Studies on Energy Efficient Airport Lighting Design

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

Master of Engineering
in
Illumination Engineering

Submitted by

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EXAMINATION ROLL NO - M4ILN19017

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Studies on Energy Efficient Airport Lighting Design"** submitted by **SMITA DAS**, (Exam. Roll No.**M4ILN19017**, Registration No. **140679 of 2017-18**) of this university in partial fulfillment of requirements for the award of degree of Master of Engineering in Illumination Engineering, Department of Electrical Engineering, is a bonafide record of the work carried out by her 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 **SMITA DAS**, 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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Date: *(Signature of Examiners)*

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CERTIFICATE

This is to certify that Ms Smita Das, a student of M.E. in Illumination Engineering, Electrical Engineering Department, Jadavpur University, has worked as an Intern in the Lighting Advisory Bureau of this Organisation from 1st June, 2018, to 31st March, 2019.

She carried out a project on "Airport Lighting Design" under the guidance of Ms Uma Lanka, Associate Vice President – Design. During the tenure of her training with us, she has been sincere, hardworking and diligent in carrying out the assignment entrusted to her.

We wish her all success in her future endeavor.

For CROMPTON GREAVES CONSUMER ELECTRICALS LIMITED

S D'Souza

S D'SOUZA
Sr.Manager – Human Resources

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

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

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

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

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Dated: **--**
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Abstract

A detailed studies on energy efficient lighting design for all the indoor and outdoor activity areas of the airport has been carried out by using computer aided lighting system tools like DIALux and AGI32 software. This includes collecting inputs from the client followed by the design simulation which determine the average illuminance level and uniform light distribution with proper arrangement of the luminaires. The design simulation has been done in Crompton Greaves Consumer Electricals Limited Mumbai (Head Office) with LED and Conventional light sources as per requirement. However, LED lighting design simulation showed energy efficient and cost effective solution as compared to conventional light sources. In this project, LED lighting fixtures are used for studying airport lighting design.

CH-1:

INTRODUCTION

INTRODUCTION

1.1: General

"Shine your light and make a positive impact on the world; there is nothing so honorable as helping improve the lives of others." — **Roy T. Bennett**

Light plays a pivotal role in our day-to-day lives. A better quality and quantity of light create a unique ambience. Lighting is mainly concerned with the visual performance and visual comfort by maintaining adequate and proper workspace illumination. The visual comfort of a lighting system affects motivation and well being of the workers which contributes for their better performance and productivity. This led to innovative indoor lighting concepts.

Light has triple effects:

Light for visual functions:

- Illumination of task area in conformity with relevant standards
- Glare-free and convenient

Light for emotional perception:

- Lighting enhancing architecture
- Creating scenes and effects

Light creating biological effects:

- Supporting people's circadian rhythm
- Stimulating or relaxing

The concept of airport lighting design is well equipped with Indian standards of airport indoor and outdoor areas [1] which directly affect the productivity of airport indoor areas environment which includes speed and accuracy of work, glare and motivation. Visual comfort is considered in terms of glare created by luminaries. Light reflected from any highly polished or shiny objects within the visual field causes visual discomfort. This tends to reduce the efficiency of any computer or non-computer tasks. Energy efficient and cost effective lighting design installations replace conventional light sources and provide a better scope of airport lighting. Good lighting can guide the passengers effortlessly to their destination in airport. An appropriate and adequate lighting create a comfortable environment.

Airports are the most complex buildings in the world. The design must enable efficient flow of baggage and passengers, satisfy safety requirements, and support thousands of employees. With the increasing number of air travelers and increased air Cargo, Airports are becoming hubs of retail, hospitality, business and logistics. With this alarming growth, lighting is a key element which support the goals for cost reduction, operational efficiency, safety and sustainability. LED lighting can create an ambience, improve way finding and support a financial bottom line across wide variety of business operations.

In this project, a typical airport indoor and outdoor areas lighting design has been covered. Due to company Policy, I couldn't disclose the Airport name designed by me.

1.2: Literature Review

- A series of Indian Standards on aerodrome lighting fittings talks about runway lighting, taxiway lighting, approach lighting, obstructions light etc. [2].
- General study for using LED to replace traditional light sources has been described about the power circuit design based on the constant current flyback and the heat distribution matter [3].
- The dimmability of light-emitting diodes (LEDs) offers lighting designers great flexibility in illuminating an indoor environment [4].
- Light emission from solid-state devices was understood based on the band theory of semiconductors and p–n junction by the process of electroluminescence where light is emitted through a radiative recombination of electrons and holes on the application of electric field in solid-state materials.
- The invention of blue LED is extremely important because it is 'the final piece of the puzzle' to create LEDs of all primary colors i.e., R-G-B (Red-Green-Blue). These primary color sources can be combined to produce any wavelength in the visible spectrum including white light.
- **Akasaki**, **Amano** and **Nakamura** won the 2014 Nobel Prize in physics for enabling the growth of highly crystalline and uniform GaN and effectively doping it in order to create highly energy efficient blue LEDs [5].

Several Airport lighting guideline standards like **IS 7785 Part 2** deal with specific requirements of the elevated type fixed focus high intensity bidirectional runway edge lighting fittings, in order to ensure their safe performance, good construction and high class of workmanship. This is in conjunction with **IS 7785 Part 3** for elevated type aerodrome lighting fittings. **IS 11071 Part 2** signifies detail of photometric performance and the essential mechanical and electrical requirements (excluding lamps) of the inset type runway centre line lighting fittings to be installed in runway pavements. For street lighting, **IS 1944 (Part 1)-1970** specify the levels of illumination levels and uniformity criteria for street lighting.

1.3: Objectives of the project

Airports are the gateway to an open world. New airport terminals are designed in an accordingly open and transparent fashion. Room and light are in complete harmony. During the day, large windows provide copious amounts of daylight in the building. At night, artificial lighting is more than just brightness for the rushing passenger. It also clarifies the structure of the open-design architecture. This architecture inspires emotions in people – by day and night it provides the right setting for high quality and cosmopolitanism.

Airports are transfer stations for millions of people. An ordered and clear routing of passenger traffic between terminals and counters is indispensable for smooth check-in and transfer processes.

- The purpose of this project is to improve the design of airport terminals to provide a more convenient environment for passengers and airport staff. The design includes both indoor and outdoor areas, consisting Land side, Terminal side and Air side airport areas.
- The primary objective of the design is to shorten the time and improve the process for passengers from check-in to boarding without undermining the airport, aircraft and airline security.
- To create more humanistic, more convenient and more thoughtful environment for passengers.

Ch-2:

THEORY OF LIGHTING

2.1: Conventional Light Sources:

2.1.1: Incandescent Lamps:

The incandescent light bulb or lamp is a source of electric light that works by incandescence, which is the emission of light caused by heating the filament. They are made in an extremely wide range of sizes, wattages, and voltages. It typically consists of a glass enclosure containing a tungsten filament. An electric current passes through the filament, heating it to a temperature that produces light.

2.1.2: Halogen Lamps

A halogen lamp is also known as a tungsten halogen, is an incandescent lamp consisting of a tungsten filament sealed into a compact transparent envelope which is filled with a mixture of an inert gas and a small amount of a halogen such as iodine or bromine. The combination of the halogen gas and the tungsten filament produces a halogen cycle chemical reaction which re-deposits evaporated tungsten to the filament, increasing its life and maintaining the clarity of the envelope.

2.1.3: HID (High Intensity Discharge) Lamps

HID bulbs are categories by the type of gas used in the bulb. The primary types used in horticulture include Metal Halide (MH), and High Pressure Sodium (HPS).

- **Metal Halide**

A **metal-halide lamp** is an electrical lamp that produces light by an electric arc through a gaseous mixture of vaporized mercury and metal halides(compounds of metals with bromine or iodine). The lamps consist of a small fused quartz or ceramic arc tube which contains the gases and the arc, enclosed inside a larger glass bulb which has a coating to filter out the ultraviolet light produced.

- **HPSV (High Pressure Sodium Vapour) Lamps**

The HPS lamp consists of a narrow arc tube supported by a frame in a bulb. The arc tube has a high pressure inside for higher efficiency. Sodium, mercury and xenon are usually used inside the arc tube. The arc tube is made of aluminum oxide ceramic which is resistant to the corrosive effects of alkalis like sodium.

2.1.4: LPSV (Low Pressure Sodium Vapour) Lamps

The LPS Lamp creates a monochromatic yellow light. As it starts it creates a red glow due to the neon gas. The neon gas lights at a lower temperature. As the temperature increases, the sodium begins to vaporize and the lamp turns to a pure yellow.

2.1.5: Fluorescent Lamps

A fluorescent lamp, or fluorescent tube, is a low-pressure mercury-vapor gas-discharge lamp that uses fluorescence to produce visible light. An electric current in the gas excites mercury vapor, which produces short-wave ultraviolet light that then causes a phosphor coating on the inside of the lamp to glow. A fluorescent lamp converts electrical energy into useful light much more efficiently than incandescent lamps.

2.2: White LED

A **light-emitting diode** is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

Fig 2.1: White LED

- **Monochromatic mixing** – High brightness LEDs are available in different colors such as red, green, blue, and amber across the visible spectrum. Color mixing using the primary colors (RGB) enables a range of white light sources with CCTs throughout the black body locus.
- **Using white LEDs** – White LEDs are available in broad bin selection ranges with CCTs from 2500 to 10000K (warm, neutral, or cool in appearance). White LEDs are typically manufactured by placing a blue LED in a package internally coated with a light

converting phosphor. Use of phosphors in the conversion process results in some energy loss, thereby making this technique less efficient compared to the color mixing technique. Additionally, a high CRI white LED results in lower lumens output due to an increased absorption of power from blue light. [6]

- The main semiconductor materials used to manufacture LEDs are:
- ✓ **Indium gallium nitride (InGaN):** blue, green and ultraviolet high-brightness LEDs
- ✓ **Aluminum gallium indium phosphide (AlGaInP):** yellow, orange and red high-brightness LEDs
- ✓ **Aluminum gallium arsenide (AlGaAs):** red and infrared LEDs
- ✓ **Gallium phosphide (GaP):** yellow and green LEDs.

2.2.1: Advantages of LED

- **Energy efficient –** LED's are now capable of givinghigher luminous efficacy.
- **Long Lifetime** – 50,000 hours or more if properly engineered.
- **Rugged** – LED's are also called "Solid State Lighting (SSL) as they are made of solid material with no filament or tube or bulb to break
- **No warm-up period** – LED's light instantly – in nanoseconds
- **Not affected by cold temperatures** – LED's "like" low temperatures and will startup even in subzero weather
- **Directional** – With LED's we can direct the light where we want it, thus no light is wasted.
- **Excellent Color Rendering** – LED's do not wash out colors like other light sources such as fluorescents, making them perfect for displays and retail applications
- **Environmentally friendly** – LED's contain no mercury or other hazardous substances
- **Controllable** – LED's can be controlled for brightness and color.

2.2.2: Measurement Standards of LED

LM79: An LM79 report measures the performance (light) of LED-based luminaires based on specific and collective components which include drive current (mA), CCT (color temperature), wattage, efficiency and distribution. LM79 requires complete luminaires testing procedures. It is an approved method of measuring electrical and photometric measurements of complete SSL products. It does not cover external operating circuits or external heat sinks (e.g. LED chips, LED packages and LED modules). It uses absolute photometry rather than relative photometry.

LM80: LM-80 refers to a method for measuring the lumen depreciation of solid-state lighting sources, such as LED packages, modules and arrays. LM-80 and TM-21 provide an industry standard for lumen maintenance testing and for lumen maintenance extrapolations for LED components.

2.3: CCT (Correlated Colour Temperature)

CCT or Correlated Colour Temperature refers to the color of the light itself. Although T stands for temperature, the CCT does not refer to the actual temperature of the light source; instead, it describes the temperature to which we would have to heat a black body to make it glow in the same color. It is the temperature of the black body whose chromaticity resembles the chromaticity of the light source.

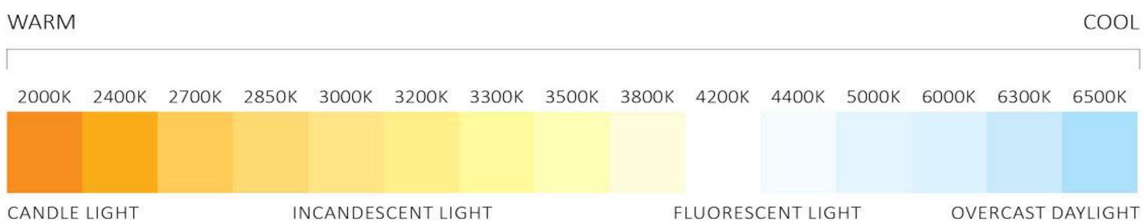

Fig 2.2: CCT of different hue

2.4: CRI (Colour Rendering Index)

CRI or Colour Rendering Index is the ability of the light source to quantify colors. CRI refers to how a light source renders the colors of other objects and surfaces. CRI can reach a maximum value of 100, which means the light source has the same color-rendering capability as natural daylight. Color rendering is increasingly distorted as the CRI becomes lower, and there is no lower limit negative CRI values indicate extremely poor light sources that completely distort color perception. Low-pressure sodium lighting has negative CRI whereas fluorescent lights range from about 50 for the basic types. Typical LEDs have about 80+ CRI.

