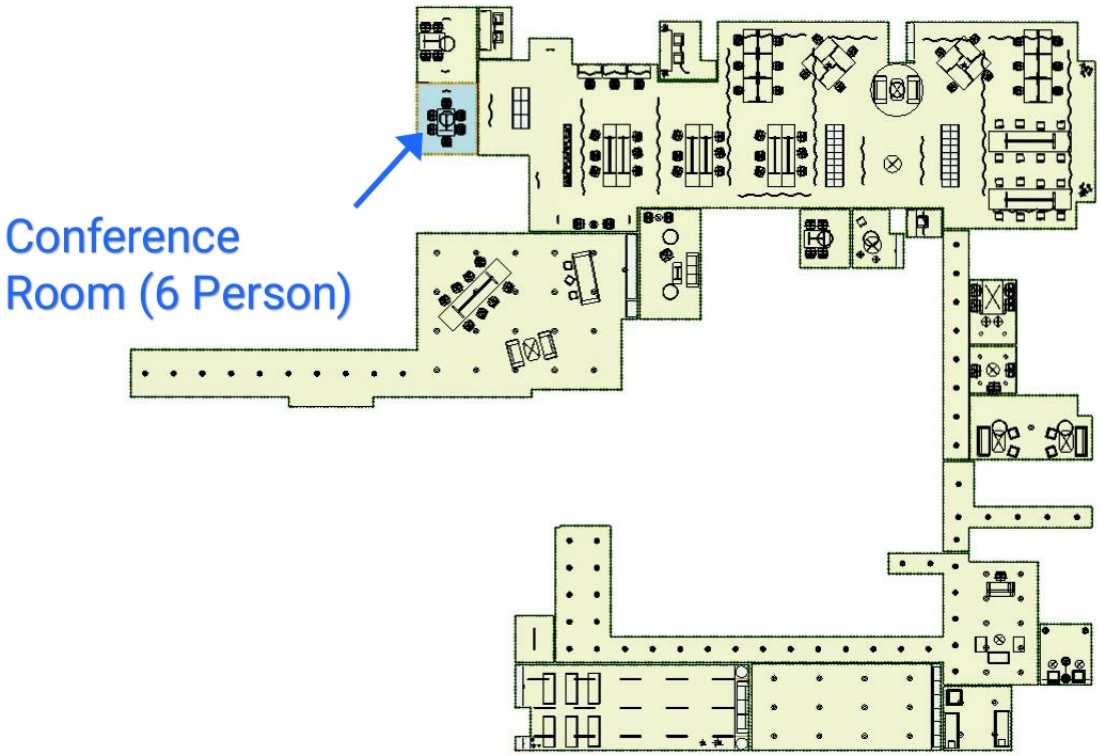


Figure 7.3: **Layout of 'Conference Room (6 Person)'**

c) Luminaire Layout:

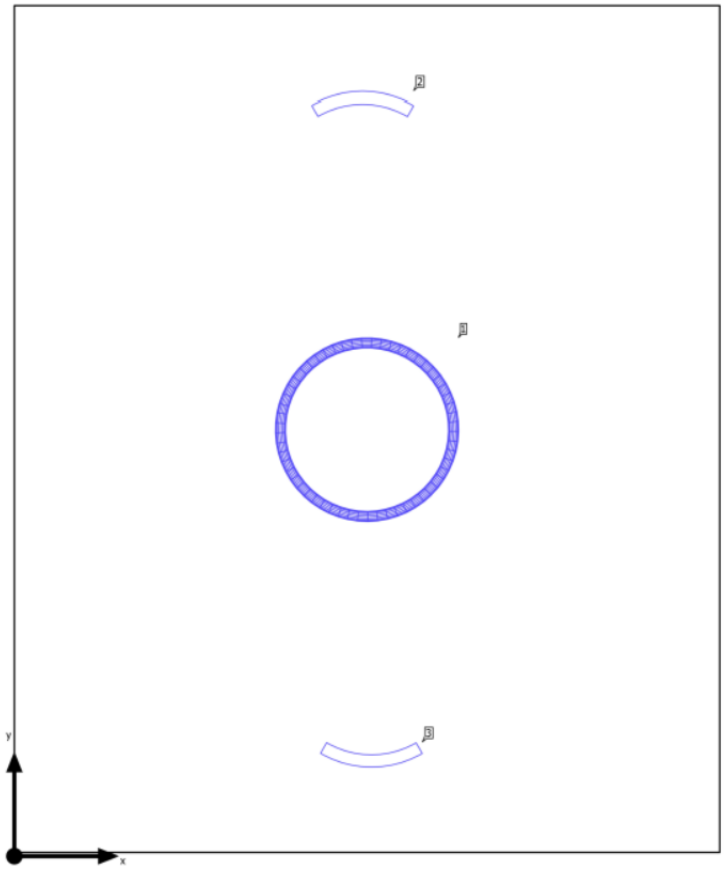


Figure 7.4: **2D View of Luminaire Layout**

- Hight of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

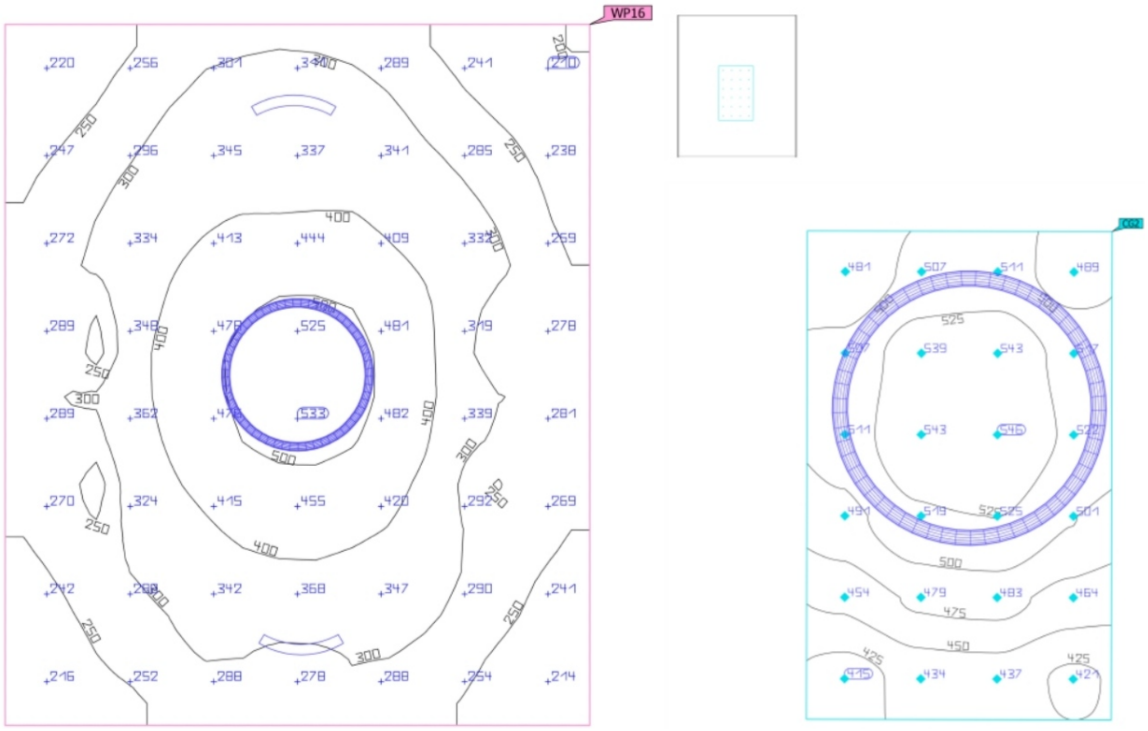


Figure 7.5: **Isolines on Work-Plane (Room Area, Table Area)**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0 W	6040 lm	109.8 lm/W
2	Lightnet	RP3OSE-830E-C1	Ringo Star Cluster Suspended - P3	16.0 W	1403 lm	87.7 lm/W

e) 3D Standard View of 'Conference Room (6 Person)':

Figure 7.6: **3D Standard View, Light Distribution Display**

f) Simulated Output:

Conference Room (6 Person)

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
87.0 W	14.34 m²	6.07 W/m² = 1.87 W/m²/100 lx (Room)	325 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Conference Room (6 Person)) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	325 lx (≥ 300 lx) ✓	199 lx	542 lx	0.61	0.37	WP16

Calculation surfaces

Properties	$\bar{E}$	E_{min}	E_{max}	g_1	g_2	Index
6P MTG DESK Perpendicular illuminance Height: 0.800 m	493 lx	415 lx	546 lx	0.84	0.76	CG2

g) Discussions:

Design Parameters	**Maintained Average Illuminance(E_m)**	**Overall Uniformity (U_o)**	**Lighting Power Density (LPD)**
Achieved Values	325 lx (Room Area) 493 lx (Table Area)	0.61 (Room Area) 0.84 (Table Area)	6.7 W/m^2
Recommended Values	300 lx	0.60	11.5 W/m^2

7.2.2 Lighting Design of Co-working Space

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011, in Open Office Area

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity = 0.40.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 9.10 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

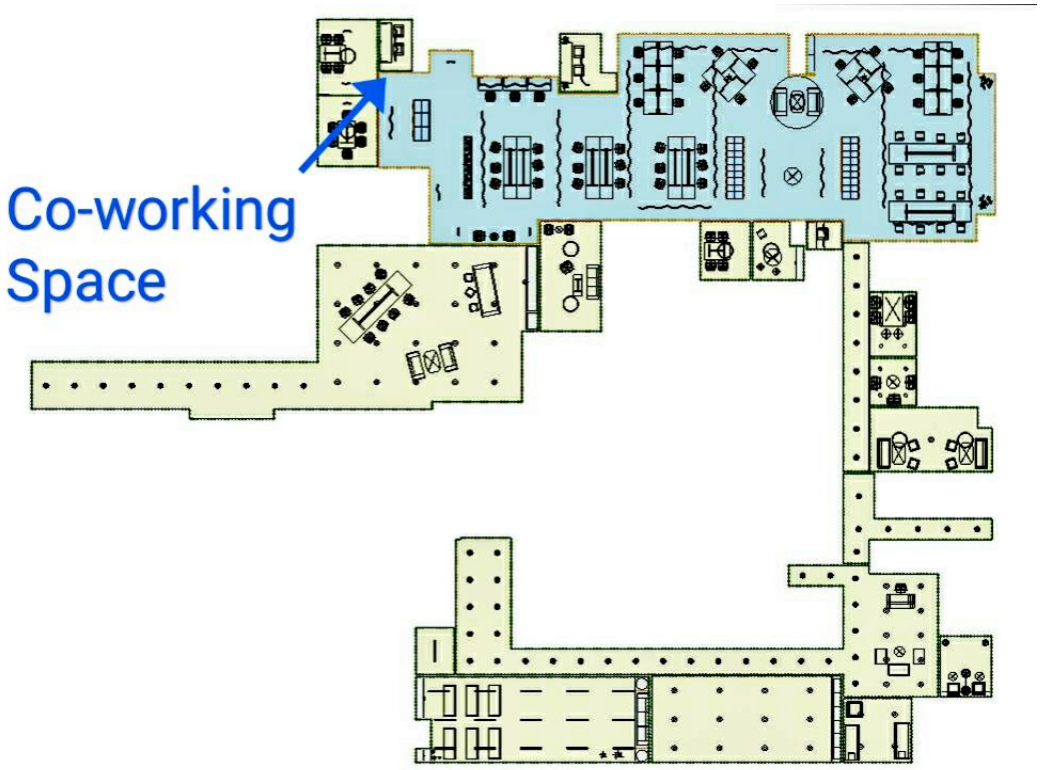


Figure 7.7: **Layout of 'Coworking Space'**

c) Luminaire Layout:

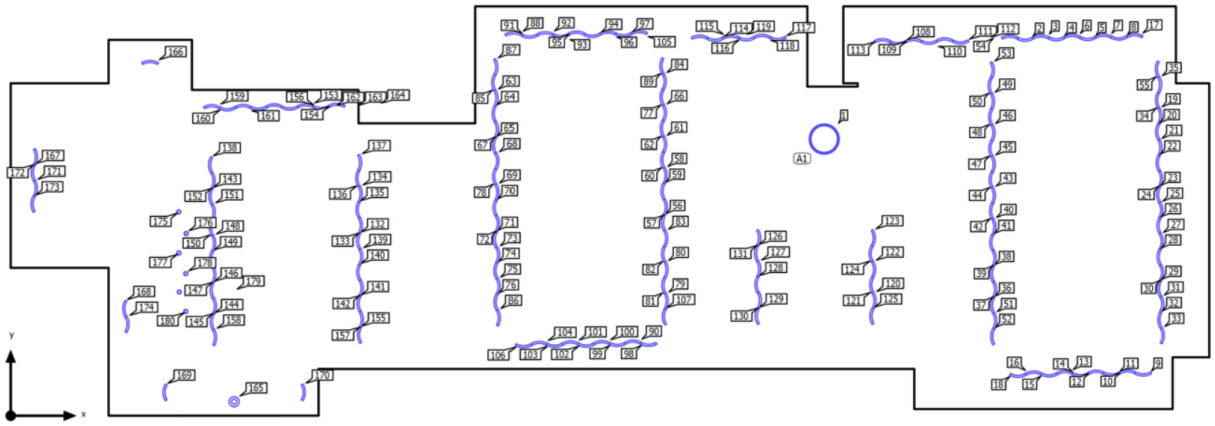


Figure 7.8: **2D View of Luminaire Layout**

- Hight of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

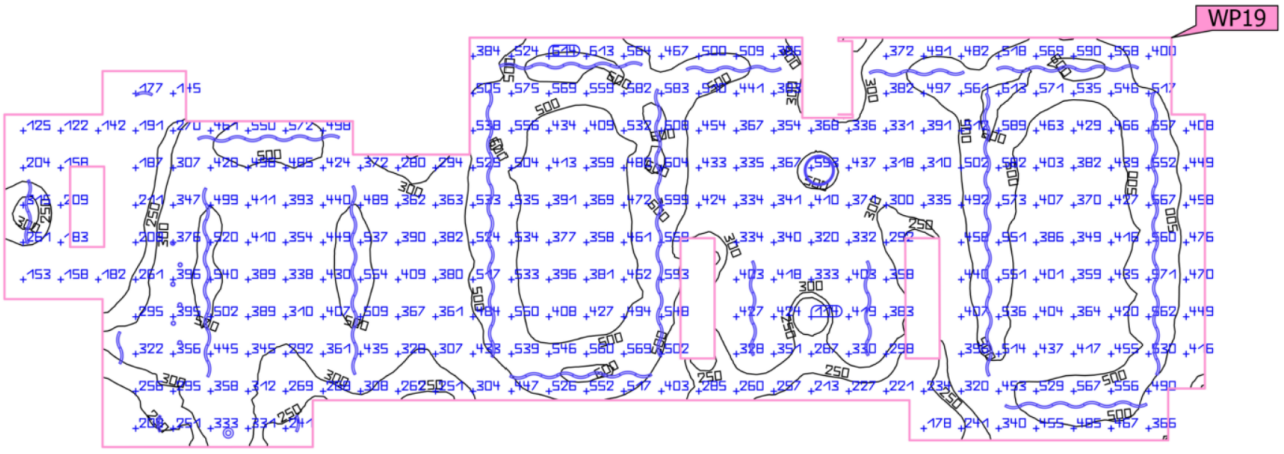


Figure 7.9: **Isolines on Work-Plane**

Building 1 · Story 1 · Coworking Space

Luminaire list

Φ_{total}	P_{total}	Luminous efficacy
248750 lm	2824.0 W	88.1 lm/W

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0 W	6040 lm	109.8 lm/W
6	FLOS S.p.A.	07.9525/PW LED/1W/111°	NEUTRON 1 FIXED ROUND FLOOR LED SIDE	1.0 W	25 lm	25.4 lm/W
1	Lightnet	BG7OSE-830H-D300-U	Basic Superflat - G7	11.0 W	1244 lm	113.1 lm/W
172	Lightnet	RP3OSE-830E-C1	Ringo Star Cluster Suspended - P3	16.0 W	1403 lm	87.7 lm/W

e) 3D Standard View of 'Coworking Space':

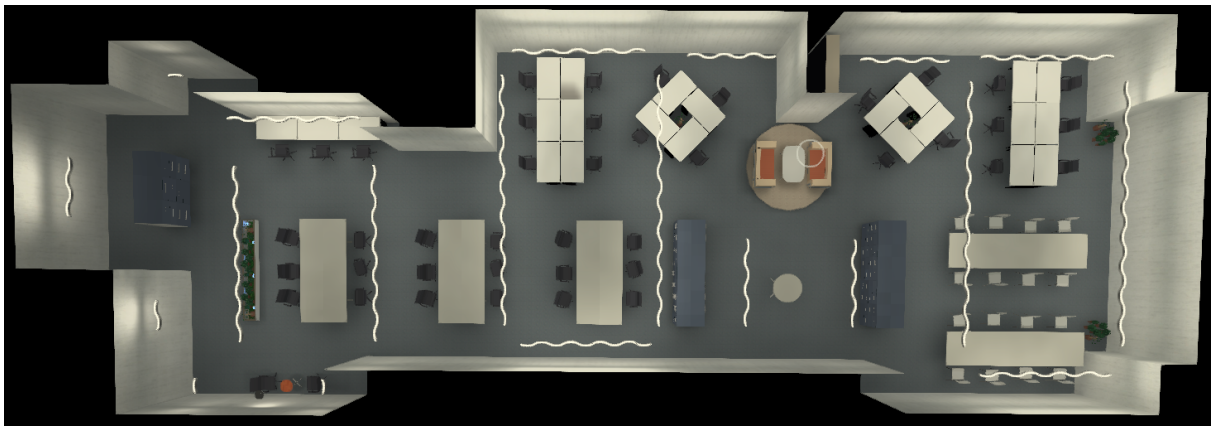


Figure 7.10: **3D Standard View 1**

Figure 7.11: **3D Standard View 2**

f) Simulated Output:

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Coworking Space) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	407 lx (≥ 300 lx) ✓	51.1 lx	640 lx	0.13	0.080	WP19

g) Discussions:

Design Parameters	**Maintained Average Illuminance(E_m)**	**Overall Uniformity (U_o)**	**Lighting Power Density (LPD)**
Achieved Values	407 lx	0.13	7.85 W/m^2
Recommended Values	300 lx	0.40	9.10 W/m^2

Here, the uniformity obtained is 0.13, which is quite low, but the reason for this is because there are some locations (like some of the space's corners) where light is not adequately reaching. We can easily demonstrate improved uniformity by using a different working plane inside the necessary working area, but as it is noted in the problem description that the position of the furnitures (i.e., working area) can vary, the specific working plane has not been shown.

7.2.3 Lighting Design of Creative Space

a) Design Considerations:

This Area can be treated as General Office Room. According to the IS 3646 Part-1 (1992) and EN 12464-1:2011, in General Office Room

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o)=0.60.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

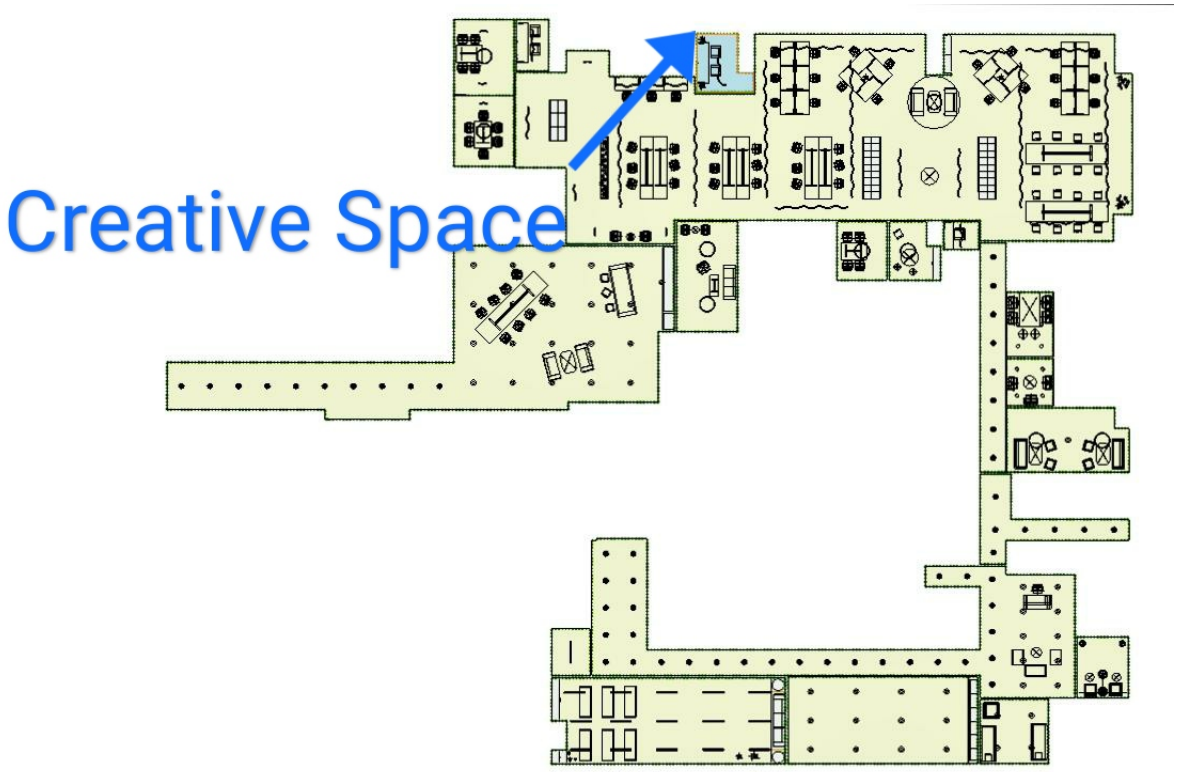


Figure 7.12: **Layout of 'Creative Space'**

c) Luminaire Layout:

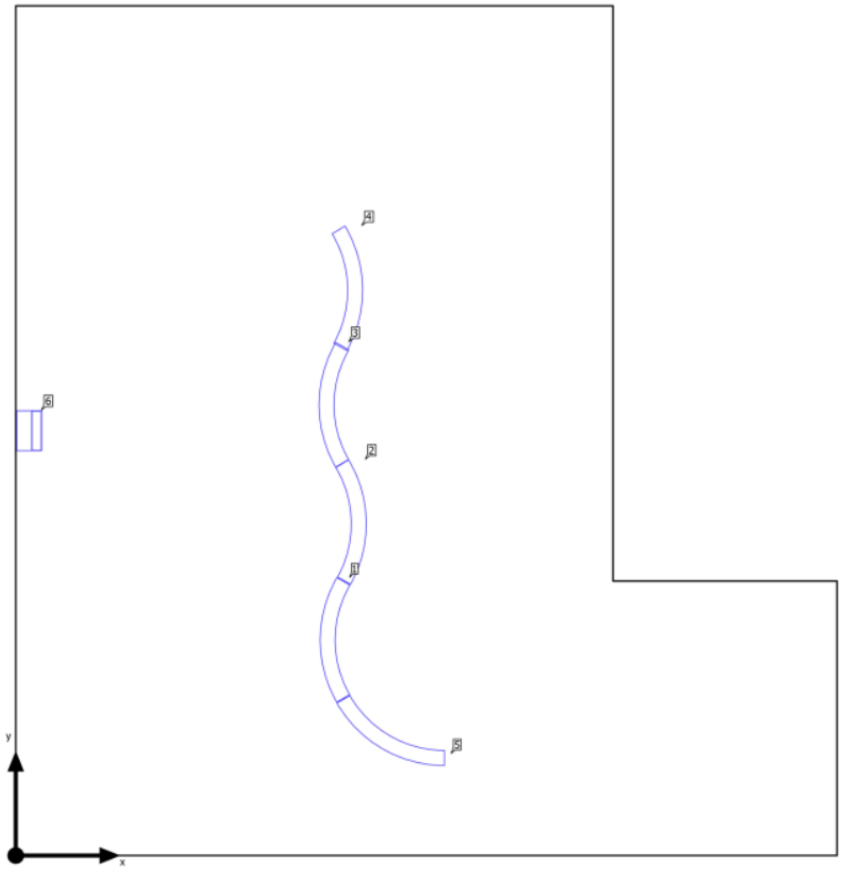


Figure 7.13: **2D View of Luminaire Layout**

- Height of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

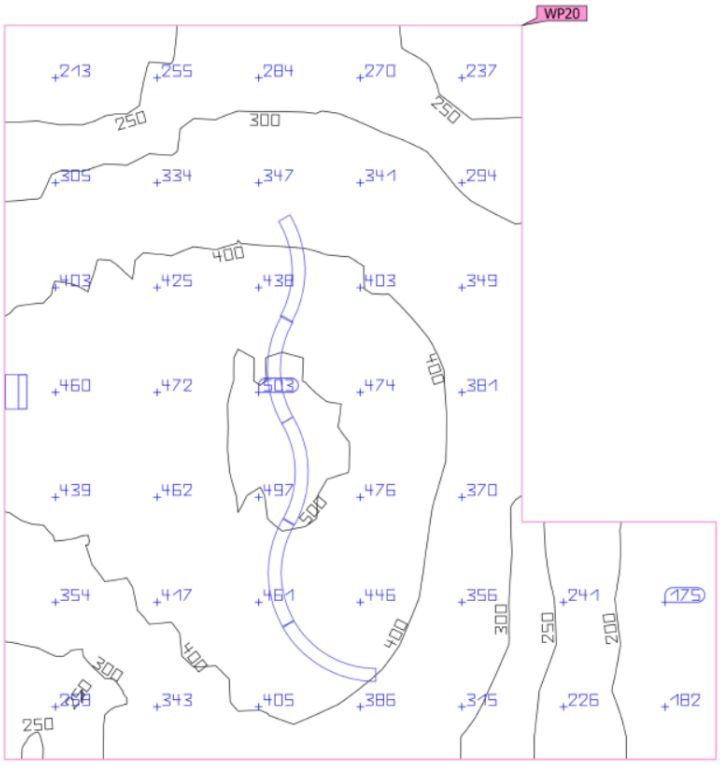


Figure 7.14: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1	FLOS S.p.A.	F0011009 2X9W TOP LED	TIGHT LIGHT	20.0 W	641 lm	32.0 lm/W
5	Lightnet	RP3OSE-830E-C1	Ringo Star Cluster Suspended - P3	16.0 W	1403 lm	87.7 lm/W

e) 3D Standard View of 'Creative Space':

Figure 7.15: **3D Standard View, Light Distribution Display**

f) Simulated Output:

Creative Space

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
100.0 W	9.15 m²	10.93 W/m² = 3.06 W/m²/100 lx (Room)	357 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Creative Space) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	357 lx (≥ 200 lx) ✓	164 lx	518 lx	0.46	0.32	WP20

Calculation surfaces

Properties	$\bar{E}$	E_{min}	E_{max}	g_1	g_2	Index
FOCUS D TABLE Perpendicular illuminance Height: 0.800 m	388 lx	253 lx	475 lx	0.65	0.53	CG1

g) Discussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Density (LPD)
Achieved Values	357 lx (Room Area) 388 lx (Table Area)	0.46 (Room Area) 0.65 (Table Area)	10.93 W/m^2
Recommended Values	300 lx	0.60	11.5 W/m^2

Even though the entire room does not have the requisite uniformity, the task area does, thus this is not a major problem since in this type of room, where a single person is working, a little less uniformity is not a major problem.