Fig 2.3: CRI of different light sources

2.5: Maintenance Factor

Maintenance factor (MF) is defined as the "ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the initial average illuminance obtained under the same conditions for the installation" therefore taking account of all losses including lamp lumen maintenance.

$$E_{maintained} = E_{initial} \times MF$$

$$MF = LLMF \times LSF \times LMF \times RSMF$$

RSMF (**ROOM SURFACE MAINTENANCE FACTOR**)**:** takes account of the effect of dirt and dust accumulation and other degradation of the reflectivity of the room surfaces. The main determining factor is the environment which can be classified on a sliding scale from "Very Clean" to "Dirty“.

LSF (LAMP SURVIVAL FACTOR): takes account of the effect of the failure of light sources during the maintenance period.

LMF (LUMINAIRE MAINTENANCE FACTOR): takes account of the effect of dust and dirt accumulation on the luminaire. Luminaires are classified according to their degree of sealing and their distribution, obviously dust accumulation on an open uplight is far more onerous than on a sealed downlight.

LLMF (LAMP LUMEN MAINTENANCE FACTOR): takes account of the effect of the lumen depreciation of the light sources during the maintenance period.

2.6: Utilization Factor:

Utilization Factor or Coefficient of utilization may be defined as “the ratio of total lumens received on the working plane to the total lumens emitted by the light source”.

Utilization factor =Lumens received on the working plane/Lumens emitted by the lamp

2.7: Codes and Standards for office lighting

As airport lighting indoor consists of a number of offices and conference areas, lighting design of various other rooms can be done by using standards like IS 3646 Part I and Part II.

2.7.1: IS 3646: 1992 (PART 1 & PART 2)

IS 3646 Part I covers the principles and practice governing good lighting in buildings and relates chiefly to the lighting of & working areas in industrial, commercial .**IS 3646 Part II (1966)** covers the recommended values of illumination and limiting values of glare index. In order to be able just to discern features of the human face, a luminance of approximately 1 cd/m^2 is necessary. This can be achieved under normal lighting conditions with a horizontal illuminance of approximately 20 lux. So 20 lux is regarded as the minimum illuminance for all non-working interiors. A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminances. Therefore, the following scale of illuminances is recommended.

20-30-50-75-100-150-200-300-500-750-1000-1500-2000 etc, lux.

Because circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity intended, of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. For working interiors the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

The higher value of the range should be used:

- Unusually low reflectance or contrast are present in the task;
- Errors are costly to rectify;
- Visual work is critical;
- Accuracy or higher productivity is of great importance; and
- The visual capacity of the worker makes it necessary.

The lower value of the range may be used:

- Reflectance or contrasts are unusually high;
- Speed and accuracy is not important; and
- The task is executed only occasionally.

2.8: ECBC (Energy Conservation Building Code)

The purpose of the ECBC is to provide minimum requirements for the energy-efficient design and construction of buildings. LPD refers to Lighting Power Density values of the building, which is well explained in ECBC 2009[8] standard. The Code also provides two additional sets of incremental requirements for buildings to achieve enhanced levels of energy efficiency that go beyond the minimum requirements.

2.8.1: Building Area Method [8]

Determination of interior lighting power allowance (watts) by the building area method shall be in accordance with the following: (a) Calculate the gross lighted carpet area for each building area type. (b) 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.

Space Function	LPD (W/m^2)	Space Function	LPD (W/m^2)
Office-enclosed	11.8	• For Reading Area	12.9
Office-open plan	11.8	Hospital	
Conference/Meeting/Multipurpose	14.0	• For Emergency	29.1
Classroom/Lecture/Training	15.1	• For Recovery	8.6
Lobby*	14.0	• For Nurse Station	10.8
• For Hotel	11.8	• For Exam Treatment	16.1
• For Performing Arts Theater	35.5	• For Pharmacy	12.9
• For Motion Picture Theater	11.8	• For Patient Room	7.5
Audience/Seating Area*	9.7	• For Operating Room	23.7
• For Gymnasium	4.3	• For Nursery	6.5
• For Convention Center	7.5	• For Medical Supply	15.1
• For Religious Buildings	18.3	• For Physical Therapy	9.7
• For Sports Arena	4.3	• For Radiology	4.3
• For Performing Arts Theater	28.0	• For Laundry – Washing	6.5
• For Motion Picture Theater	12.9	Automotive – Service Repair	7.5
• For Transportation	5.4	Manufacturing Facility	
Atrium-first three floors	6.5	• For Low Bay (<8m ceiling)	12.9
Atrium-each additional floor	2.2	• For High Bay (>8m ceiling)	18.3

Table 2.1: Interior Lighting Power: Building area method

2.8.2: Space Function Method [8]

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

(a) Determine the appropriate building type and the allowed lighting power density from Table for ECBC Buildings. In cases where both a common space type and building specific space type are listed, building specific space type LPD shall apply.

(b) 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.

(c) 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.

(d) **ECBC 2009, ASHRAE90.1.2013** (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standards are used to calculate LPD values. For selection of luminaires, the LPD value analysis is done thoroughly among which the lowest LPD gives the lowest energy consumption for airport lighting as per airport guidelines.

(e) **Annex 45** suggests that clear international initiatives by the **International Energy Agency**(IEA), **EU**, **CIE**, **IEC**, **CEN** and other international bodies are taken up in order to:

- upgrade lighting standards and recommendations
- integrate values of lighting energy density ($\mathrm{KWh/m^2}$) into building energy codes
- monitor and regulate the quality of innovative light sources
- pursue research into fundamental human requirements for lighting (visual and non-visual effects of light)
- stimulate the renovation of inefficient old lighting installations by targeted measures the introduction of more energy efficient lighting products and procedures can at the same time provide better living and working environments and also contribute in a cost-effective manner to the global reduction of energy consumption and greenhouse gas emissions.

Space Function	LPD (W/m^2)	Space Function	LPD (W/m^2)
Office-enclosed	11.8	• For Reading Area	12.9
Office-open plan	11.8	Hospital	
Conference/Meeting/Multipurpose	14.0	• For Emergency	29.1
Classroom/Lecture/Training	15.1	• For Recovery	8.6
Lobby*	14.0	• For Nurse Station	10.8
• For Hotel	11.8	• For Exam Treatment	16.1
• For Performing Arts Theater	35.5	• For Pharmacy	12.9
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• For Performing Arts Theater	28.0	• For Laundry – Washing	6.5
• For Motion Picture Theater	12.9	Automotive – Service Repair	7.5
• For Transportation	5.4	Manufacturing Facility	
Atrium-first three floors	6.5	• For Low Bay (<8m ceiling)	12.9
Atrium-each additional floor	2.2	• For High Bay (>8m ceiling)	18.3
Lounge/Recreation*	12.9	• For Detailed Manufacturing	22.6
• For Hospital	8.6	• For Equipment Room	12.9
Dining Area*	9.7	• For Control Room	5.4
• For Hotel	14.0	Hotel/Motel Guest Rooms	11.8
• For Motel	12.9	Dormitory – Living Quarters	11.8
• For Bar Lounge/Leisure Dining	15.1	Museum	
• For Family Dining	22.6	• For General Exhibition	10.8
• Food Preparation	12.9	• For Restoration	18.3
Laboratory	15.1	Bank Office – Banking Activity Area	16.1
Restrooms	9.7	Retail	
Dressing/Locker/Fitting Room	6.5	• For Sales Area	18.3
Corridor/Transition*	5.4	• For Mall Concourse	18.3
• For Hospital	10.8	Sports Arena	
• For Manufacturing Facility	5.4	• For Ring Sports Area	29.1
Stairs-active	6.5	• For Court Sports Area	24.8
Active Storage*	8.6	• For Indoor Field Area	15.1
• For Hospital	9.7	Warehouse	
Inactive Storage*	3.2	• For Fine Material Storage	15.1
• For Museum	8.6	• For Medium/Bulky Material Storage	9.7
Electrical/Mechanical Facility	16.1	Parking Garage – Garage Area	2.2
Workshop	20.5	Transportation	
Convention Center – Exhibit Space	14.0	• For Airport – Concourse	6.5
Library		• For Air/Train/Bus – Baggage Area	10.8
• For Card File & Cataloging	11.8	• For Ticket Counter Terminal	16.1
• For Stacks	18.3		

Table 2.2: Interior Lighting Power: Space function method

2.9: Ingress Protection (IP) Ratings

As defined in international standard **IEC 60529**, it classifies the degrees of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water in electrical enclosures. The standard aims to provide users more detailed information than vague marketing terms such as waterproof.

The digits (characteristic numerals) indicate conformity with the conditions summarized in the tables below. For example, an electrical socket rated IP22 is protected against insertion of fingers and will not be damaged or become unsafe during a specified test in which it is exposed to vertically or nearly vertically dripping water. IP22 or 2X are typical minimum requirements for the design of electrical accessories for indoor use.

First Digit: Solids Protection; Second Digit: Liquids Protection

First Digit: Solids

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

Level	Size protected against	Effective against
0	Not protected	No protection against contact and ingress of objects
1	>50mm	Any large surface of the body, such as the back of the hand, but no protection against deliberate contact with a body part.
2	>12.5mm	Fingers or similar objects.
3	>2.5mm	Tools, thick wires, etc.
4	>1mm	Most wires, screws, etc.
5	Dust Protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact.
6	Dust Tight	No ingress of dust; complete protection against contact.

Table 2.3: IP Ratings of first digit

Second Digit: Liquids

Protection of equipment against ingress of water.

Level	Size protected against	Effective against
0	Not protected	-
1	Dripping water	Dripping water (vertically falling drops) shall have no harmfull effect.
2	Dripping water when tilted up to 15°	Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.
3	Spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.
4	Splashing water	Water splashing against the enclosure from any direction shall have no harmful effect.
5	Water jets	Water projected by a nozzle (6.3mm) against enclosure from any direction shall have no harmful effects.
6	Powerful water jets	Water projected in powerful jets (12.5mm nozzle) against the enclosure from any direction shall have no harmful effects.
7	Immersion up to 1m	Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).
8	Immersion beyond 1m	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects.

Table 2.4: IP Ratings of first digit

2.10: Impact Protection (IK) Rating

Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts in accordance with **IEC 62262:2002** and **IEC 60068-2-75:1997**.

IK00 Not protected

IK01 Protected against 0.14 joules impact.
Equivalent to impact of 0.25 kg mass dropped from 56 mm above impacted surface.

IK02 Protected against 0.2 joules impact.
Equivalent to impact of 0.25 kg mass dropped from 80 mm above impacted surface.

IK03 Protected against 0.35 joules impact.
Equivalent to impact of 0.25 kg mass dropped from 140 mm above impacted surface.

IK04 Protected against 0.5 joules impact.
Equivalent to impact of 0.25 kg mass dropped from 200 mm above impacted surface.

IK05 Protected against 0.7 joules impact.
Equivalent to impact of 0.25 kg mass dropped from 280 mm above impacted surface.

IK06 Protected against 1 joules impact.
Equivalent to impact of 0.25 kg mass dropped from 400 mm above impacted surface.

IK07 Protected against 2 joules impact.
Equivalent to impact of 0.5 kg mass dropped from 400 mm above impacted surface.

IK08 Protected against 5 joules impact.
Equivalent to impact of 1.7 kg mass dropped from 300 mm above impacted surface.

IK09 Protected against 10 joules impact.
Equivalent to impact of 5 kg mass dropped from 200 mm above impacted surface.

IK10 Protected against 20 joules impact.
Equivalent to impact of 5 kg mass dropped from 400 mm above impacted surface.

CH-3:

LIGHTING DESIGN CRITERIA & METHODOLOGY

3.1: General

Lighting is an important aspect of interior design as it enhances the aesthetic appeal and creates the mood and ambiance of a living space. Lighting fixtures that illuminate a room creates a safe and comfortable environment besides adding style to the interior décor. Light is the main element that gives the room a special look and transforms it into a seamless combination of functionality and style. Besides playing a functional role it creates a visually dynamic space. Lighting can make or break the ambiance of a room. Hence proper lighting is an important element of decorating our home.

These broad objectives form the basis for lighting decisions:

- **Visibility (or selective visibility):**

A film without sound is a silent movie. A film without light is radio. Exposure and contrast are two essential elements of selective visibility in cinematography. Much of the artistry of cinematography is in the control of lightness and darkness throughout the film's latitude, selectively exposing objects and characters to appear bright and glowing, slightly shaded, darkly shaded, barely visible, or completely lost in darkness, as desired. Equally important is the direction of light.

- **Naturalism:**

Lighting helps set the scene; it locates the scene in time and space. The quality and direction of the light and the sources it implies are part of what makes a scene convincing. Often unconsciously, we recognize lighting that portrays time, season, place, and weather conditions. The lighting is evocative of the way the air feels and smells, whether it is dusty or clean, foggy or clear, cool or hot, humid or dry.