7.2.4 Lighting Design of IT Lounge, Pantry & Wide Corridor

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011,in IT Lounge, Pantry with Corridor Office Area

- Maintained Average Illuminance (E_m) = 150 lx (200 lx for IT Lounge, Pantry Area & 100 lx for Corridor is Good).
- Overall Uniformity (U_o)= 0.40.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 9.10 W/m^2 (Lobby), 7.10 W/m^2 (Corridor).

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

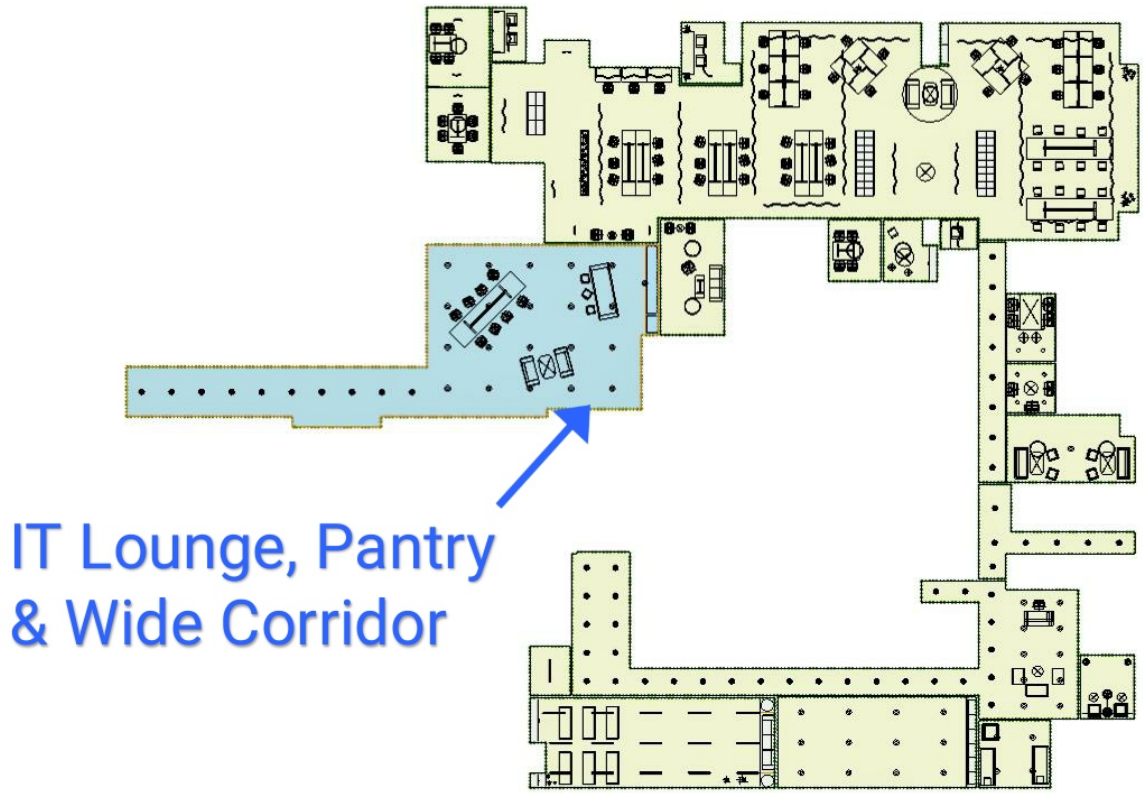


Figure 7.16: **Layout of 'IT Lounge, Pantry & Wide Corridor'**

c) Luminaire Layout:

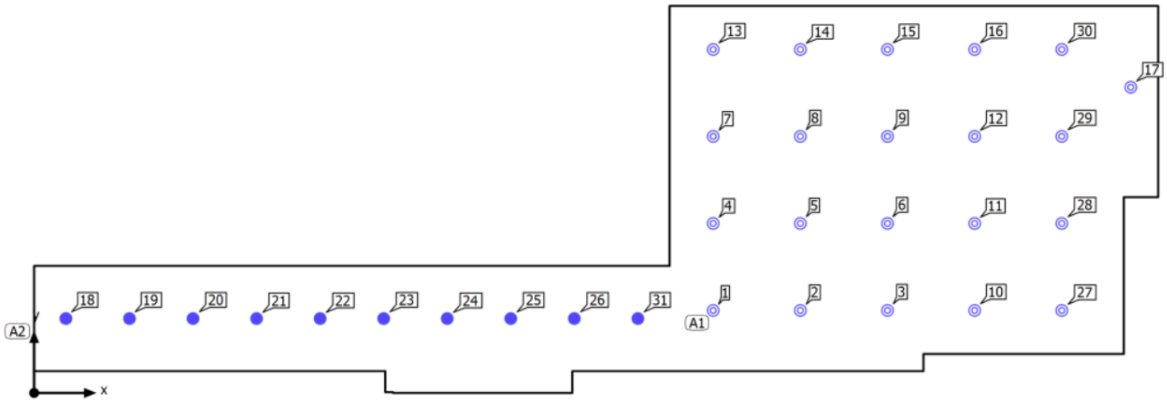


Figure 7.17: **2D View of Luminaire Layout**

- Hight of the area = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

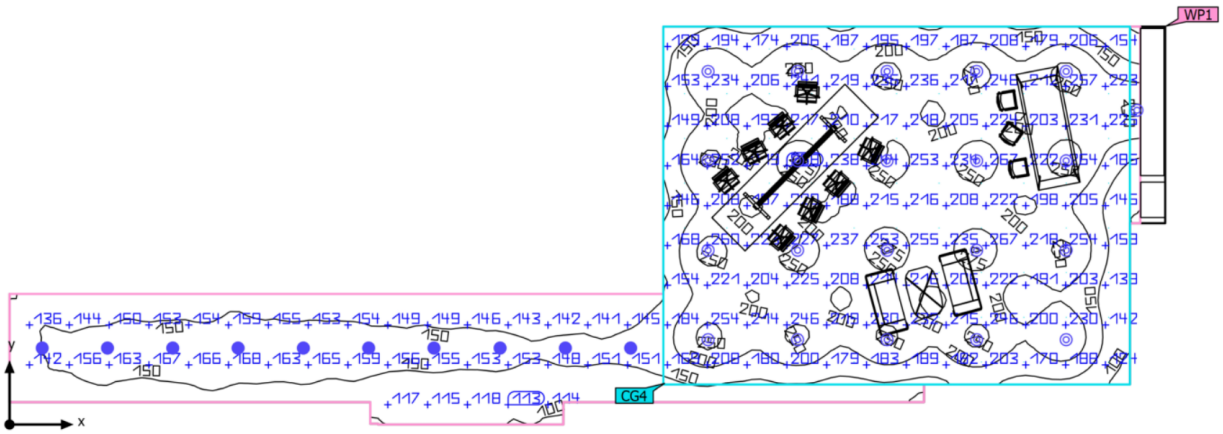


Figure 7.18: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
10	Artemide S.p.A.	A031000	MICONOS SUSPENSION	15.0 W	1372 lm	91.5 lm/W
21	Lightnet	BG7OSE-830H-D300-U	Basic Superflat - G7	11.0 W	1244 lm	113.1 lm/W

e) 3D Standard View of 'IT Lounge, Pantry & Wide Corridor':

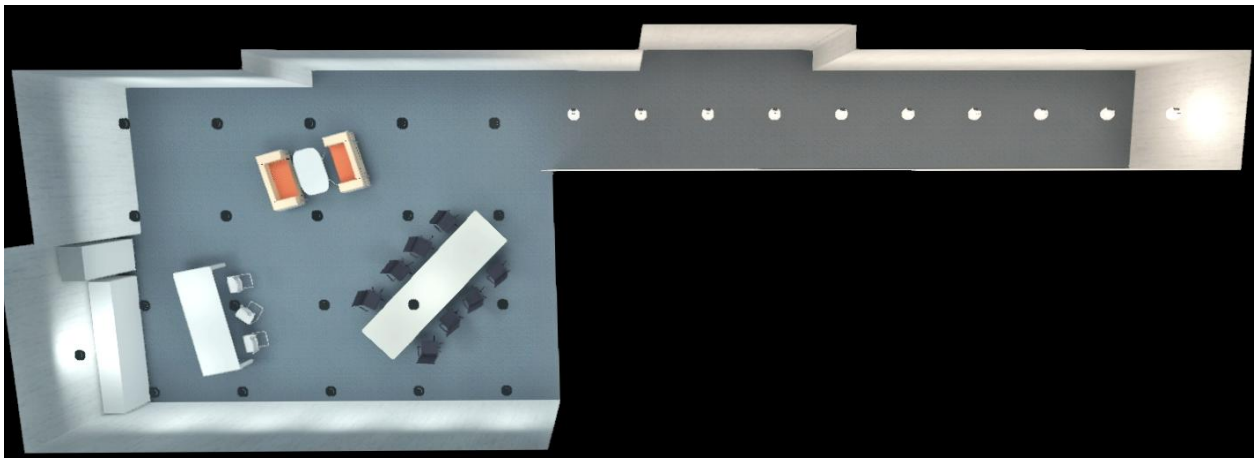


Figure 7.19: **3D Standard View**

Figure 7.20: **Light Distribution Display**

f) Simulated Output:

IT Lounge, Panty & Wide Corridor

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
381.0 W	164.36 m²	2.32 W/m² = 1.24 W/m²/100 lx (Room) 2.36 W/m² = 1.26 W/m²/100 lx (Working plane)	187 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (IT Lounge, Panty & Wide Corridor) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	187 lx (≥ 150 lx) ✓	83.4 lx	277 lx	0.45	0.30	WP1

Calculation surfaces

Properties	$\bar{E}$	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 15 Perpendicular illuminance Height: 0.800 m	211 lx	119 lx	249 lx	0.56	0.48	CG4

g) Dicussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Dinsity (LPD)
Achieved Values	187 lx	0.45	2.32 W/m^2
Recommended Values	150 lx	0.40	9.10 W/m^2 (Lobby) 7.10 W/m^2 (Corridor)

Here, the entire room (including the corridor) is provided with 187 lx, but the IT lounge and pantry area are provided with 211 lx (excluding corridor). The uniformity attained for the entire room (including the corridor) is 0.45. In the IT Lounge & Pantry Area (excluding the corridor), where we received 0.56 uniformity is our main concern.

7.2.5 Lighting Design of AV Studio

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011, in AV Studio

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o)= 0.50.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 9.10 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

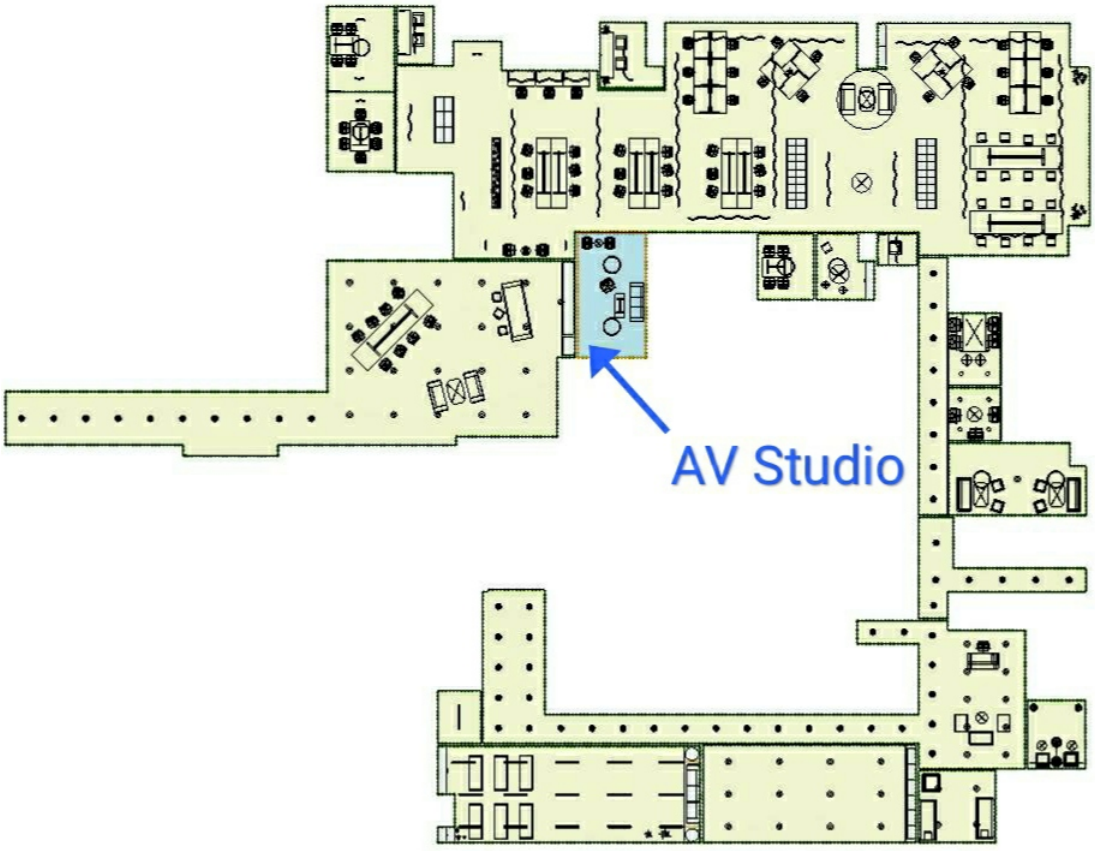


Figure 7.21: **Layout of 'AV Studio'**

c) Luminaire Layout:

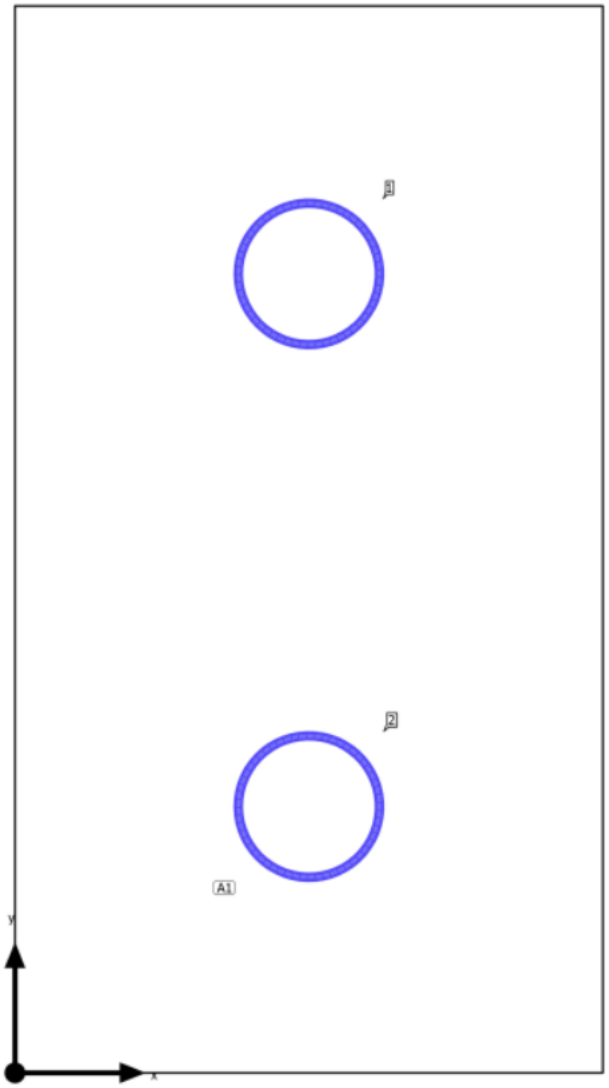


Figure 7.22: **2D View of Luminaire Layout**

- Height of the area = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

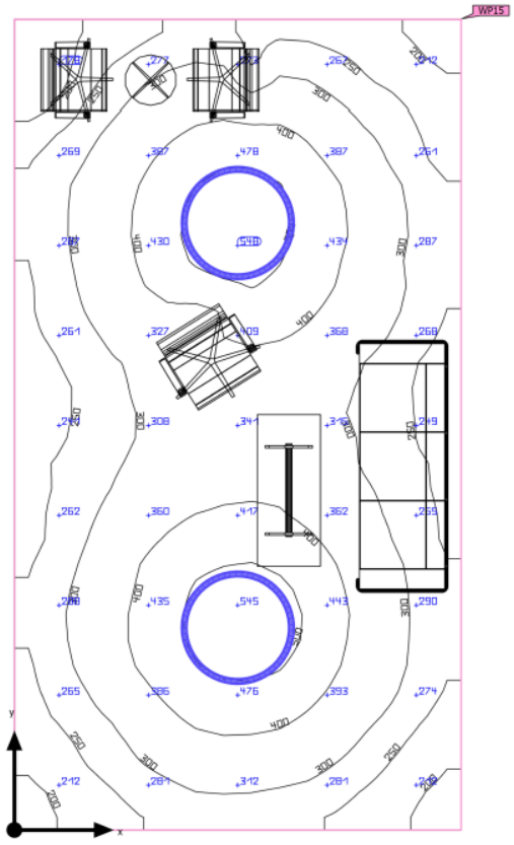


Figure 7.23: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
2	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0 W	6040 lm	109.8 lm/W

e) 3D Standard View of 'AV Studio':

Figure 7.24: **3D Standard View, Light Distribution Display**

f) Simulated Output:

AV Studio

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
110.0 W	22.64 m^2	4.86 W/m^2 = 1.47 W/m^2/100 lx (Room)	329 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (AV Studio) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	329 lx (≥ 300 lx) ✓	133 lx	554 lx	0.40	0.24	WP15

g) Dicussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Dinsity (LPD)
Achieved Values	329 lx	0.40	4.86 W/m^2
Recommended Values	300 lx	0.50	9.10 W/m^2

7.2.6 Lighting Design of 'Deep Plan Meeting Room (4 Person)'

a) Design Considerations:

According to the IS 3646 Part-1 (1992) and EN 12464-1:2011, in Meeting Room

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o)=0.60.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.50 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

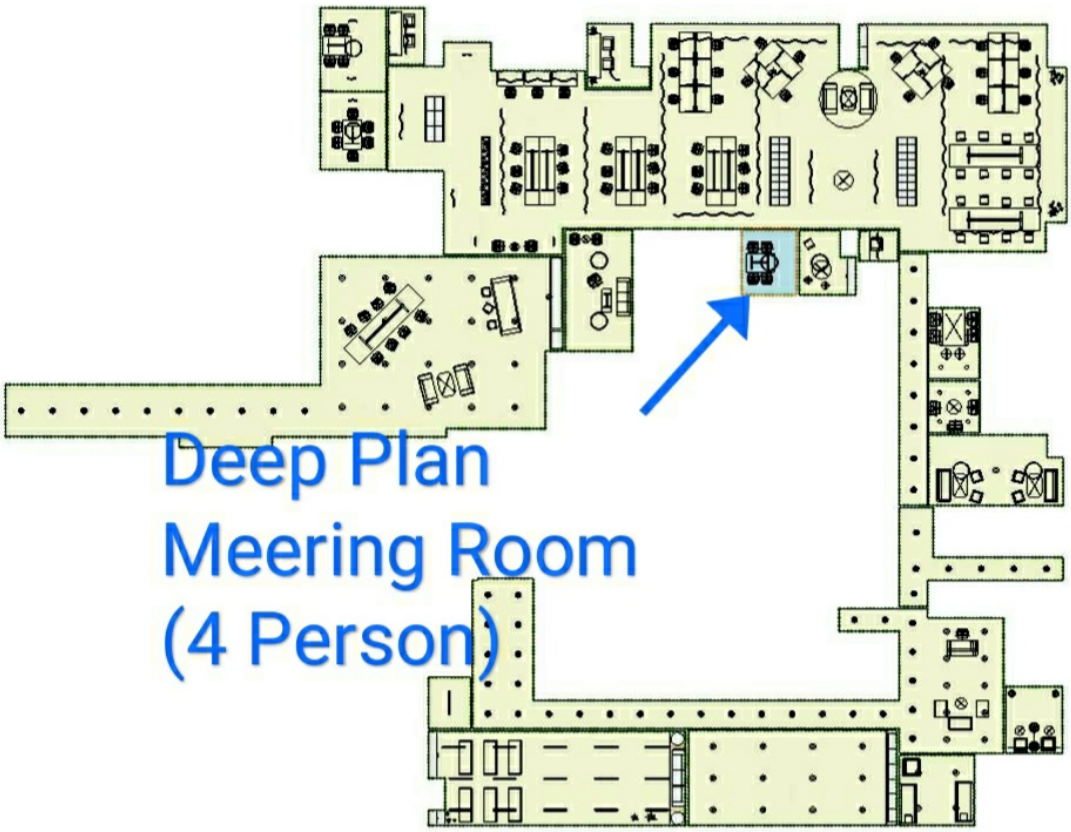


Figure 7.25: **Layout of 'Deep Plan Meeting Room (4 Person)'**

c) Luminaire Layout and Lighting Report:

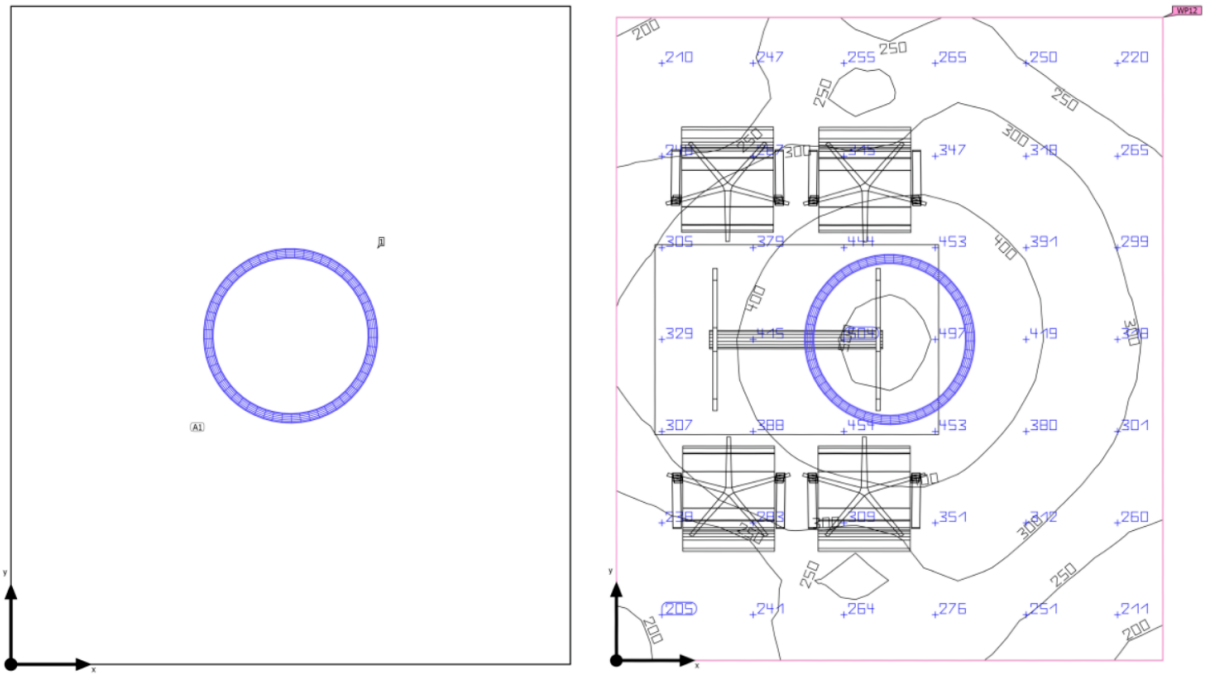


Figure 7.26: **2D View of Luminaire Layout and Lighting Report**

- Hight of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

Figure 7.27: **3D Standard View, Light Distribution Display**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0 W	6040 lm	109.8 lm/W

d) Simulated Output:

Deep Plan Meeting Room (4 person)

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
55.0 W	9.78 m²	5.62 W/m² = 1.76 W/m²/100 lx (Room)	320 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Deep Plan Meeting Room (4 person)) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	318 lx (≥ 300 lx) ✓	179 lx	509 lx	0.56	0.35	WP12

Visual task areas

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1 (Target)	g_2	Index
Visual task area 1 Perpendicular illuminance Height: 0.800 m, Surrounding area: 0.500 m	433 lx (≥ 300 lx) ✓	327 lx	506 lx	0.76 (≥ 0.40) ✓	0.65	ET1

e) Discussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Density (LPD)
Achieved Values	318 lx (Room Area) 433 lx (Table Area)	0.56 (Room Area) 0.76 (Table Area)	5.62 W/m^2
Recommended Values	300 lx	0.60	11.5 W/m^2

7.2.7 Lighting Design of Meeting Room (2 Person)

a) Design Considerations:

According to the IS 3646 Part-1 (1992) and EN 12464-1:2011, in Meeting Room

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o)=0.6.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.50 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

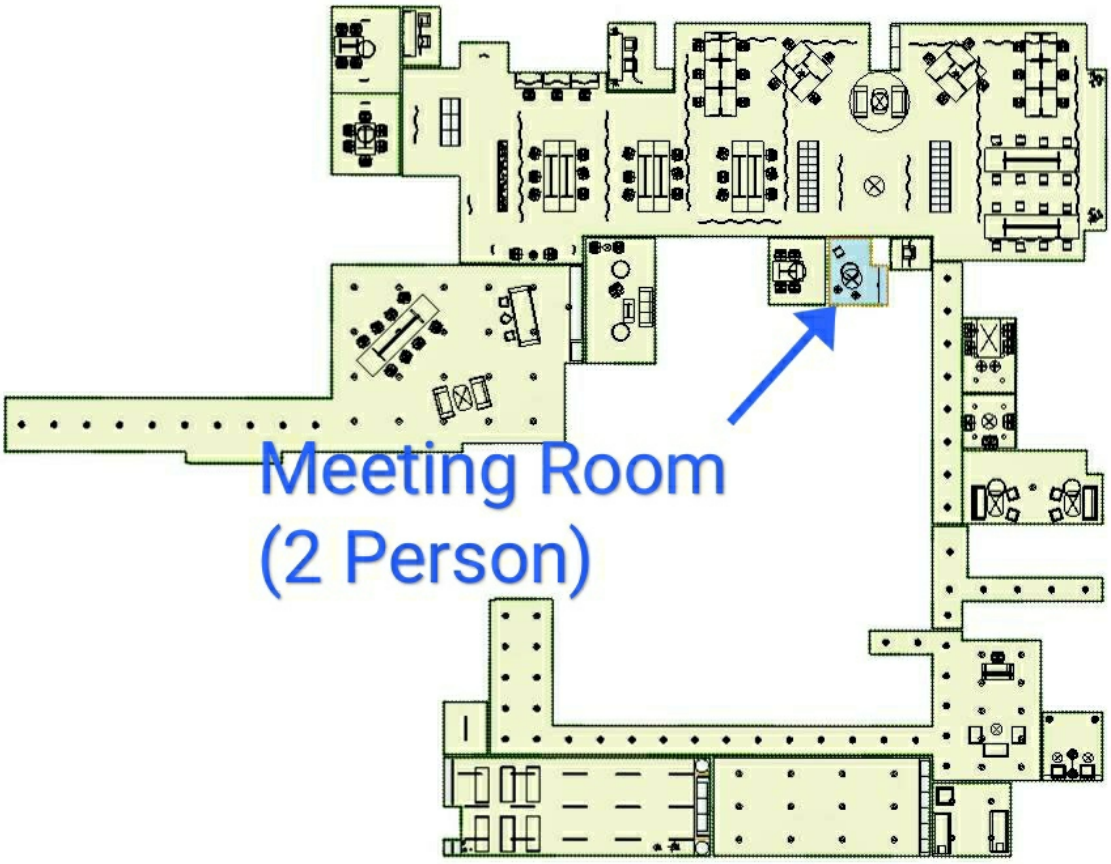


Figure 7.28: **Layout of 'Meeting Room (2 Person)'**

c) Luminaire Layout:

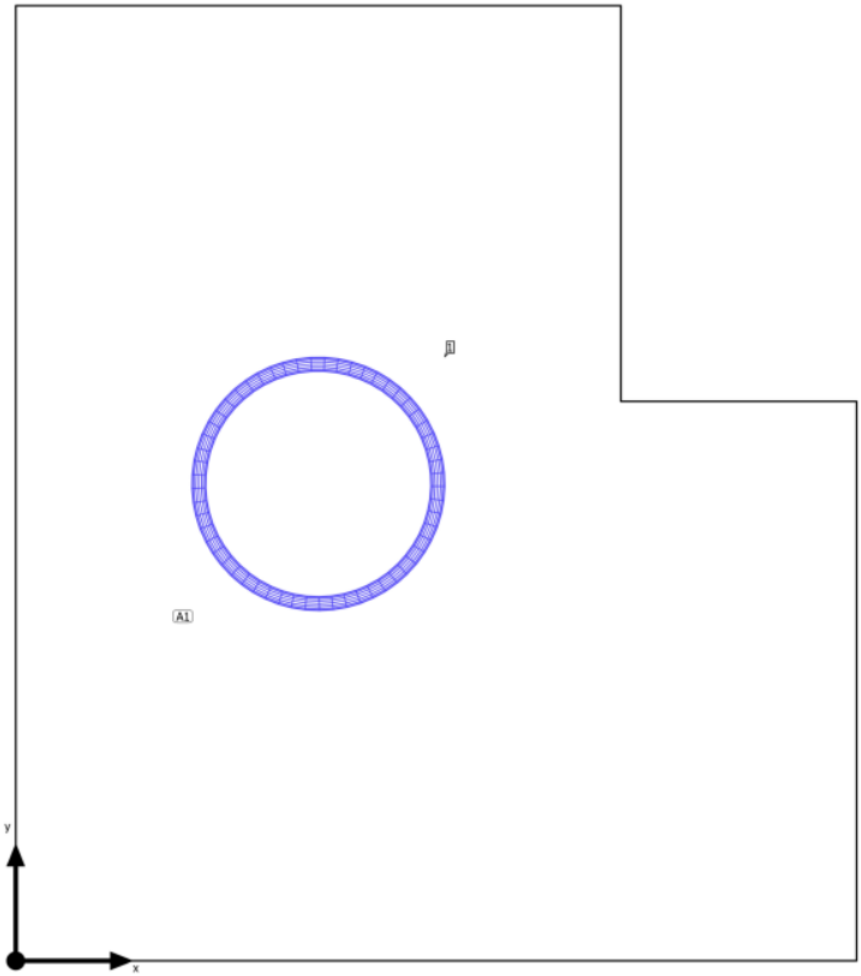


Figure 7.29: **2D View of Luminaire Layout**

- Height of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

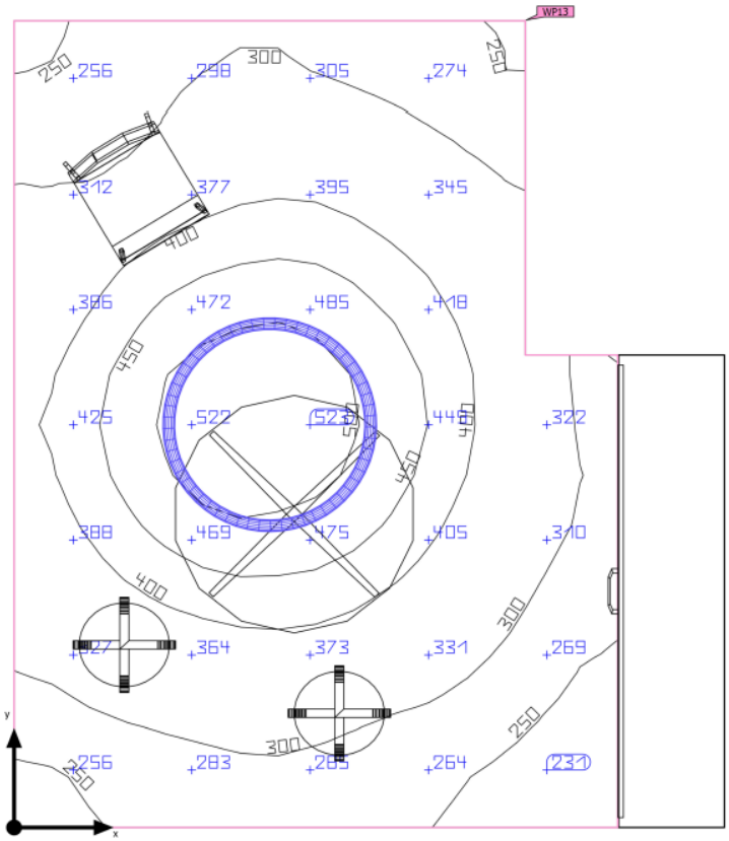


Figure 7.30: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0 W	6040 lm	109.8 lm/W

e) 3D Standard View of 'Meeting Room (2 Person)':

Figure 7.31: **3D Standard View, Light Distribution Display**

f) Simulated Output:

Meeing Room (2 person)

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
55.0 W	8.95 m²	6.15 W/m² = 1.72 W/m²/100 lx (Room)	358 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Meeing Room (2 person)) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	358 lx (≥ 300 lx) ✓	214 lx	529 lx	0.60	0.40	WP13

g) Dicussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Dinsity (LPD)
Achieved Values	358 lx	0.60	6.15 W/m^2
Recommended Values	300 lx	0.60	11.5 W/m^2

7.2.8 Lighting Design of Open Meeting Space (4-6 Person)

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011, in Meeting Room

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o) = 0.50.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

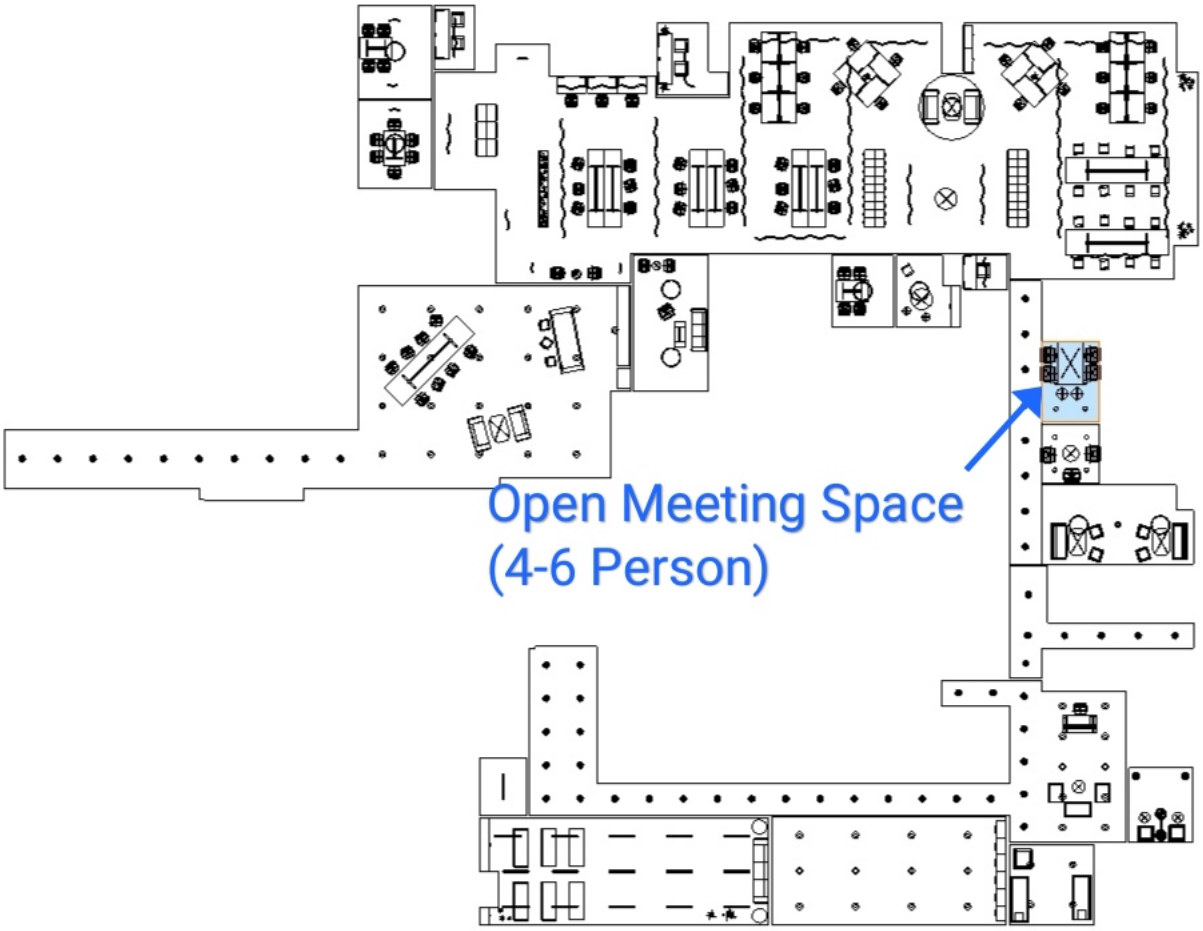


Figure 7.32: **Layout of 'Open Meeting Space (4-6 Person)'**

c) Luminaire Layout:

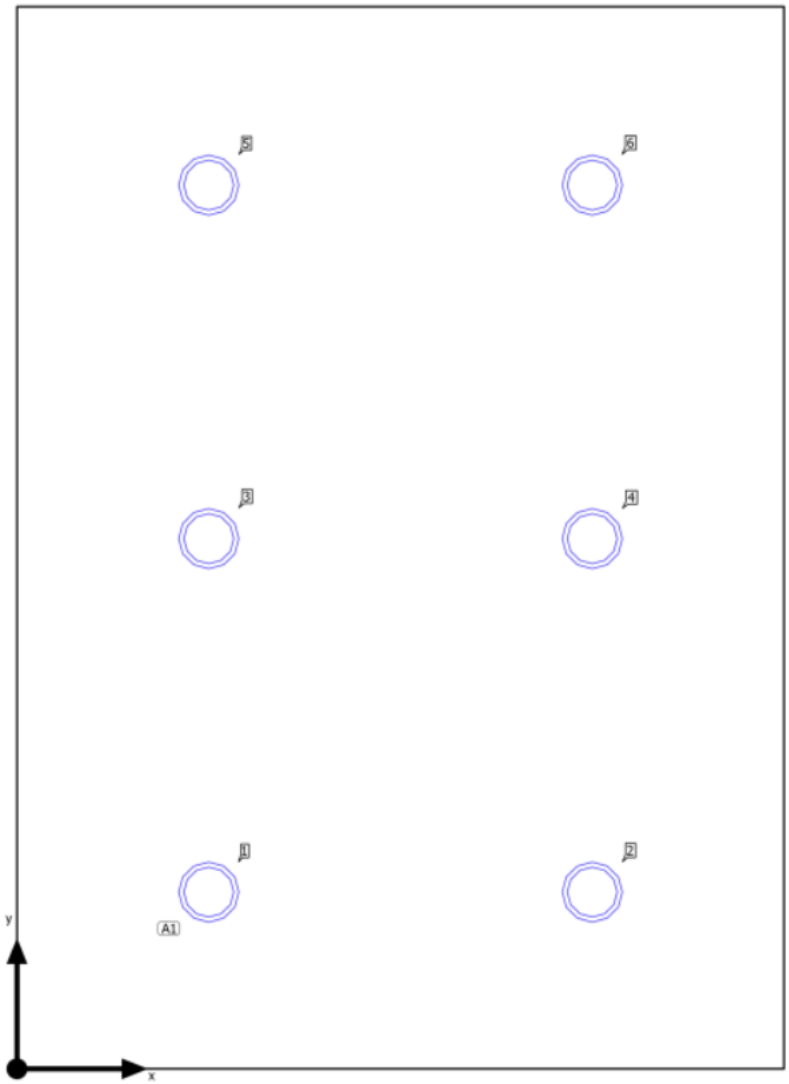


Figure 7.33: **2D View of Luminaire Layout**

- Height of the room = 2.4 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

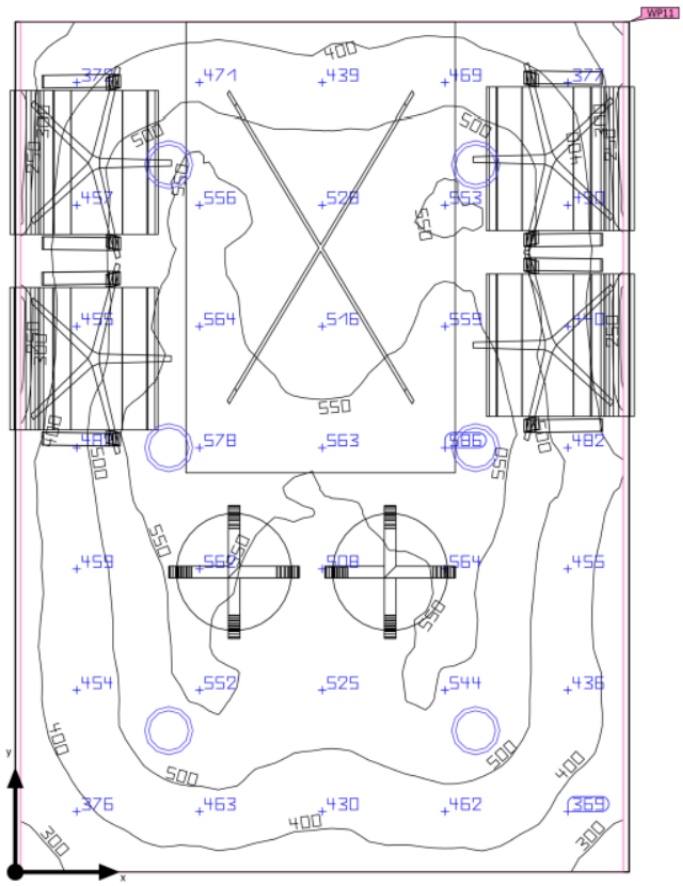


Figure 7.34: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
6	Philips		DN571B PSE-E 1xLED12S/830 F SG-O	11.8 W	1050 lm	89.0 lm/W

e) 3D Standard View of 'Open Meeting Space (4-6 Person)':