- **Composition:**

Good lighting in buildings can help people to see what is around them, use landmarks to navigate, identify signs and spaces, see others' faces and participate in activities. It is important to remember that reflection and contrast are the keys to vision; glare from lights is not good; uniformity of light on ceilings and walls makes spaces appear more attractive; spotlights can make faces appear more aggressive than more diffuse lighting; sudden changes in light level should be avoided and 'domestic' style lights contribute to a homely atmosphere.

- **Mood:**

We usually need higher levels of light to operate during the day and lower levels when we're winding down at night. Using bright lights at night usually decreases the body's melatonin levels, essentially throwing off our internal clock and hindering sleep, cognition, hormone release times, blood pressure and glucose levels. When there is a lack of melatonin, people can experience sleep problems that lead to behavioral changes.

- **Bright light** tends to intensify emotions.
- **Dim light** tends to make us crave unhealthy foods.
- **Warm lighting** creates a more relaxing and intimate setting.

3.2: Quality characteristics of Lighting

Traditional quality criteria:

- Sufficient illumination level
- Harmonious brightness distribution
- Glare limitation
- Avoidance of reflections
- Good modeling
- Correct light color
- Appropriate color rendering

New quality criteria:

- Changing lighting situations
- Personal control
- Energy efficiency
- Daylight integration
- Light as an interior design element

Illuminance – definition of terminology

Illuminance maintenance value ($\overline{E_m}$):

It is the value below which the illuminance level must not fall in the visual task area.

Visual task area:

Illuminance levels are specified for specific visual tasks and are designed for the area in which these may take place. If the exact location is unknown, the room as a whole or a defined area of the workstation is used for specification. The visual task area may be a horizontal, vertical or inclined plane.

Area immediately surrounding the visual task area:

Here illuminance may be one level lower than in the visual task area (e.g. 300 lux to 500 lux).

Uniformity (U_0):

In order to perform visual tasks in illuminated areas, there should not be any great differences in brightness so that uniformity should not fall below

$$U_0 = \frac{E_{min}}{E_{avg}}$$

Reflectance factors:

The reflectance factors of the room and object surfaces determine not only the perception of the room but also the reflected light and thus the room's brightness. The reflectance factor table in the system helps us to determine the reflectance factors

Glare:

Direct glare:

Causes:

- Luminaires without glare control
- Very bright surfaces

Effects:

- Loss of concentration
- More frequent mistakes
- Fatigue

Remedy:

- Luminaires with limited luminance levels
- Blinds on windows

Reflected Glare:

Causes:

- Reflective surfaces
- Incorrect luminaire arrangement
- Incorrect workstation position Effect

Effects:

- Loss of concentration
- More frequent mistakes
- Fatigue

Remedy:

- Matching luminaire to workstation (layout)
- Indirect lighting
- Matt surfaces

Spatial illumination:

In order to enhance people and object recognition in a room, basic requirements are placed on cylindrical illuminance $\bar{E}_z$ and modelling. Hence, $\bar{E}_z$ should be as high as 150 lx in rooms used for communication. Modelling is the ratio between cylindrical and horizontal illuminance at a specific point and should be between 0.3 and 0.6.

3.3: Lighting Design Procedure

To achieve the best overall outcome in a lighting installation, it is important to avoid the tendency of rushing straight into luminaire selection before determining more broadly what is required from the system. The use of a structured design process helps to avoid this.

Fig 3.1: Typical LED Lighting

The key steps in the lighting design process are:

I. Identify the requirements.
II. Determine the method of lighting

III. Select the lighting equipment.
IV. Calculate the lighting parameters and adjust the design as required.
V. Determine the control system.
VI. Choice of luminaire.
VII. Inspect the installation upon completion

The initial stages are discussed below:

I. Identifying the requirements

This involves gaining a full understanding of what the lighting installation is intended to achieve. This includes the following:

- Task Requirements
  - Illuminance
  - Glare
- Mood of Space
- Relation to shape of space
- Things to be emphasized
- Things to hide
- Direction of light
- Interaction of daylight

II. Determine the method of lighting

At this stage, consideration is given to **how the light is to be delivered**, e.g. will it be recessed, surface mounted, direct or indirect, or will up-lighting be used, and its primary characteristics, e.g. will it be prismatic, low brightness or mellow light.

Consideration should be given at this stage to the **use of daylight** to minimize the need for artificial light.

III. Select the lighting equipment

Once the method of lighting has been selected, the most appropriate light source can then be chosen followed by the luminaire.

The following attributes should be studied when choosing the light source:

- Light output (lumens)

- Total input wattage
- Efficacy (lumens per Watt)
- Lifetime
- Physical size
- Surface brightness / glare
- Color characteristics
- Electrical characteristics
- Requirement for control gear
- Compatibility with existing electrical system
- Suitability for the operating environment

A number of factors also affect luminaire choice:

- Characteristics of the light source and control gear
- Luminaire efficiency (% lamp light output transmitted out of the fixture)
- Light distribution
- Glare control
- Finish and appearance
- Size
- Accessibility of components for maintenance
- Ability to handle adverse operating conditions
- Aesthetics
- Thermal management

IV. Calculate the lighting parameters

Lighting calculation methods fall into three broad categories:

1. Manual calculation Methods:
2. Three Dimensional Modelling:
3. Visualization:

Photometric data for light sources and luminaires is commercially available to contribute to these calculations.

Discussion of the following methods in details:

1. **Manual Calculation method**

There are a wide range of manual computation methods for the calculation of different lighting aspects. These include complex methods for calculating the illuminance from a wide variety of shapes of luminous objects. The majority of these have now been superseded by computer programs.

The Lumen Method was the mainstay for interior lighting and has remained in use as a quick and relatively accurate method of calculating interior illuminance.

The **Lumen Method** calculates the average illuminance at a specific level in the space, including an allowance for the light reflected from the interior surfaces of the room. The calculation method has a set of assumptions that, if followed, gives a reasonable visual environment. Inadequate attention to the assumptions will produce poor results.

The basic assumptions are:

- All the luminaires in the room are the same and have the same orientation
- The luminaires do not have a directional distribution and are aimed directly to the floor
- The luminaires are arranged in a uniform array on the ceiling and have the same mounting height
- The luminaires are spaced less than the maximum spacing to mounting height ratio nominated in the coefficient of utilization tables.

The average illuminance produced by a lighting installation, or the number of luminaires required to achieve a specific average illuminance, can be calculated by means of Utilization Factor ($\boldsymbol{UF}$), a $\boldsymbol{UF}$ being the ratio of the total flux received by a particular surface to the total lamp flux of the installation.

Lumen Method Formula:

The average illuminance E_h over a reference surface s can be calculated from the "**Lumen method**" formula.

$$\boldsymbol{E_h = \frac{\emptyset * n * N * LLF * UF(s)}{Surface\ Area(s)}}$$

Where,

$\emptyset$: Initial bare lamp flux (lumens)

n: The number of lamps per luminaire

N: The number of luminaires

LLF: The total light loss factor

$UF(s)$: The utilization factor for the reference surface (s) of the chosen luminaire

Utilization factors can be determined for any surface or layout of luminaires. The "UF" symbol is normally shown followed by an extra letter in brackets, to denote the surface, for example, $UF(s)$ is the utilization factor for the floor cavity and $UF(w)$ is the utilization factor for the walls.

Although the lighting designer can calculate utilization factors, lighting companies publish utilization factors for standard conditions for their luminaires. The standard method of presentation is shown below. To use this table, it is only necessary to know the Room Index and the effective reflectance of the three standard surfaces (floor cavity, walls and ceiling cavity) as shown in Fig 3.2.

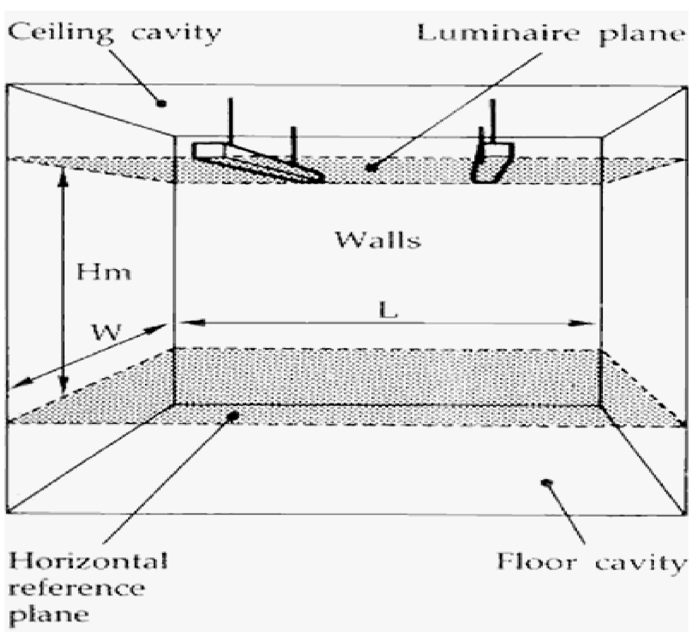


Fig 3.2: Room dimension

Room Index:

The Room Index is a measure of the angular size of the room, and is the ratio of the sum of the plan areas of the F and C surfaces to the area of the W surface. For rectangular rooms the room index is given by:

$$RI=\frac{L*W}{(L+W)H_m}$$

Where:

L= The length of the room

W= The width of the room

H_m= The height of the luminaire plane above the horizontal reference plane.

If the room is re-entrant in shape, for example L shaped, then it must be divided into two or more non-re- entrant sections, which can be treated separately.

Spacing to Mounting Height Ratio:

The Spacing to Mounting Height Ratio (SHR) is the spacing between luminaires divided by their height above the horizontal reference plane.

2. Three Dimensional modeling

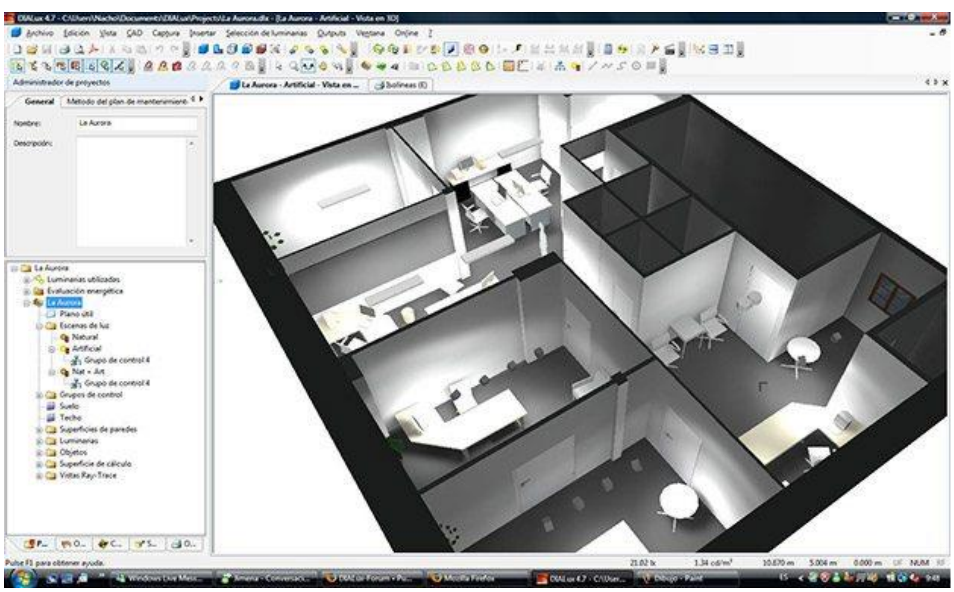


Fig 3.3: 3D modeling in DIALux

Although it was possible to calculate the luminance of all the surfaces in a room, the calculations were extremely laborious and could only be justified in the most special cases. However, the advent of computer modelling enabled a more flexible approach to lighting design and significantly increased the information available to the designer.

In contrast to the Lumen Method, lighting programs enable the lighting designer to broaden the assumptions:

- A mixture of luminaires can be used
- The luminaires no longer have to be arranged in a regular array.
- Directional luminaires can be modeled.
- A large number of calculation points can be considered to give a meaningful uniformity calculation.
- The illuminance and luminance of all surfaces can be calculated.

This gives the lighting designer a much greater understanding of what is happening in the room.

Although there is some general understanding of the need for appropriate luminance distribution in the vertical plane, there is little information, experience or understanding for many designers to determine:

- What the luminance of surfaces should be in varying situations
- What is an acceptable luminance uniformity
- Whether there should there be a maximum luminance uniformity
- What is the desired graduation in luminance
- At what point is the luminance distribution of the wall unacceptable

It is important in using a lighting calculation program that the output records the type of luminaire used, the location of the luminaires, the assumed lumen output of the lamp, the light loss factor and the aiming points.

3. Visualization

These are programs that create a perspective rendering of the space in levels of detail that vary from a block representation of the space, to photographic quality renderings, depending on the sophistication of the program and the level of detail of the interior to be entered.

The programs fall into two basic types:

- **Flux transfer or radiosity calculations**
- **Ray tracing calculations**

A Lambertian surface is a perfect diffuser, where light is reflected in all directions, irrespective of the angle of incidence of the light such that irrespective of the viewing angle the surface has the same luminance. A specular surface is a mirror like surface, where the angle of reflection of the light is the same as the angle of incidence.

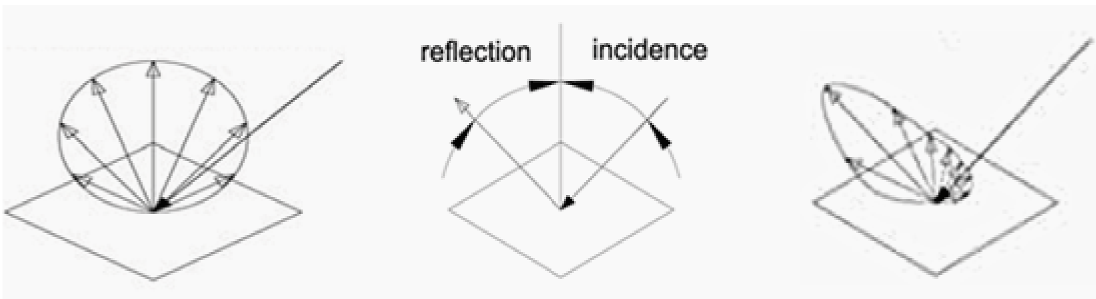


Fig 3.4: Left: Lambertian surface; Middle: Specular surface; Right: Semi-specular surface

Fig 3.4 represents examples of these surfaces. A real life surface is a combination of both surfaces (semi-specular) and has both specular and diffuse characteristics. Some materials are more specular while others are more diffuse.

A flux transfer or radiosity program treats all surfaces as diffuse or Lambertian surfaces; as a result their rendering tends to appear flat with soft shadow details. It will tend to overestimate the uniformity. Ray tracing traces the individual rays of light from the source to the eye as it reflects from surface to surface around the room. As a result ray tracing can allow for the specular component of the surfaces.

Some programs calculate the entire lighting by ray tracing while others calculate the space on a flux transfer basis and have an overlay of ray tracing of specific areas to improve the quality of the rendering. When ray tracing is added, reflections are added in polished surfaces and shadows become sharper.

The output should include:

- ***Installation information*** – the type and location of all luminaires and the aiming information. The lamp details should be included as well as the specific catalogue number of photometric file that has been used.
- ***Light technical parameters*** – the illuminance, uniformity and other parameters that have been calculated to achieve the design.
- ***Verification information*** – adequate details to enable the lighting calculation to be verified. This should include the luminaire type, the photometric file, surface reflectances that were assumed, light loss factors, lumen output of lamps and mounting and aiming locations.

V. Determine the control system:

Fig 3.5: Smart LED lighting control system

The effectiveness and efficiency of any lighting installation is affected as much by the control system as by the light sources and fixtures chosen.

Give consideration to:

- Providing multiple switches to control the number of lights that come on at any one time. Using one switch to turn on all the lights in a large room is very inefficient.

- Placing switches at the exits from rooms and using two-way switching to encourage lights to be turned off when leaving the room.

- Using 'smart' light switches and fittings which use movement sensors to turn lights on and off automatically. These are useful in rooms used infrequently where lights may be left on by mistake, or for the elderly and disabled.
- Using timers, daylight controls and motion sensors to switch outdoor security lights on and off automatically controls are particularly useful for common areas, such as hallways, corridors and stairwells, in multi-unit housing.

- Using solar powered lighting for garden and security lights.

- Using dimmer controls for incandescent lights (including halogens). This can save energy and also increase bulb life. Most standard fluorescent lamps cannot be dimmed, but special dimmers and lamps are available. If lamps are to be dimmed it is important to ensure that the correct equipment is used, especially when retrofitting more energy efficient lamps.

VI. Choice of Luminaire:

The performance of a luminaire should be considered just as carefully as its cost. In the long term a well designed, well constructed luminaire will be cheaper than a poor quality unit; and the salient features of a good quality luminaire are:

- Sound mechanical and electrical construction and a durable finish.
- Adequate screening of high luminance lamps to minimize discomfort and glare.
- Adequate heat dissipation to prevent over-heating of the lamp, wiring and ancillary equipment.
- High light output ratio with the appropriate light distribution.
- Ease of installation, cleaning and maintenance.

CH-4

ILLUMINATION FOR AIRPORT SYSTEM

4.1: General

Airports are large, complex and generally highly profitable industrial enterprises. They are part of a nation's essential transportation infrastructure, which, besides providing thousands of jobs at the airport itself, supports a much broader audience in social and economic terms. It has been estimated that for every job at the airport, an additional one is created in the region. As large industrial complexes, airports consist primarily of:

- **Terminal Side**
- **Land Side**
- **Air side**

With the growing number of air travelers and increased air cargo, airports are becoming hubs of retail, hospitality, business and logistics. Amid this rapid growth, lighting is one element that can support our goals for cost reduction, operational efficiency, safety, and sustainability, while at the same time delivering a memorable brand experience. LED lighting can create a unique ambiance, improve way finding, and support our financial bottom line across a wide variety of business operations.

Proper Illumination is an important criterion for the following factors discussed below:

- Ensure the airport is safe and easy to navigate for passengers
- Offer a safe and comfortable working environment for staff
- Improve operational efficiency with planned maintenance and remote monitoring
- Grow revenues with a more appealing retail and hospitality proposition
- Reduce costs, light pollution, and carbon emissions with energy-efficient LED lighting and controls

4.2: Illumination standards

Illumination level standards with reference to **EN 12464-1: 2011**, **IS 3646-II: 1996**, **IS 11116: 1984**, **ECBC**, **NBC**, guidelines are followed in this project.

The total activity area of the airport is classified into Land side, Terminal Side and Air side airport areas as discussed in details below:

- **Land side** consists of Parking areas, roads and tunnels, etc.
- **Terminal Side** involves Arrival and departure halls, check-in and information desks, connection areas and travelers, customs and passport control, baggage claim area,

luggage handling, air traffic control, retail and leisure area, offices and conference rooms, facades and architecture, etc.

- **Air side** consists of Apron areas, Hangar and Logistics.

These areas are vividly explained below using figures

4.2.1: Land Side Airport area

An airport is a destination for millions of people as they embark on a journey for business or pleasure. But for millions more who live and work in the vicinity, we're also a neighbor. Good lighting solutions can make the land side of the airport feel safe and welcoming, without creating unwanted light pollution or glare.

- ✓ **Parking Area**

Great lighting is essential to delivering a positive user-experience in any parking garage. The bright, uniform illumination of LED lighting diminishes shadows and improves visibility, helping people feel safer and drivers feel more in control. Lighting on demand and ease of maintenance ensure energy savings and decreased operational costs. Our goal is to provide a safe, secure, cost-effective and sustainable solution for the parking garage.

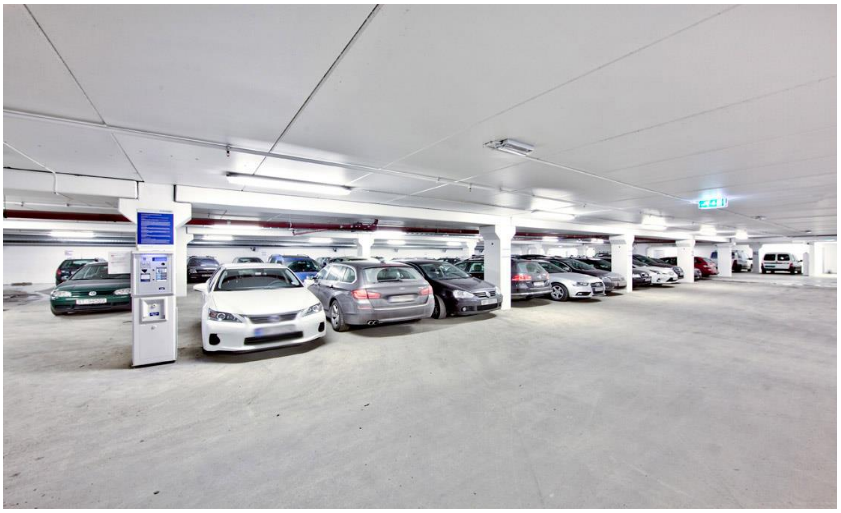


Fig 4.1: Parking area

- ✓ **Roads and Tunnels**

The complexities of transportation infrastructure mean varying types of illumination are needed to ensure traffic flows smoothly, people feel safe, and cities save on costs. Smart LED street lighting is a cost-effective and sustainable choice for cities today – and into the future. With state-of-the-art LED lighting and simple controls, the road is brightly lit and the lighting is easily managed. Tunnel offers a range of different systems, services, and luminaires to meet varying types of tunnel requirements.

Fig 4.2: Tunnels

4.2.2: Terminal Side

Whether passengers are departing or arriving, they need to feel relaxed and welcome. The scene is set for a full airport experience with LED lighting systems that create a safe and inspiring ambiance in all areas. But also make use of important signage and information easy to read, to enable quick guidance, while improving the traveler flow. To create a positive and exciting traveler experience that will make the airport as a first choice. The terminal side is where we can make the first impressions count.

- ✓ **Arrival and Departure Halls**

Arrival and departure halls can be the busiest parts of the airport. Passengers need to orientate themselves in unfamiliar, and often chaotic, surroundings. Good lighting can guide them effortlessly to their destination and therefore the departure environment should be comfortable and calm, easing the burden of waiting, especially in the case of delays.

Fig 4.3 depicts the arrival hall lighting system of the airport and fig 4.4 represents the departure hall lighting design.

Fig 4.3: Arrival Hall

Fig 4.4: Departure Hall

- ✓ **Check-in and information desks**

The better the light quality, the easier it is for staff to interact with passengers and check their passports and documentation. It makes the experience less taxing and more time efficient. So the waiting line goes more smoothly and everyone stays calm and collected.

Fig 4.5 shows the lighting design for Check-in and information desks area.

Fig 4.5: Check-in and information desks

- ✓ **Connection areas and travelators**

For an airport, which is often open 24 hours a day, connection areas and travelers are the arteries of the airport. They link the different areas together logistically. Lower light levels create a sense of tranquility in busy connection areas. Brighter ambiances can heighten the feeling of efficiency and speed on travelers.

Fig 4.6: Connection areas and travelators

- ✓ **Customs and Passport control**

Security is paramount to the safe operation of the airport, not to mention its reputation. Visitors expect their documents to be checked quickly and efficiently with the minimum of hassle. At the same time, custom staff must appear authoritative and professional. The right lighting can aid their concentration and improve facial recognition at customs and passport control, increasing throughput and making the whole process more efficient and secure.

Fig 4.7: Customs and Passport control

- ✓ **Security check areas**

As concerns about airport security intensify, passengers are investigated more than ever before. Body checks and scans must be conducted in a dignified way that ensures passengers feel respected and the actions of staff are beyond question. Lighting provides the clarity that the security check needs to stay vigilant and keep everyone safe.

Fig 4.8 as shows a typical Security check-in area of airport.

Fig 4.8: Security check areas

✓ **Baggage claim area**

A typical baggage claim area contains baggage carousels or conveyor systems that deliver checked baggage to the passenger. Waiting to be reunited with the baggage after a flight can be an anxious time for passengers. A natural lighting solution that mimics daylight will enhance guidance and comfort for the traveler to quickly find the right baggage carrousel and collect its baggage as fast as possible.

Fig 4.9: Baggage claim area

✓ **Luggage Handling**

Behind the scenes, taking care of baggage handling and making sure everything keeps moving can be a stressful job. A natural lighting solution that mimics daylight will enhance comfort and wellbeing for the staff that have to carry out their work in confined spaces. It also aids concentration, improves communication and reduces the number of baggage errors.

Fig 4.10: Luggage Handling area

- ✓ **Air traffic control tower**

Air traffic controllers are the heart of airport and essential for its safe operation. To keep airplanes flying safely and on time, they need to guide pilots with precision accuracy, 24 hours a day. Mistakes are not an option. The challenge is to provide exactly the right ambiance to aid concentration and make interpreting complex instrumentation as easy as possible – whatever the time of day or night.

Fig 4.11 depicts Air traffic control office room where one can guide the aircraft through the ground so to solve the primary purpose of preventing any accidents of the aircrafts.