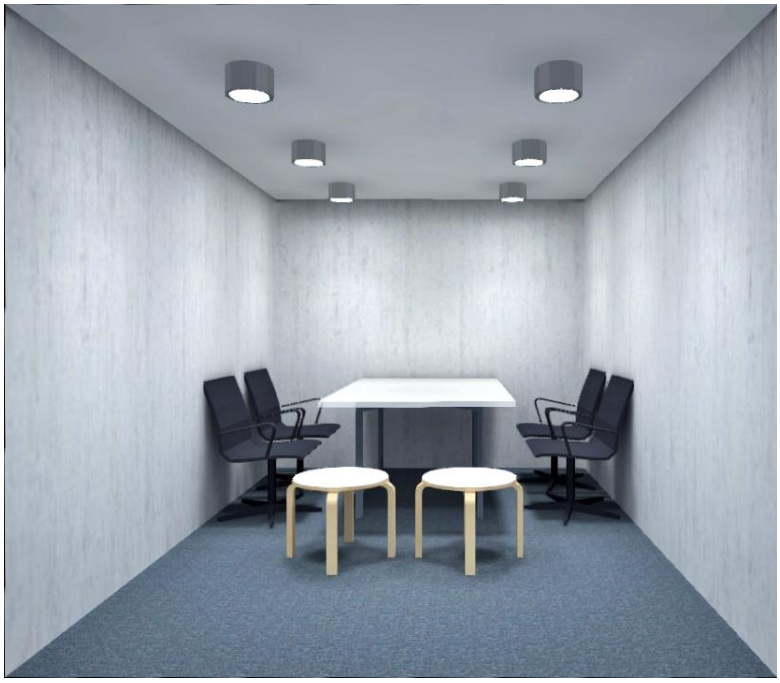


Figure 7.35: **3D Standard View**

f) Simulated Output:

Open Meeting Space (4-6 people)

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
70.8 W	10.33 m^2	6.85 W/m^2 = 1.42 W/m^2/100 lx (Room)	483 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Open Meeting Space (4-6 people)) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	483 lx (≥ 300 lx) ✓	240 lx	586 lx	0.50	0.41	WP11

g) Discussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Density (LPD)
Achieved Values	483 lx	0.50	6.85 W/m^2
Recommended Values	300 lx	0.50	11.5 W/m^2

7.2.9 Lighting Design of Collab

a) Design Considerations:

This Area can be treated as General Office Room. According to the IS 3646 Part-1 (1992) and EN 12464-1:2011, in General Office Room

- Maintained Average Illuminance (E_m) = 300 lx.
- Overall Uniformity (U_o) = 0.50.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

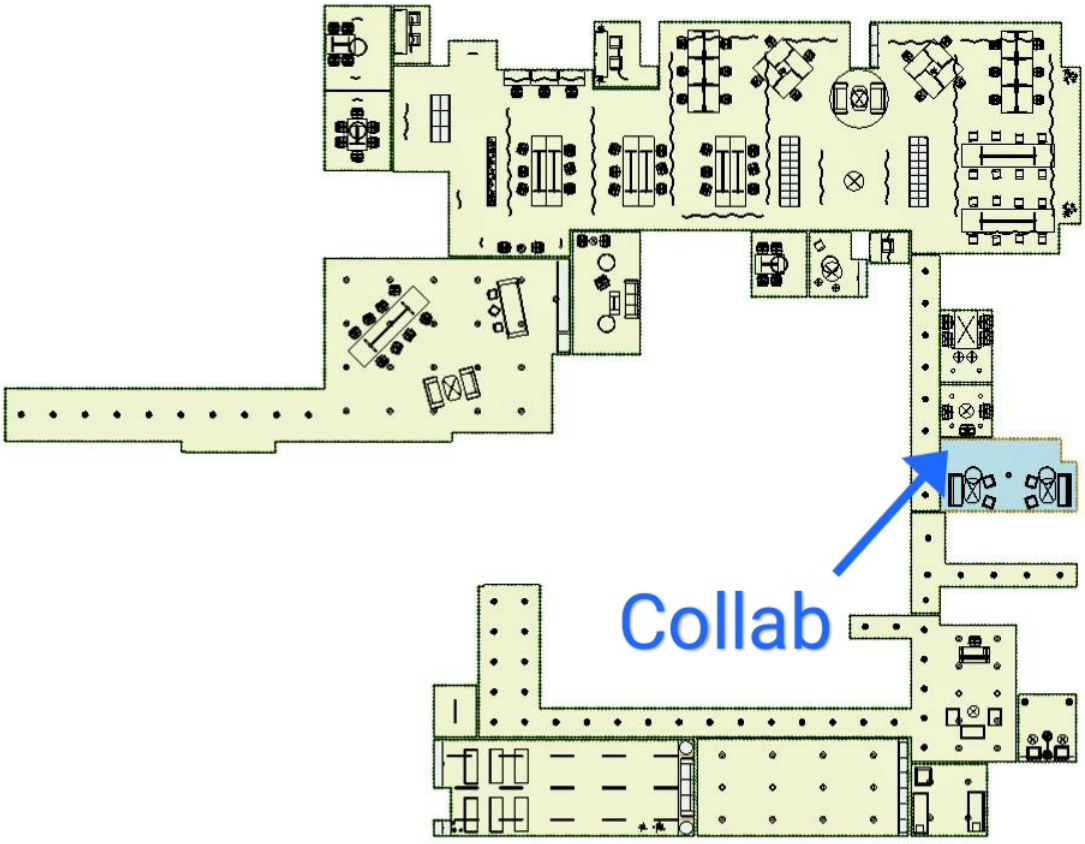


Figure 7.36: **Layout of 'Collab'**

c) Luminaire Layout:

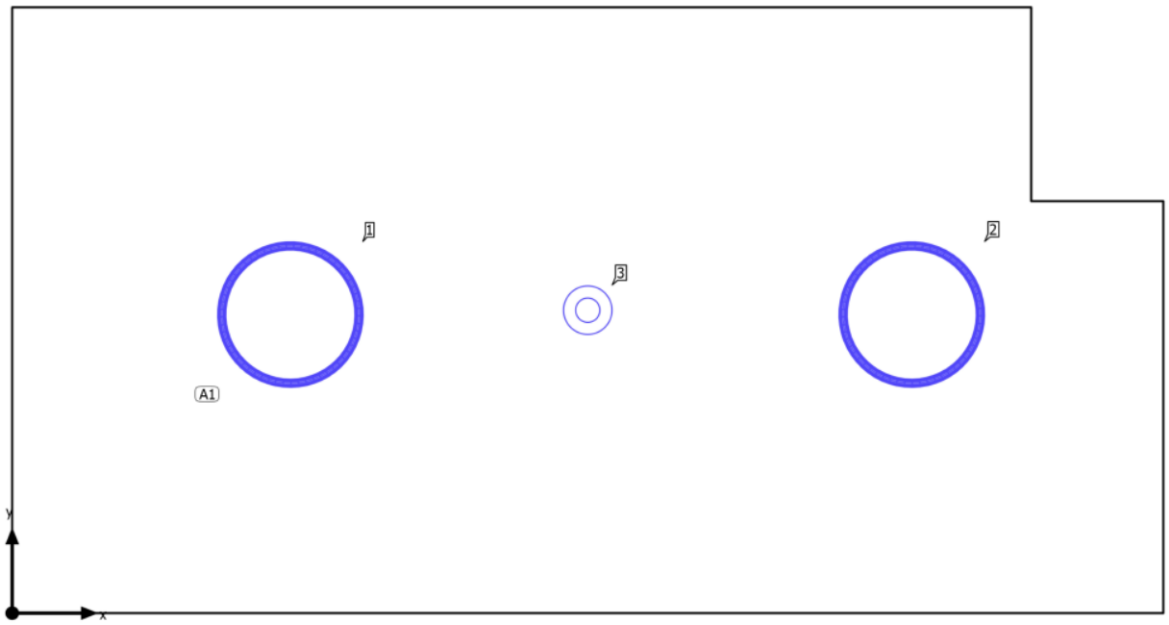


Figure 7.37: **2D View of Luminaire Layout**

- Height of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

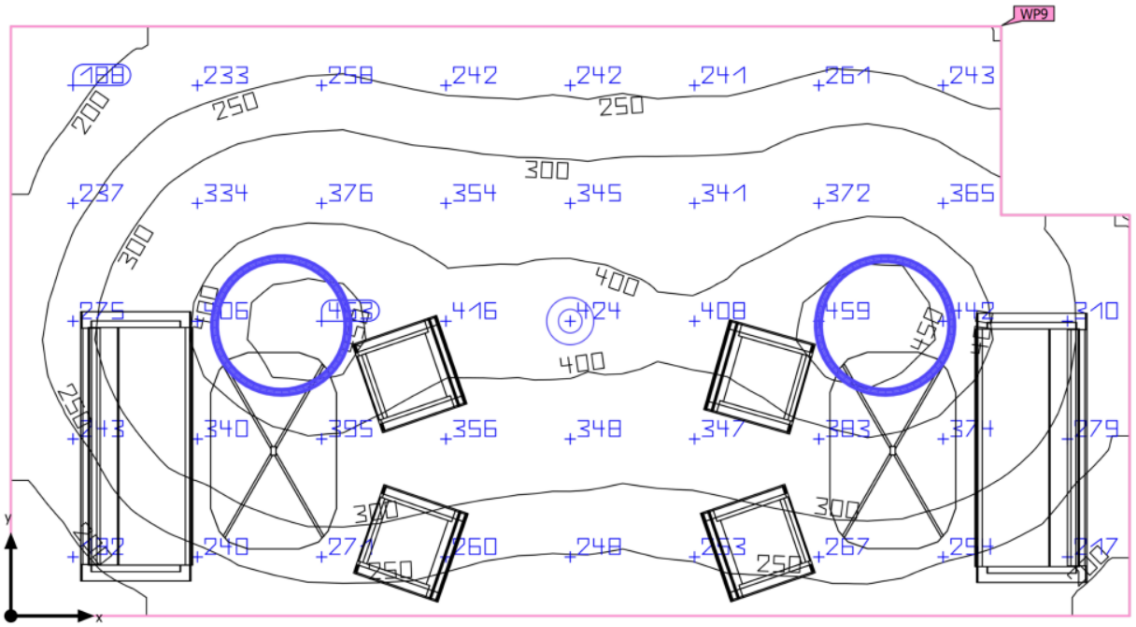


Figure 7.38: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
2	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0 W	6040 lm	109.8 lm/W
1	Lightnet	BG7OSE-830H-D300-U	Basic Superflat - G7	11.0 W	1244 lm	113.1 lm/W

e) 3D Standard View of 'Collab':

Figure 7.39: **3D Standard View**

Figure 7.40: **Light Distribution Display**

f) Simulated Output:

Collab

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
121.0 W	25.74 m^2	4.70 W/m^2 = 1.50 W/m^2/100 lx (Room)	313 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Collab) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	313 lx (≥ 300 lx) ✓	160 lx	474 lx	0.51	0.34	WP9

g) Discussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Density (LPD)
Achieved Values	313 lx	0.51	4.70 W/m^2
Recommended Values	300 lx	0.50	11.5 W/m^2

7.2.10 Lighting Design of Waiting Lounge with Wide Corridor

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011,in Waiting Lounge with Wide Corridor

- Maintained Average Illuminance (E_m) = 150 lx.
- Overall Uniformity (U_o)= 0.40.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 7.70 W/m^2 (Rest Room), 7.10 W/m^2 (Corridor).