Fig 4.11: Air Traffic Control Office

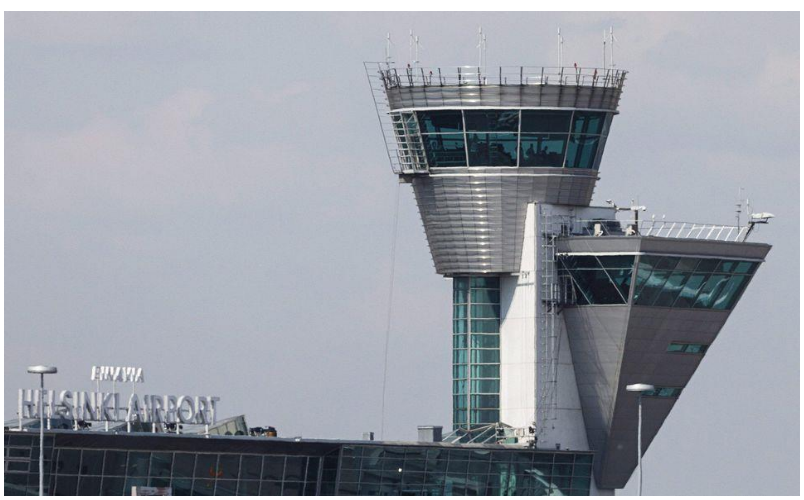


Fig 4.12: Air Traffic Control Tower

✓ **Retail and Leisure area**

To create customized lighting designs that attract travelers and keep them engaged while they are in the terminal. Targeted, engaging experiences stimulate shoppers, highlight key locations throughout the area, guide visitors, and encourage exploration.

Fig 4.13: Leisure area

✓ **Offices and Conference Rooms**

Offices and conference rooms have changed over the years. Once single-use spaces, offices are now often multi-use facilities that depend on the availability of sophisticated and dynamic resources — especially lighting. LED lighting supports sustainability goals and occupant well-being, while our connected lighting systems provide a firm base for the growing push towards smart buildings. Data-driven insights gathered from the connected lighting network optimize service delivery and operations, improve workplace design, and positively impact employee experience.

Fig 4.14: Office room

✓ **Facades and Architecture**

LED lighting offers unprecedented design freedom in terms of color, dynamics, miniaturization, architectural integration and energy efficiency – opening up new possibilities in brand building and ambience creation, for instance by dynamically changing the lighting, using various highlighting and color effects. Architectural facade lighting can effectively turn the airport into a prominent landmark, a living symbol of hospitality.

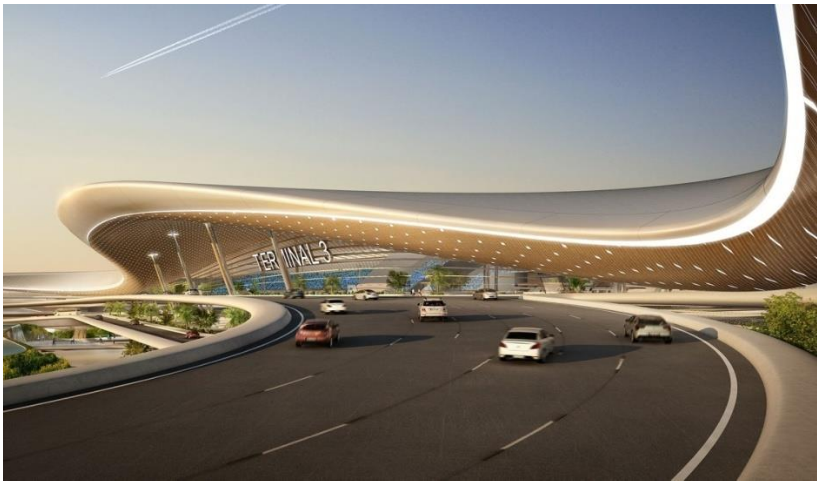


Fig 4.15: Airport Facades

4.2.3: Air Side

The air side at the airport is a hive of activity that needs to be handled safely and efficiently. The lighting should be bright enough for staff to be able to perform visual tasks, but not so bright that it causes glare and discomfort.

✓ **Apron**

The areas where airplanes park to load or offload cargo, passengers and luggage need to be lit effectively for essential operations to take place such as refueling or safety checks.

Bright white light helps staff to handle cargo, catering and fueling and read information correctly. It is also reassuring for passengers waiting at the gate to board because they can see that safety and security protocols are maintained at all times.

FUNCTIONS OF APRON LIGHTING:

- To assist the pilot to taxi his aircraft into and out of the final parking position;

- To provide lighting suitable for embarkation and disembarkationof passengers, personnel to perform the functions of loading and unloading cargo, refueling and performing other apron service functions; and
- To maintain airport security.

Fig 4.16: Apron

✓ **Hangar**

Behind the scenes our support personnel need to carry out all aspects of routine maintenance work. Effective lighting is essential for operational productivity and efficiency. Bright, white light not only improves visibility, it can also help those working late at night to stay alert and focused. So we can minimize disruptions and improve our airport’s safety record.

Fig 4.17: Hangar

✓ **Logistics**

Keeping employees safe in the logistic areas is critical. Highly uniform, inherently directional white LED lighting helps eliminate shadows and dark corners where accidents may occur. A flexible lighting system allow us to deliver the right levels of light where and when they are needed, increasing the efficiency and quality of our operations. LED lighting helps to create an intuitive, fully capable, state-of-the-art lighting system.

Fig 4.18: Logistics area

CH-5

LIGHTING DESIGN OF AIRPORT INDOOR AND OUTDOOR AREAS

5.1: Introduction

Airports are important infrastructure facilities for their regions and the global economy. People of diverse origins and cultures frequent them. Light promotes information and orientation. It facilitates recognizing and experiencing highly frequented airport areas. In bright rooms, passengers navigate more easily and arrive at their desired destinations more quickly.

Worldwide trends in the aviation industry indicate that monitoring and controlling airfield lighting systems increases the airport capacity and operation efficiency, improving the safety in air-traffic control and the aircrafts. Airport airfield ground lighting (AGL) systems are in charge of emphasizing the runway, giving visual reference of speed and alignment to aircrafts in the final stages of approaching, landing, and taxiing operations .The so-called marker lights, or beacons, are lamps installed in devices, which modify the pattern, intensity, color, and direction of the light emission.

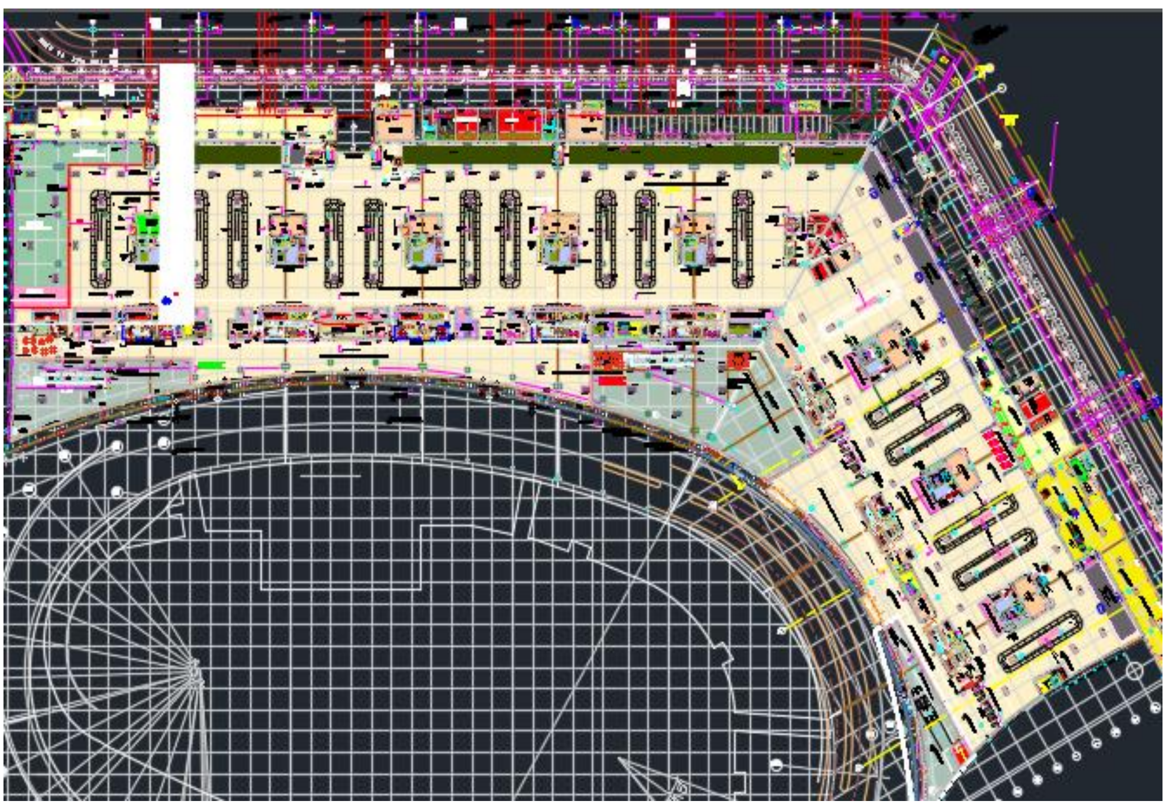
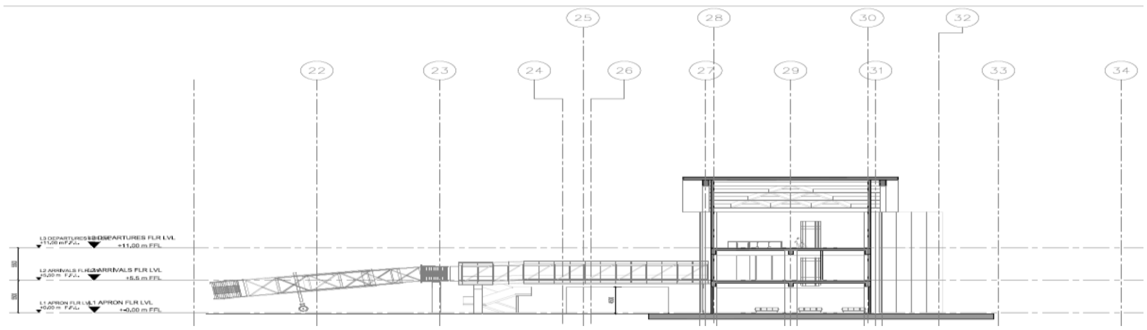


Fig 5.1: Terminal Building Airport

Fig 5.1 shows the AutoCAD layout of the top view of terminal building of airport which includes all activity areas as discussed below.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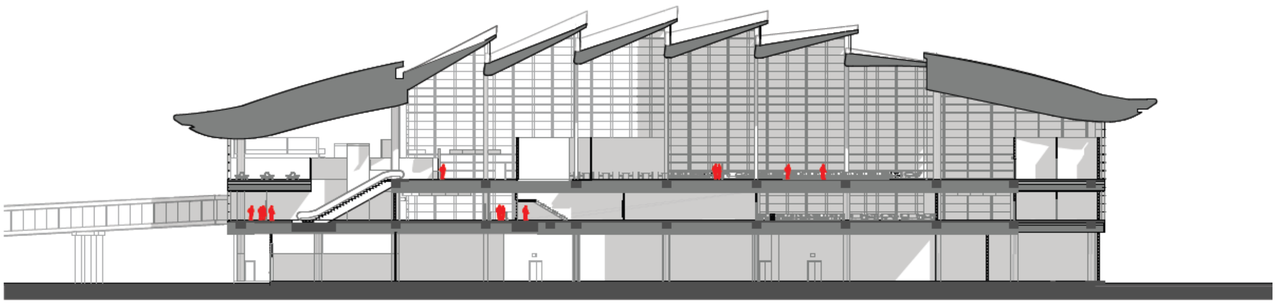
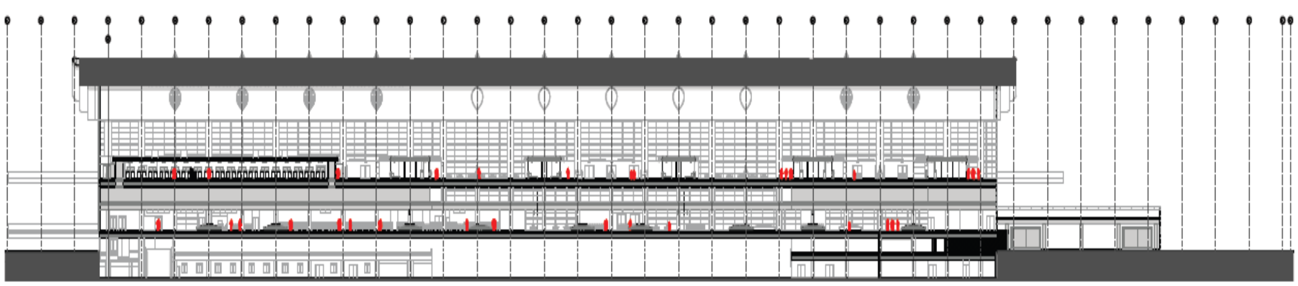
DEPARTURES FLR LVL
+11,00 m FFL
ARRIVALS FLR LVL
+5,5 m FFL
L1 APRON FLR LVL
+-0,00 m FFL

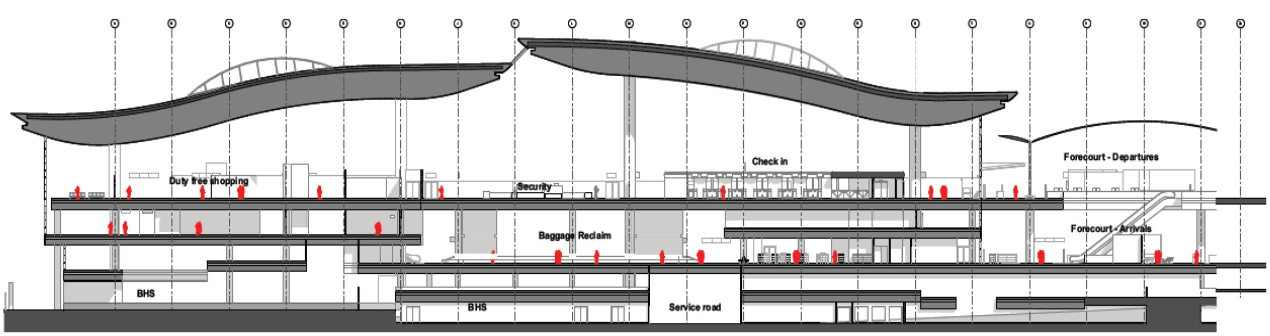
(a)



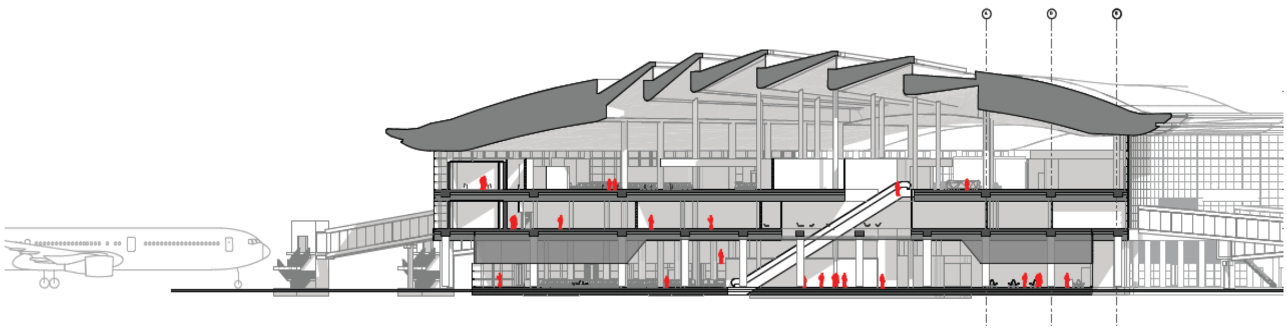
(b)



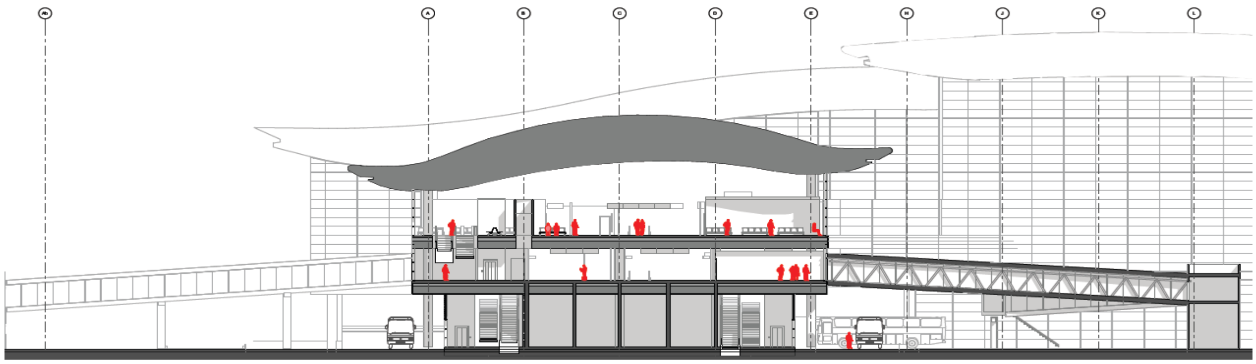
(c)


Duty free shopping
Security
Check in
Forecourt - Departures
Baggage Reclaim
Forecourt - Arrivals
BHS
BHS
Service road

(d)



(e)



(f)

Fig 5.2: (a),(b),(c),(d),(e) and(f) depicts the elevation of airport terminal building from different viewing sides

Fig 5.2 shown the sectional elevation views of the airport terminal building from different sides.

5.2: Summary of standard of designed level of illumination for different activities

Table 5.1 represents values of average illuminance [7] on various airport activity areas as shown below:

Application	***Average Illumination (Lux)***
Terminal Side	
Arrival Halls	**200**
Departure Halls	**300**

Check-in & Information Desks	**400**
Customs and Passport Control	**400**
Connection areas and travelers	**150**
Security check areas	**500**
Baggage claim areas	**200**
Luggage Handling areas	**500**
Office and conference rooms	**500**
Air Traffic Control Room	**400**
Leisure area	**150**
Retail area	**500**
Cargo sorting area	**300**
Fire station control room	**300**
Air Side	
Apron area	**20**
Hangar area	**300**
Land Side	
Car Parking Indoor area	**30**
Street lighting	**30**

Table 5.1: Illuminance value of different airport activity areas

5.3: Design Tools

1. DIALux Software

DIALux is free software developed by DIAL for professional light planning. This software is being used by many light planners and designers worldwide. This software is really helpful to design simply and intuitively lighting systems for indoor and outdoor. By using DIALux, we will be able to plan the lighting we will use in a room, or in a building. With DIALux, we are able to calculate and visualize the daylight, as well as plan our lighting scenes, plan the color and intensity of the lights we will use, position on the project the emergency lighting, with the right legal number of luminaires, and many more. This advanced yet easy to use software has a simple 3D rendering functionality, which is very useful for calculations of interior, exterior and street lighting.

DIALux also calculates the energy consumption of the lighting project for the implementation of existing rules at national and international level.

DIALux does not come with any installed luminaire fixtures, instead we have to install lighting manufacturers DIALux plugins, which are online catalogs of the luminaires. The DIALux calculation program is available free of charge.

2. AGI32 Software

AGi32 is first and foremost, a calculation tool for accurate photometric predictions: A technical tool that can compute illuminance in any situation, assist in luminaire placement and aiming, and validate adherence to any number of lighting criterion.

However, there is so much more that can be done to enhance the understanding of photometric results. Visualization is extremely important to comprehend changes in luminance for different materials and surface properties and predict the effect of various luminaire designs in real-world, light and surface interaction.

- **Direct Calculation Method:**

Direct Calculation Method considers only light directly from luminaires to calculation points and is capable of point-by-point results only, it cannot be rendered. This method lends itself particularly well to exterior lighting projects such as site lighting, roadway and sports applications. It may also be utilized for fast direct light calculations in interior facilities. The obstructive nature of surfaces is considered.

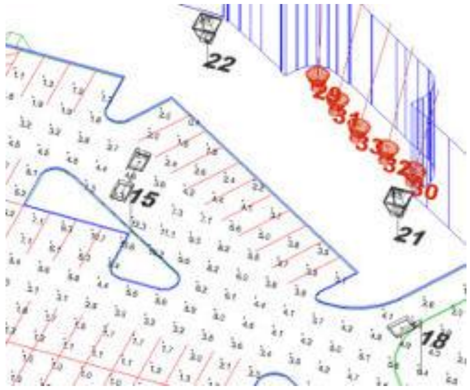


Fig 5.3: Typical Calculation grid on AGI32 Software

- **Full Radiosity Method:**

The Full Radiosity Method enables all features for the accurate computation of interreflected light. Full Radiosity Method is required for interior lighting applications where interreflected light and indirect lighting are important or when rendering is desired. Due to the rigorous nature of interreflected lighting calculations, Full Radiosity Method projects require a little additional run time over Direct Method projects of the same scale

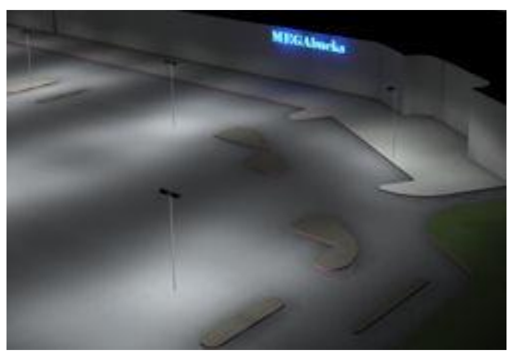


Fig 5.4: 3D Rendering image on AGI32

5.4: Social Impacts

Positive impacts include direct and indirect employment, and social (and economic) benefits to people who fly. The negative impacts of airports and aviation include land take, noise, air pollution, climate change, water use, and effects on the social structures of local communities.

- Combustion of aviation fuel – which is mostly composed of kerosene - produces nitrogen oxides (NOx), carbon monoxide (CO), sulphur oxides (SOx), hydrocarbons and particulates. It also releases the greenhouse gas carbon dioxide (CO2)
- As engines are working inefficiently on approach (as they only use about 30% of the available power) a certain amount of unburnt kerosene is released. These unburnt

fuel droplets are a source of volatile organic compounds (VOCs) and give rise to odors.

- As aircraft tires get worn and burnt during take-off and (especially) landing, they release particulate matter (PM).
- Fuel dumping by aircraft releases unburned aircraft fuel into the air. This is a rare occurrence and usually only takes place in emergencies. In these circumstances, aircraft are expected to dump fuel over water where possible, and at an altitude where they are likely to evaporate before reaching the surface.
- Vehicles travelling to and from the airport, and ground service equipment (tugs for aircraft and baggage, fuel and catering lorries, buses and vans that transport passengers etc.) generate NOx, CO2, particulates and (indirectly) ozone through the burning of petrol and diesel fuel.
- Aircraft and airfield maintenance (painting, metal cleaning, de-icing etc.), and emergency and fire training use complex chemicals which can release VOCs.
- Noise from aircraft and from traffic going to and from airports is probably the most obvious environmental impact of the aviation industry because it is easily perceived and annoying, especially where this occurs frequently. Aircraft noise is generated by both the engine and the airframe and is mostly evident during landing and take-off and under frequently-used flight paths. The effects of the noise pollution include: Loss of concentration, sleep disturbance, anger, frustration and powerlessness to control the noise, fear of accidents and of potential increase in frequency of noise cardiovascular effects, mental health etc,.
- Loss of residential structures, common property resources, public utility structures.

5.5: Lighting Design of Land side areas

Airports are large, complex and generally highly profitable industrial enterprises.They are part of a nation's essential transportation infrastructure, which, besides providing thousands of jobs at the airport itself, supports a much broader audience in social and economic terms.It’s a destination for millions of people which embark a journey for business or pleasure.

5.5.1: Car parking area indoor basement area

Description:

Airport parking facilities for long and short term passengers include parking garages, large lots, and connecting service roads. These areas need special consideration near an airport to reduce glare, and light leakage into other areas. These light containment issues are best handled early in the design phase using well designed fixtures and photometric data for modeling and simulation.

Indoor car parking LED lighting is responsible for over 60% of energy consumption. It's therefore obvious that a large savings can be obtained. Replacing Fluorescent lamps and luminaires with water and dust-resistant LED luminaires can save 60% to 90% on energy costs.

Our goal is to provide a safe, secure, cost-effective and sustainable solution for our parking garage.

Design Requirements:

- For indoor, Average illuminance for car parking basement required: 30 Lux;
- Overall Uniformity: 0.25;

Luminaire used:

- Industrial box type LED Batten
- Luminous flux (Luminaire): 4281 lm
- Luminous flux (Lamps): 4284 lm
- Luminaire Wattage: 40 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 50%, 30% and 10% respectively.
- Room height: 3.2m
- Luminaire Mounting height: 3.2m
- Working Plane: Ground level
- Boundary zone:0m

Design Simulation view of Car parking basement area:

DIALux simulated view of the car parking area has been shown below in fig 5.5. It is based on positioning the calculation grid at the ground level.