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

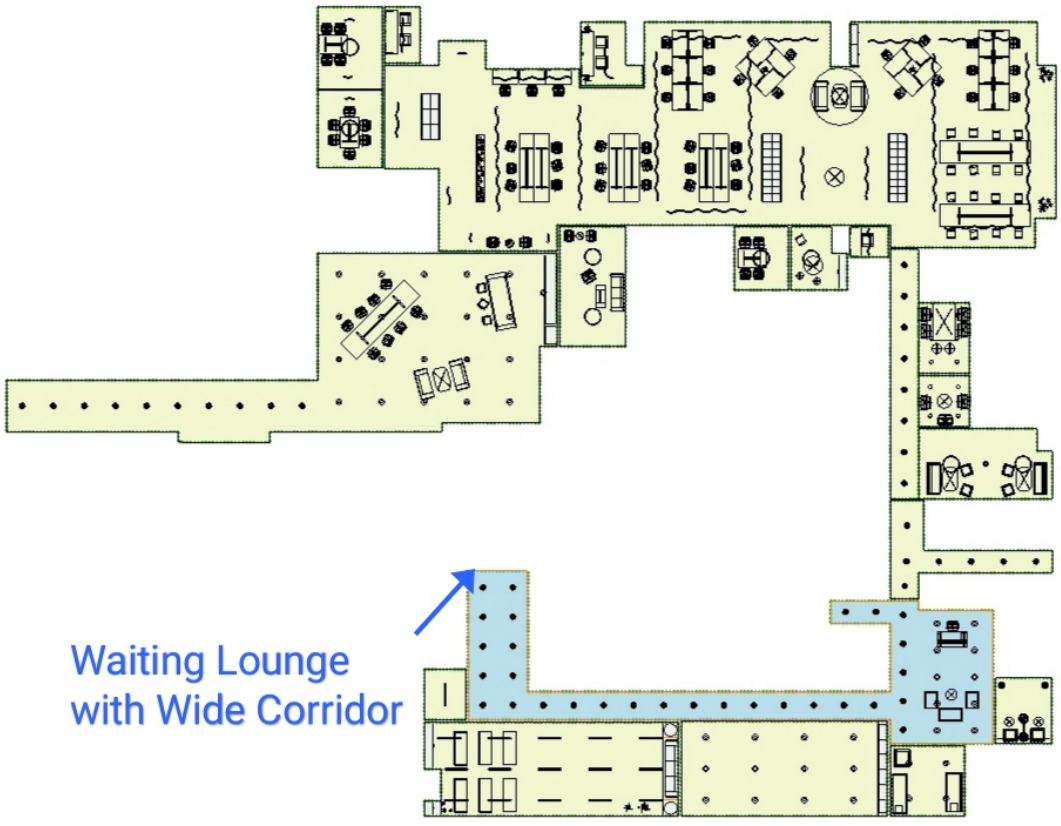


Figure 7.41: **Layout of 'Waiting Lounge with Wide Corridor'**

c) Luminaire Layout:

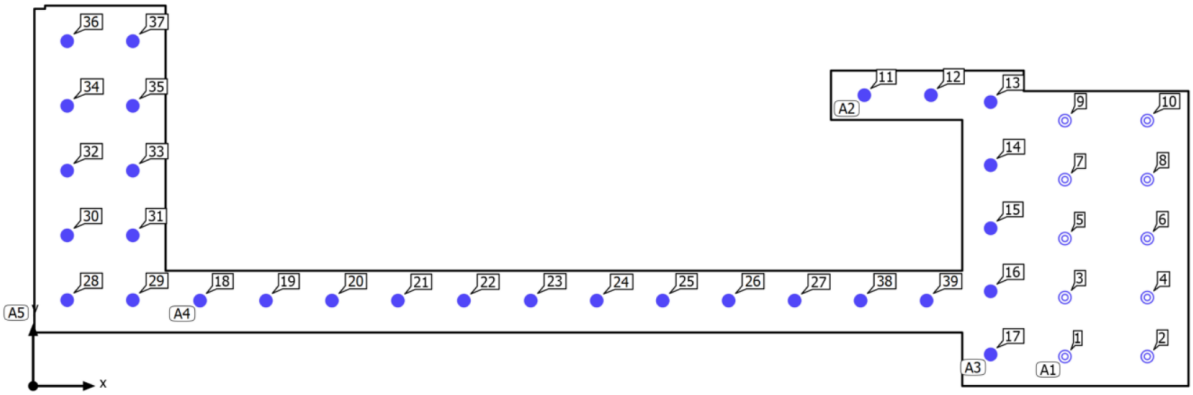


Figure 7.42: **2D View of Luminaire Layout**

- Hight of the area = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

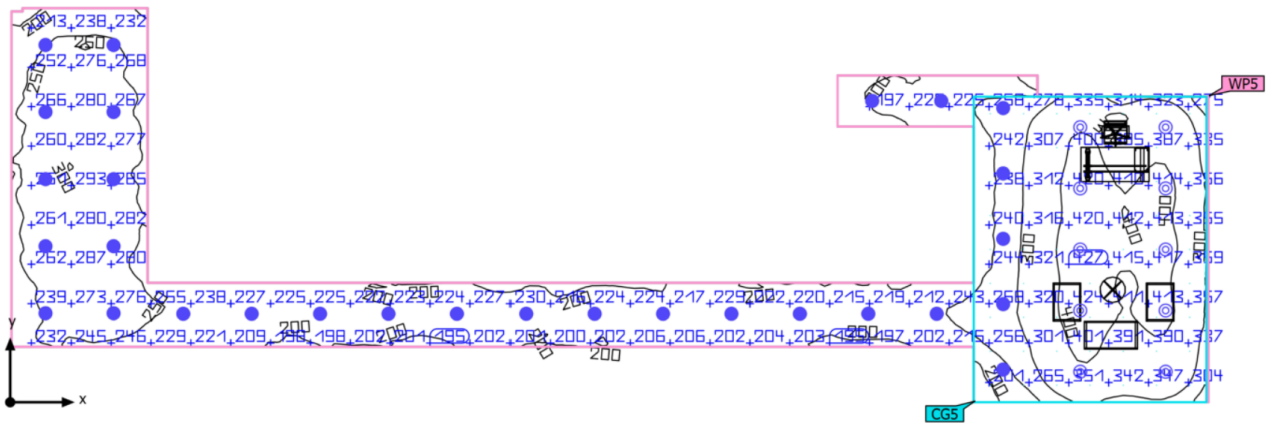


Figure 7.43: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
29	Artemide S.p.A.	A031000	MICONOS SUSPENSION	15.0 W	1372 lm	91.5 lm/W
10	Lightnet	BG7OSE-830H-D300-U	Basic Superflat - G7	11.0 W	1244 lm	113.1 lm/W

e) 3D Standard View and Light Distribution Display of 'Waiting Lounge with Wide Corridor':

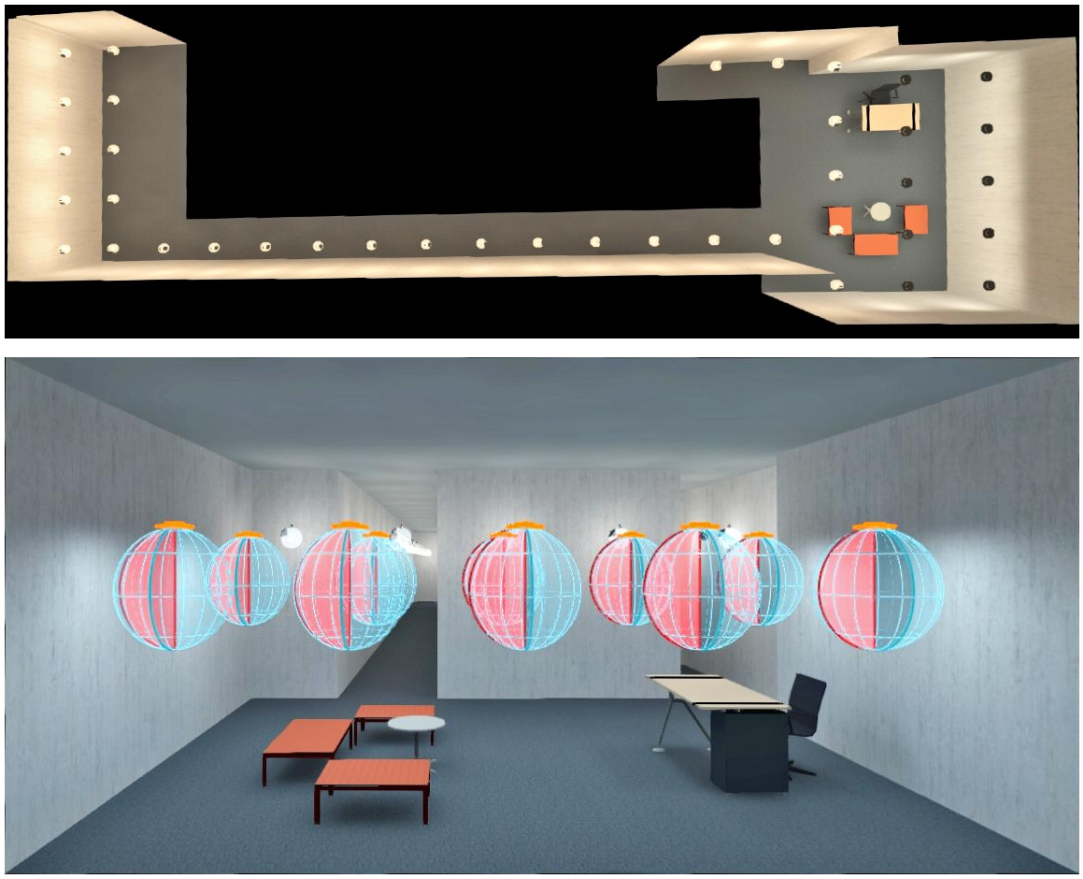


Figure 7.44: **3D Standard View and Light Distribution Display**

f) Simulated Output:

Waiting Lounge with Wide Corridor

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
545.0 W	98.57 m²	5.53 W/m² = 1.98 W/m²/100 lx (Room)	279 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Waiting Lounge with Wide Corridor) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	279 lx (≥ 150 lx) ✓	148 lx	447 lx	0.53	0.33	WP5

Calculation surfaces

Properties	$\bar{E}$	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 16 Perpendicular illuminance Height: 0.800 m	348 lx	204 lx	444 lx	0.59	0.46	CG5

g) Dicussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Dinsity (LPD)
Achieved Values	279 lx	0.53	5.53 W/m^2
Recommended Values	150 lx	0.40	7.70 W/m^2 (Rest Room) 7.10 W/m^2 (Corridor)

Here, the entire room (including the corridor) is provided with 279 lx, but the Waiting lounge is provided with 348 lx (excluding corridor). The uniformity attained for the entire room (including the corridor) is 0.53. In the Waiting Lounge (excluding the corridor), 0.59 uniformity is received.

7.2.11 Lighting Design of Wellness Room

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011, in Wellness Room

- Maintained Average Illuminance (E_m) = 200 lx.
- Overall Uniformity (U_o) = 0.5.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 7.70 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

Figure 7.45: **Layout of 'Wellness Room'**

c) Luminaire Layout:

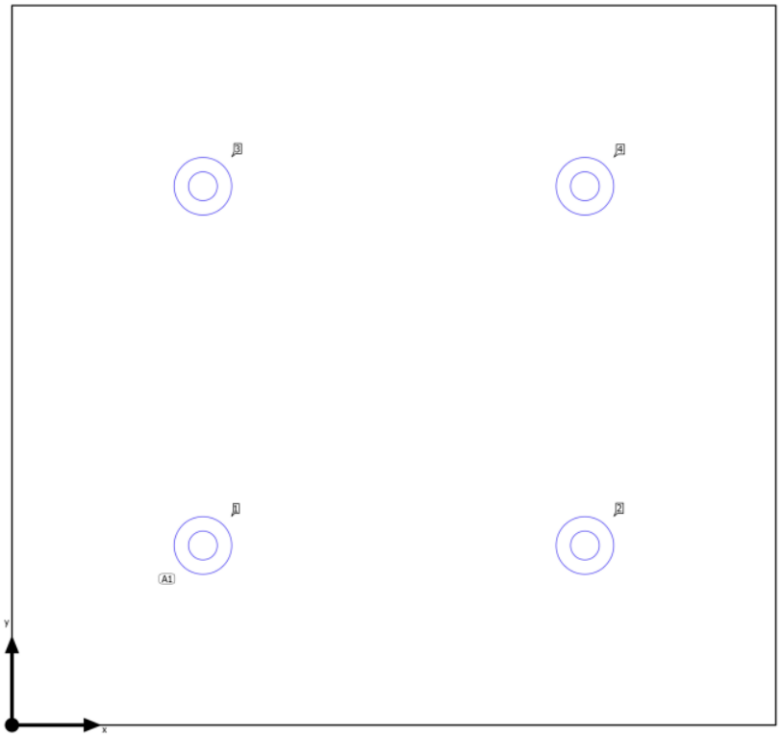


Figure 7.46: **2D View of Luminaire Layout**

- Height of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

d) Lighting Report:

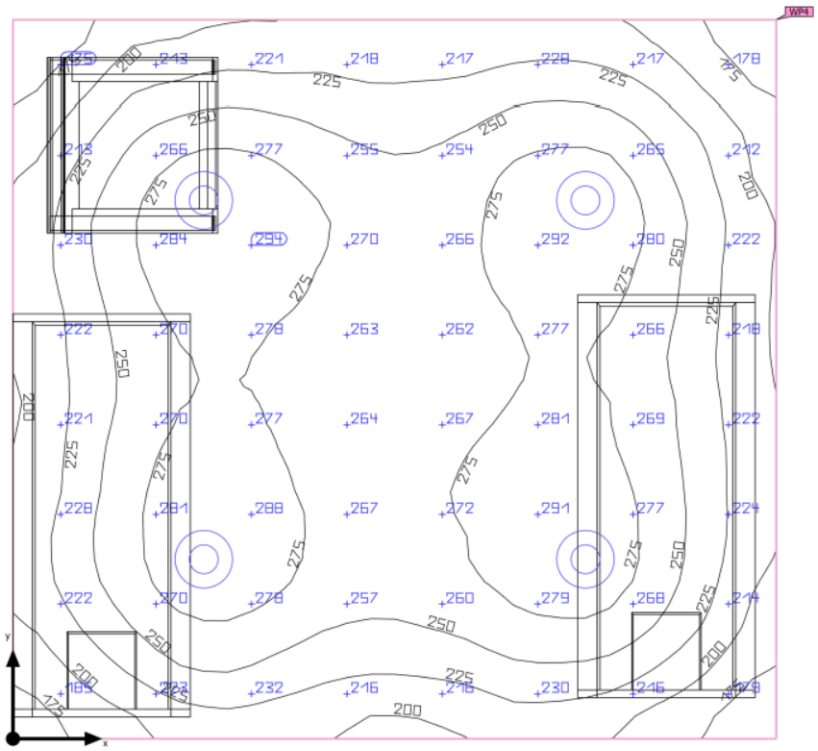


Figure 7.47: **Isolines on Work-Plane**

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
4	Lightnet	BG7OSE-830H-D300-U	Basic Superflat - G7	11.0 W	1244 lm	113.1 lm/W

e) 3D Standard View of 'Wellness Room':