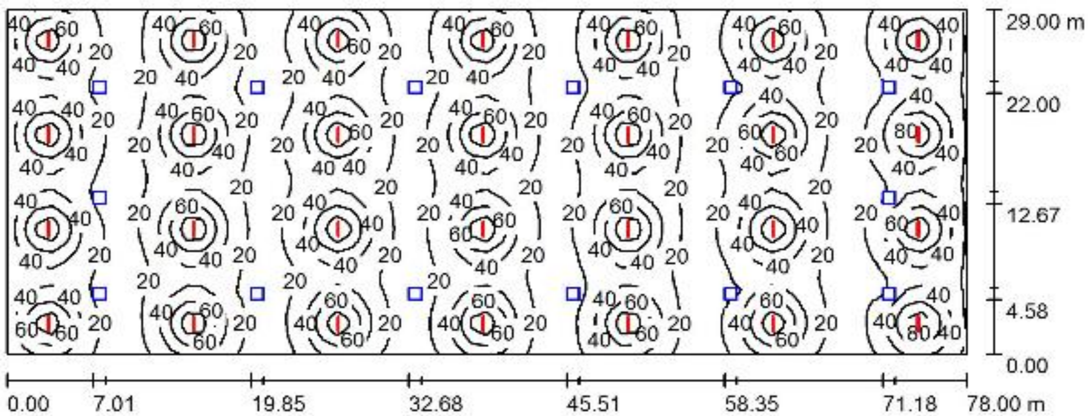


Fig 5.5: DIALux Simulation view of Car parking indoor basement area

Result overview:

Height of Room: 3.200 m, Mounting Height: 3.200 m, Light loss factor: 0.80 — Values in Lux, Scale 1:558

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	36	9.81	102	0.276
Floor	10	35	3.20	102	0.091
Ceiling	50	9.64	2.46	1398	0.255
Walls (4)	30	27	7.75	77	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m

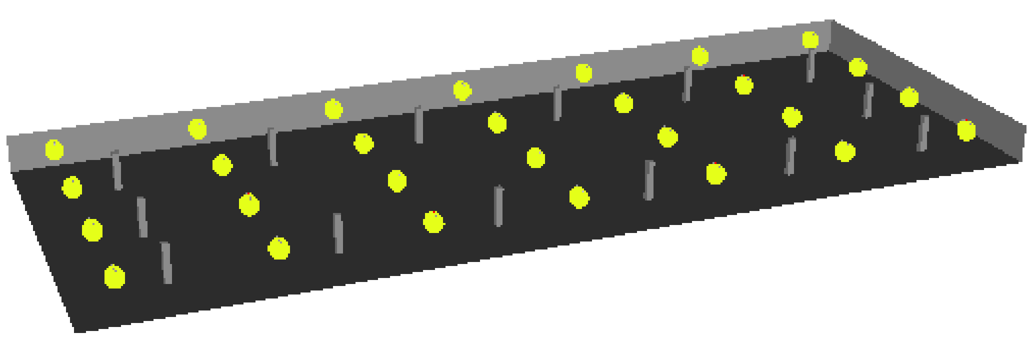
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.796, Ceiling / Working Plane: 0.227.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	28	Crompton Greaves Ltd. 01 IGP132LT8-20 (1.000)	4281	4284	40.0
			Total: 119865	Total: 119944	1121.1

Hence, from the results shown above, uniform illumination has been achieved which meets the recommended average illuminance criteria over 30 Lux with overall recommended uniformity over 0.25 respectively.

3D View of Car Parking Basement indoor area:



5.5.2: Street lighting

Description:

The complexities of transportation infrastructure mean varying types of illumination are needed to ensure traffic flows smoothly, people feel safe, and cities save on costs. Smart LED street lighting is a cost-effective and sustainable choice for cities today – and into the future. Effective LED street lighting systems are smart and versatile, so we can manage, maintain, and monitor the entire system simply and efficiently. Accurate, transparent lighting data for flexible, efficient workflow management reduce energy use by up to 50% with connected lighting.

Design Requirements:

- Average Illuminance level: 25 Lux;
- Overall Uniformity: 0.4;
- Longitudinal uniformity: 0.33;

Luminaires used:

- Hawk I series LED street light
- Luminous flux (Luminaire): 16286 lm
- Luminous flux(Lamps): 16324 lm
- Luminaire Wattage: 150 W

Design Consideration:

- LLF: 0.8;
- Road width: 11m each
- Median width: 2m
- Luminaire mounting height: 11m from the ground level
- Luminaire arrangement: Central Verge
- Bracket arm length: 1.5m
- Boom angle: 15 degrees
- Distance between the poles: 33m

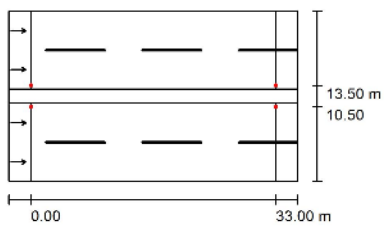
DIALux simulated view of the street lighting has been shown below in Fig 5.6. Road width of 11m on each side and median of 2m is taken into consideration in this simulation. Roadway 1 and Roadway 2 are the two roads on the either side of the median, shown below in the planning data Fig 5.6.

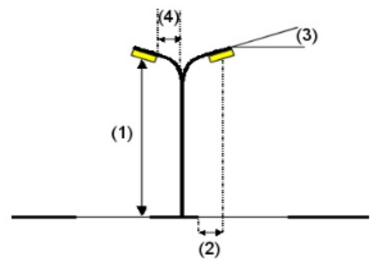
DIALux Simulation:

Roadway 2	(Width: 11.000 m, Number of lanes: 2, tarmac: R3, q0: 0.070)
Median 1	(Width: 2.000 m, Height: 0.000 m)
Roadway 1	(Width: 11.000 m, Number of lanes: 2, tarmac: R3, q0: 0.070)

Light loss factor: 0.80

Luminaire Arrangements





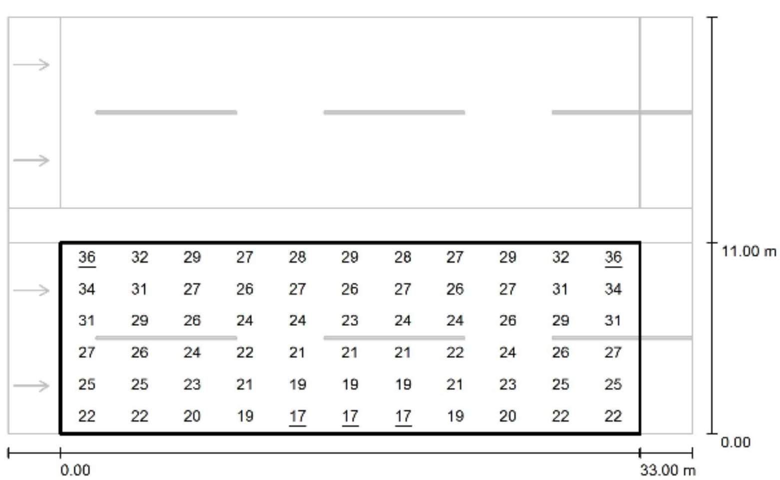
Luminaire:	Crompton Greaves Ltd. 01 LSTN1-150-CDL-A		
Luminous flux (Luminaire):	16286 lm	Maximum luminous intensities	
Luminous flux (Lamps):	16324 lm	at 70°:	211 cd/klm
Luminaire Wattage:	147.7 W	at 80°:	21 cd/klm
Arrangement:	on Median	at 90°:	6.53 cd/klm
Pole Distance:	33.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	11.097 m	Arrangement complies with luminous intensity class G3.	
Height:	11.000 m	Arrangement complies with glare index class D.4.	
Overhang (2):	0.526 m		
Boom Angle (3):	15.0 °		
Boom Length (4):	1.500 m		

Fig 5.6: Planning data of Street lighting simulation

Result Overview:

Value Chart for Roadway 1 & Roadway 2:

Street 1 / Valuation Field Roadway 1 / Value Chart (E)



36	32	29	27	28	29	28	27	29	32	36
34	31	27	26	27	26	27	26	27	31	34
31	29	26	24	24	23	24	24	26	29	31
27	26	24	22	21	21	21	22	24	26	27
25	25	23	21	19	19	19	21	23	25	25
22	22	20	19	17	17	17	19	20	22	22

Values in Lux, Scale 1 : 279

Grid: 11 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
25	17	36	0.658	0.461

22	22	20	19	17	17	17	19	20	22	22
25	25	23	21	19	19	19	21	23	25	25
27	26	24	22	21	21	21	22	24	26	27
31	29	26	24	24	23	24	24	26	29	31
34	31	27	26	27	26	27	26	27	31	34
36	32	29	27	28	29	28	27	29	32	36

24.00 m

13.00

0.00

33.00 m

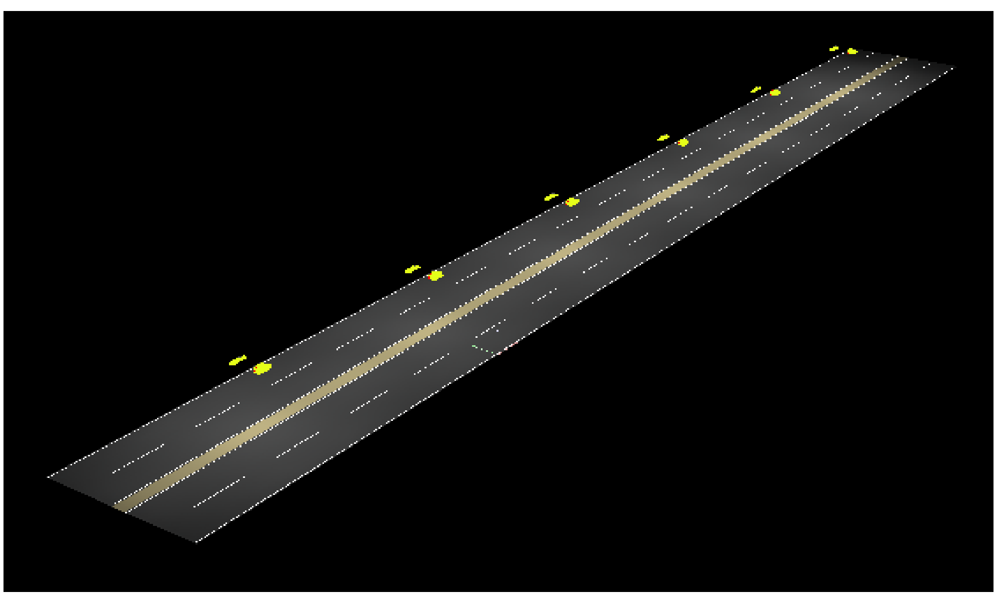
Values in Lux, Scale 1 : 279

Grid: 11 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
25	17	36	0.658	0.461

Hence, it can be concluded from the results that a proper recommended illumination can be achieved with recommended overall uniformity above 0.4 and longitudinal uniformity above 0.33 respectively on both sides of the road.

3D View of the Street:



5.6: Lighting design for Terminal side area

5.6.1: Arrival Hall

Description:

Arrival hall can be the busiest parts of the airport. Passengers need to orientate themselves in unfamiliar, and often chaotic, surroundings. Good lighting can guide them effortlessly to their destination and therefore the departure environment should be comfortable and calm, easing the burden of waiting, especially in the case of delays.

Design Requirements:

- Average illuminance required: 200 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Clear Frosted LED Downlighter
- Luminous flux (Luminaire): 7017 lm
- Luminous flux (Lamps): 7243 lm
- Luminaire Wattage: 70 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 13m
- Luminaire Mounting height: 13m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the arrival hall has been shown below in Fig 5.7. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown.

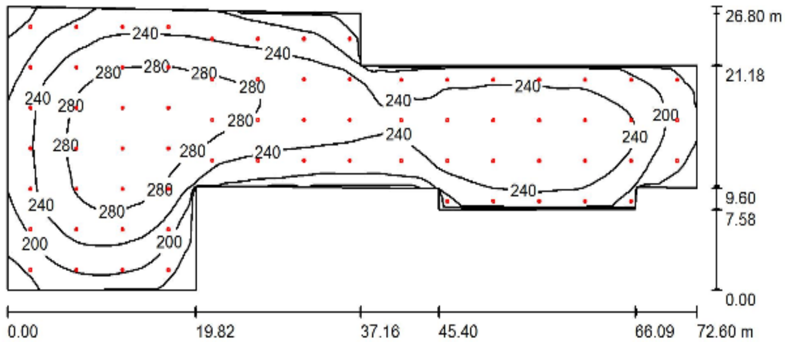


Fig 5.7: DIALux Simulation view of arrival hall

Result overview:

Height of Room: 13.000 m, Mounting Height: 13.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:520

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	238	124	310	0.519
Floor	20	233	126	304	0.539
Ceiling	70	51	32	173	0.625
Walls (12)	50	108	43	2131	/

Workplane:
Height: 0.760 m
Grid: 64 x 128 Points
Boundary Zone: 0.000 m

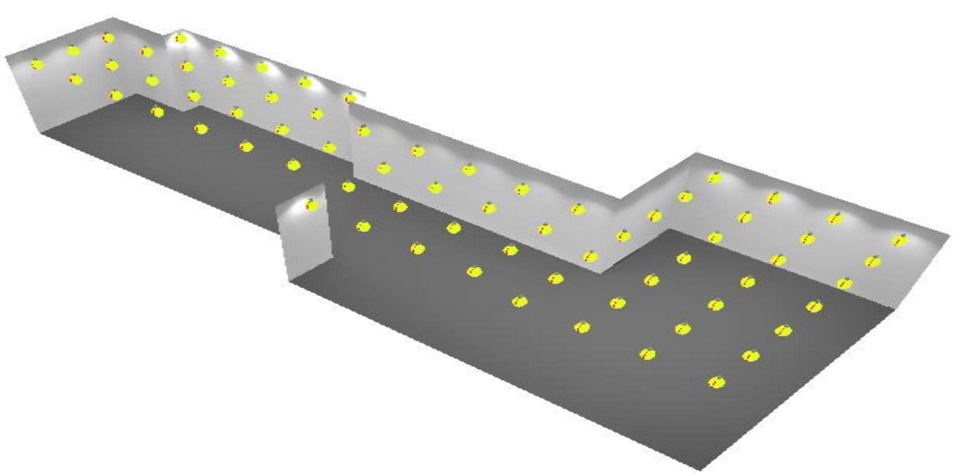
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.451, Ceiling / Working Plane: 0.215.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	70	Crompton Greaves Ltd. 01 LCDR-70-CDL/C (1.000)	7017	7243	71.2
			Total: 491162	Total: 507003	4986.1

Hence, from the results shown above, uniform illumination has been achieved which meets the recommended average illuminance criteria over 200 Lux with overall recommended uniformity over 0.5 respectively.