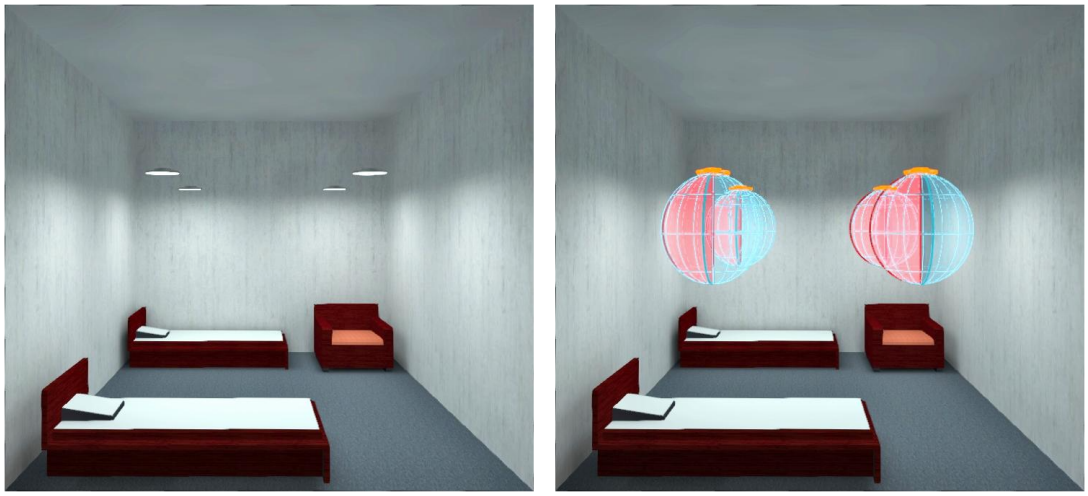


Figure 7.48: **3D Standard View, Light Distribution Display**

f) Simulated Output:

Wellness Room

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
44.0 W	14.89 m²	2.96 W/m² = 1.20 W/m²/100 lx (Room)	247 lx

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Wellness Room) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	247 lx (≥ 200 lx) ✓	155 lx	297 lx	0.63	0.52	WP4

g) Discussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Density (LPD)
Achieved Values	247 lx	0.63	2.96 W/m^2
Recommended Values	200 lx	0.50	7.70 W/m^2

7.2.12 Lighting Design of Store Room

a) Design Considerations:

According to the IS 3646 Part- 1 (1992) and EN 12464-1:2011, in Store Room

- Maintained Average Illuminance (E_m) = 200 lx.
- Overall Uniformity (U_o) = 0.4.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 6.80 W/m^2.

In the next section the Room Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are briefly covered.

b) Room Plan:

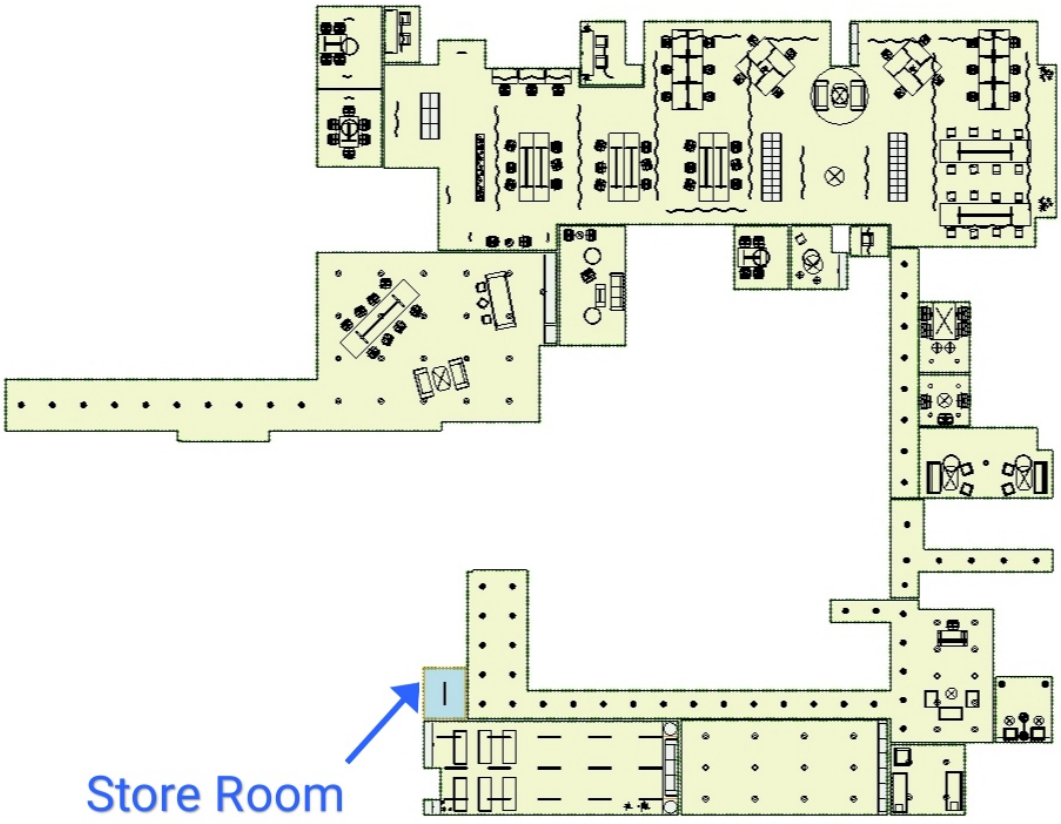


Figure 7.49: **Layout of 'Store Room'**

c) Luminaire Layout:

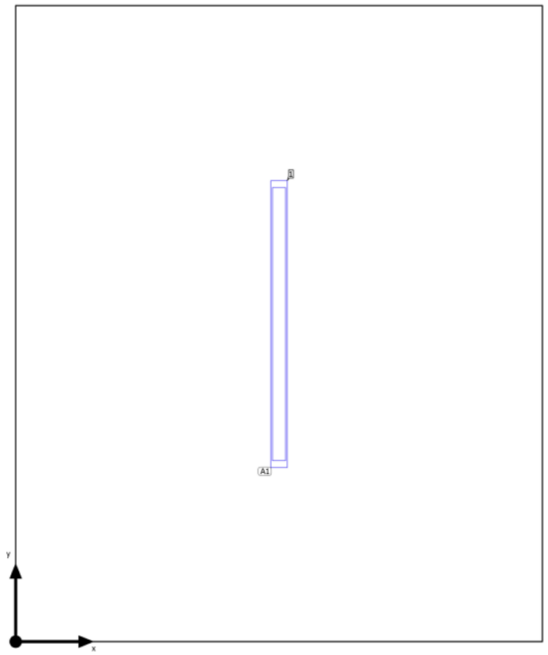


Figure 7.50: **2D View of Luminaire Layout**

- Height of the room = 3.45 m
- Maintenance Factor = 0.9
- Ceiling Reflectance = 60%
- Wall Reflectance = 70%
- Floor Reflectance = 15%

Luminaire list

pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy
1	Philips		TPS682 1xTL5-28W HFP C8	31.0 W	1912 lm	61.7 lm/W

d) Lighting Report:

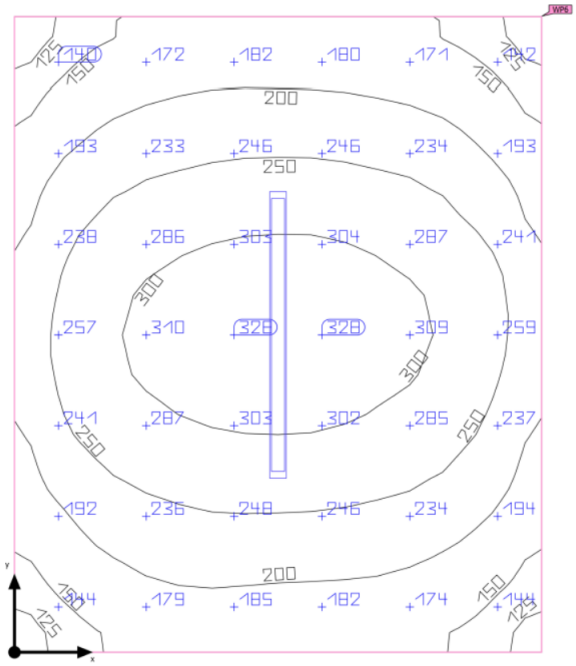


Figure 7.51: **Isolines on Work-Plane**

e) Simulated Output:

Store Room

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Working\ plane)}$
31.0 W	6.08 m^2	5.10 W/m^2 = 2.20 W/m^2/100 lx (Room)	232 lx

Working planes

Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Store Room) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	232 lx (≥ 200 lx) ✓	113 lx	329 lx	0.49	0.34	WP6

f) Discussions:

Design Parameters	Maintained Average Illuminance(E_m)	Overall Uniformity (U_o)	Lighting Power Density (LPD)
Achieved Values	232 lx	0.49	5.10 W/m^2
Recommended Values	200 lx	0.40	6.80 W/m^2

Chapter8

Load Calculation and Bill of Quantity

8.1 Bill of Quantity (BoQ)

pcs.	Manufacturer	Article No.	Article Name	Nominal Lamp Power (W)	Luminous Flux (lm)	Luminous Efficacy (lm/W)
8	Artemide S.p.A.	1306000A	ALPHABET OF LIGHT W/C CIRCOLARE 90	55.0	6040	109.8
39	Artemide S.p.A.	A031000	MICONOS SUSPENSION	15.0	1372	91.5
6	FLOS S.p.A.	07.9525/PW LED/1W/111°	NEUTRON 1 FIXED ROUND FLOOR LED SIDE	1.0	25	25.4
1	FLOS S.p.A.	F0011009 2X9W TOP LED	TIGHT LIGHT	20.0	641	32.0
37	Lightnet	BG7OSE-830H-D300-U	Basic Supeflat - G7	11.0	1244	113.1
179	Lightnet	RP30SE-830E-C1	Ringo Star Cluster Suspended - P3	16.0	1403	87.7
6	Philips		DN571B PSE-E 1xLED125/830 F SG-O	11.8	1050	89.0
1	Philips		TPS682 1xTL5-28W HFP C8	31.0	1912	61.7

8.2 Load Calculation

Room Name	**Area (m^2)**	**P_{total} (W)**	**Lighting Power Density (W/m^2)**
Conference Room (6 Person)	14.34	87	6.07
Co-working Space	359.83	2824	7.85
Creative Space	9.15	100	10.93
IT Lounge, Pantry& Wide Corridor	164.36	381	2.32
AV Studio	22.64	110	4.86
Deep Plan Meeting Room (4 Person)	9.78	55	5.62
Meeting Room (2 Person)	8.95	55	6.15
Open Meeting Space (4-6 Person)	10.33	70.8	6.85
Collab	25.74	121	4.70
Waiting Lounge with Wide Corridor	98.57	545	5.53
Wellness Room	14.89	44	2.96
Store Room	6.08	31	5.10

Total Working Surface Area = 744.60 m^2.
Total Wattage of ALL Luminaires = 4423.8 W.
Effective Lighting Power Density = 5.94 W/m^2.

Chapter9

Conclusion and Future Scope

9.1 Conclusion

This lighting design-related thesis, "Studies on Commercial Building Lighting System," governs:

- A pleasant visual and task environment for employees in various office spaces by striking a good balance between ambient lighting, task lighting, accent lighting, and decor lighting.
- A favourable first impression and a welcome atmosphere for guests.
- Smooth user flow from one location to another, increasing comfort and productivity with a good lighting environment.
- Energy savings by abiding by energy conservation regulations.

To achieve the above mentioned objectives, the case study here within this thesis work is done to obtain the lighting design parameters and energy parameters so that they can comply with the recommended values as per National and International Standards. The level of illumination, uniformity and quality requirements are to be achieved by general principles of lighting as per IS 3646 part 1 (1992) and EN 12464-1:2011 are mentioned in detail in Chapter 7. According to ECBC 2017, Lighting Power Density (LPD) was also attained, demonstrating the lighting design's energy efficiency.

9.2 Future Scope

- The goal of this study's future work is to incorporate daylight into the design in order to boost worker morale and reduce energy consumption, which this design lacked.
- Exit and emergency lighting are required because they guide building occupants to safe exits when general illumination systems fail. If no evacuation is needed, the lighting should ensure safety and comfort until the main lights can be turned back on. Therefore, exit and emergency lighting must be prioritised in future designs.
- Future iterations of this lighting design may include smart lighting in part or all of the spaces that require sensors, controllers, and specialised control techniques. As a result, significant energy can be saved while maintaining lighting needs[15].
- In order to create solutions in future designs that are pertinent to the users, it would be very interesting to research lighting applications for groups that are more vulnerable. Lighting is an issue for all social groups, and it would be particularly interesting to study lighting applications for these groups. Children, the elderly, and those who are blind may be among these populations.

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