3D View of Arrival Hall:



5.6.2: Retail Area:

Description:

Customized lighting designs attract travelers and keep them engaged while they are in the terminal. Targeted, engaging experiences stimulate shoppers, highlight key locations throughout the area, guide visitors, and encourage exploration.

Design Requirements:

- Average illuminance required: 500 Lux
- Overall Uniformity: 0.5

Luminaire used:

- Sonic LED 2' x 2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 5m
- Luminaire Mounting height: 5m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the retail area has been shown below in Fig 5.8. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting is height 5m. The position of all the objects like chairs and tables are taken into consideration and then proper and uniform illumination is achieved.

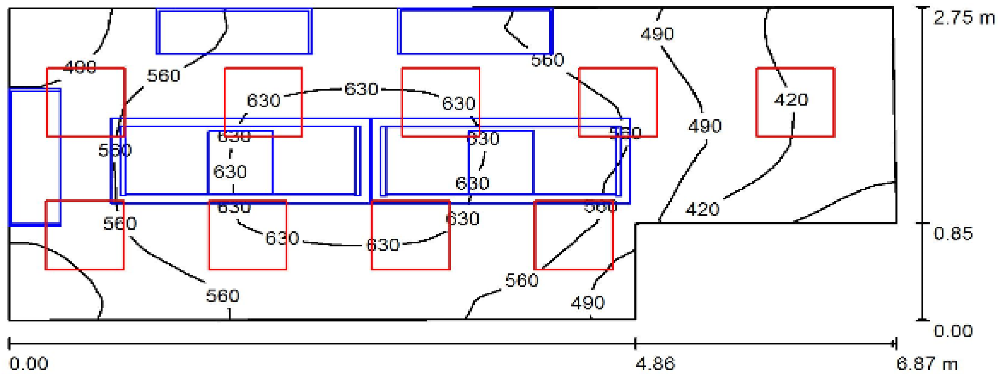


Fig 5.8: DIALux Simulation view of retail area

Result overview:

Height of Room: 5.000 m, Mounting Height: 5.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:50

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	543	316	658	0.582
Floor	20	277	43	461	0.156
Ceiling	70	299	206	452	0.688
Walls (6)	50	464	29	1839	/

Workplane:

Height:	0.760 m
Grid:	128 x 128 Points
Boundary Zone:	0.000 m

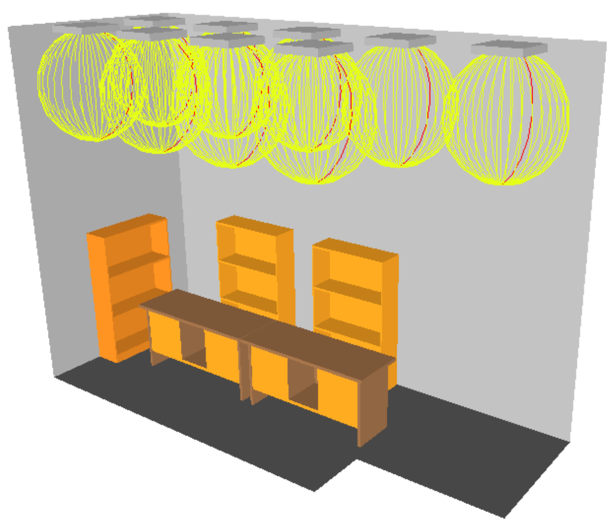
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.956, Ceiling / Working Plane: 0.550.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 37920	Total: 37921	284.8

Thus, it can be concluded form the given result that an uniform illumination has been covered throughout the entire area of recommended average illuminance over 500 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Retail area:



5.6.3: Check-in Information & Desks

Description:

The better the light quality, the easier it is for staff to interact with passengers and check their passports and documentation. It makes the experience less taxing and more time efficient. So the waiting line goes more smoothly and everyone stays calm and collected.

Design Requirements:

- Average illuminance required: 400 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- 70 W Clear Downlighter
- Luminous flux (Luminaire): 7017 lm
- Luminous flux (Lamps): 7243 lm
- Luminaire Wattage: 70 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 6.5m
- Luminaire Mounting height: 6.5m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the retail area has been shown below in Fig 5.9. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting is height 6.5m. The result overview as shown below is obtained by taking all the obstructions into design simulation.

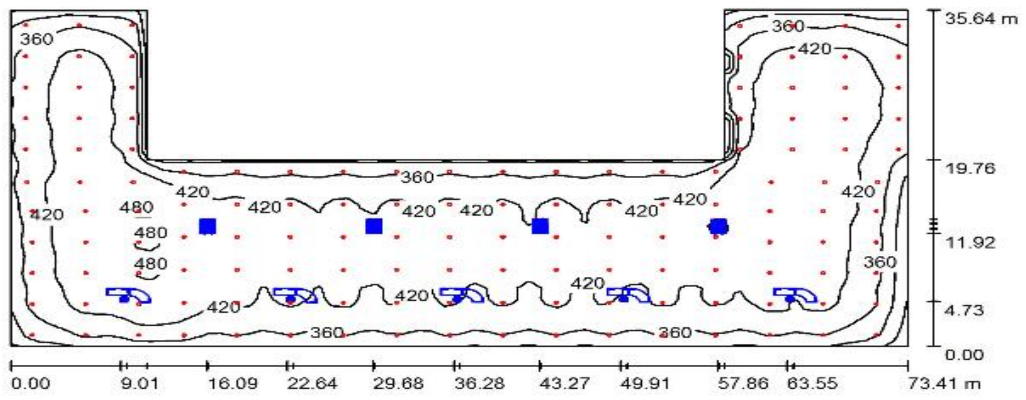


Fig 5.9: DIALux Simulation view of Check-in information and desks

Result overview:

Height of Room: 6.500 m, Mounting Height: 6.500 m, Light loss factor: 0.80 — Values in Lux, Scale 1:525

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	407	221	492	0.542
Floor	20	391	95	483	0.242
Ceiling	70	80	59	213	0.736
Walls (8)	50	165	59	875	/

Workplane:
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m

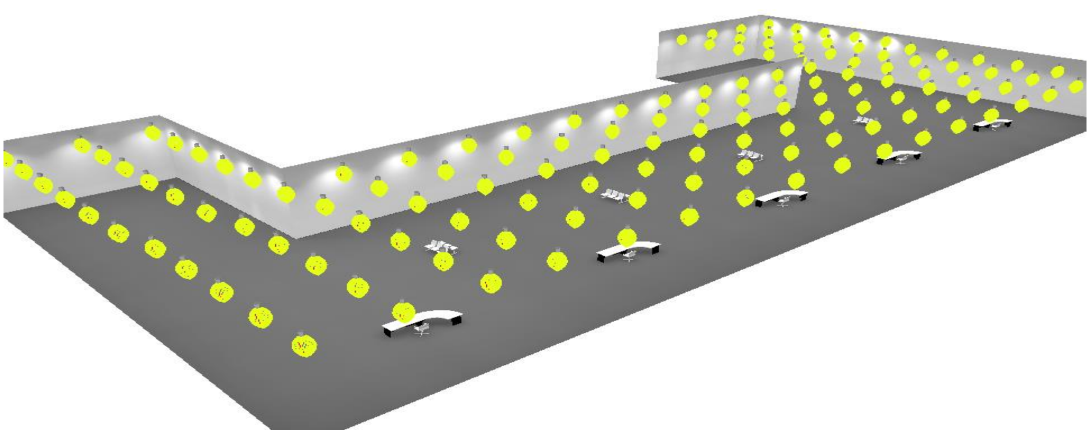
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.416, Ceiling / Working Plane: 0.199.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	137	Crompton Greaves Ltd. 01 LCDR-70-CDL/C (1.000)	7017	7243	71.2
			Total: 961273	Total: 992277	9758.5

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 400 Lux and recommended overall uniformity above 0.5 respectively.

3D view of Check-in information and desks:



5.6.4: Fine Lounge

Description:

Airport lounges offer a variety of services to passenger where they can be seen as a hybrid of hospitality and airport building typologies. Better and good quality LED lighting systems develop a gorgeous environment for people.

Design Requirements:

- Average illuminance required: 300 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2'X2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 5m
- Luminaire Mounting height: 5m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the retail area has been shown below in Fig 5.10. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting is height 5m. The result overview as shown below is obtained by taking all the obstructions into design simulation.

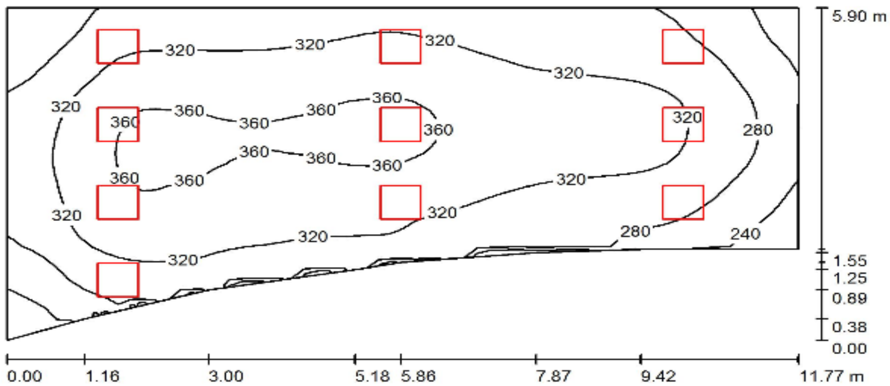


Fig 5.10: DIALux Simulation view of fine lounge

Result overview:

Height of Room: 5.000 m, Mounting Height: 5.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:85

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	316	212	370	0.671
Floor	20	279	199	323	0.715
Ceiling	70	114	79	282	0.696
Walls (11)	50	231	112	1416	/

Workplane:
Height: 0.760 m
Grid: 64 x 32 Points
Boundary Zone: 0.000 m

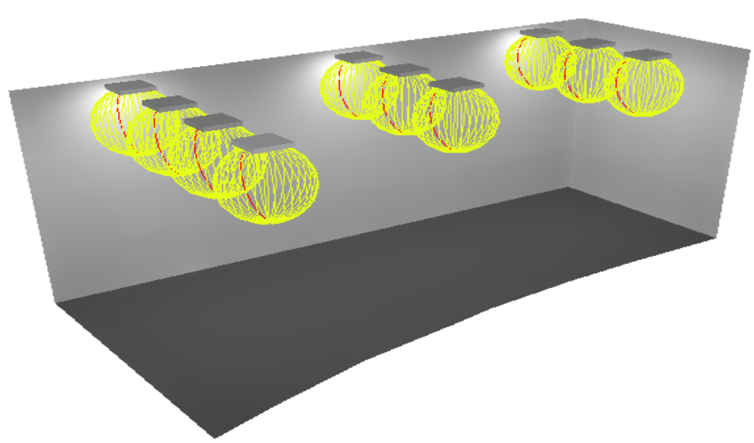
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.780, Ceiling / Working Plane: 0.360.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	10	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 42133	Total: 42134	316.4

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 300 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Fine Lounge:



5.6.5: Luggage Handling

Description:

A natural lighting solution that mimics daylight will enhance comfort and well-being for the staff that have to carry out their work in confined spaces. It also aids concentration, improves communication.

Design Requirements:

- Average illuminance required: 500 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2'X2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 5m
- Luminaire Mounting height: 5m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the retail area has been shown below in Fig 5.11. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting is height 5m.

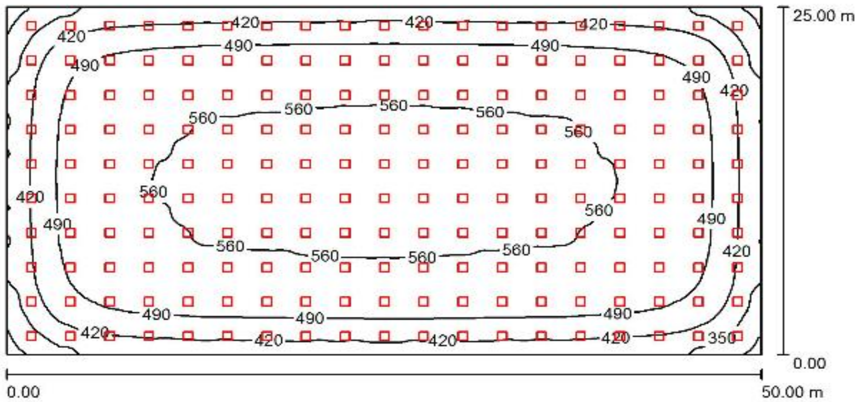


Fig 5.11: DIALux Simulation view of luggage handling area

Result overview:

Height of Room: 5.000 m, Mounting Height: 5.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:358

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	501	262	575	0.522
Floor	20	487	267	572	0.549
Ceiling	70	117	99	179	0.848
Walls (4)	50	292	169	400	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m

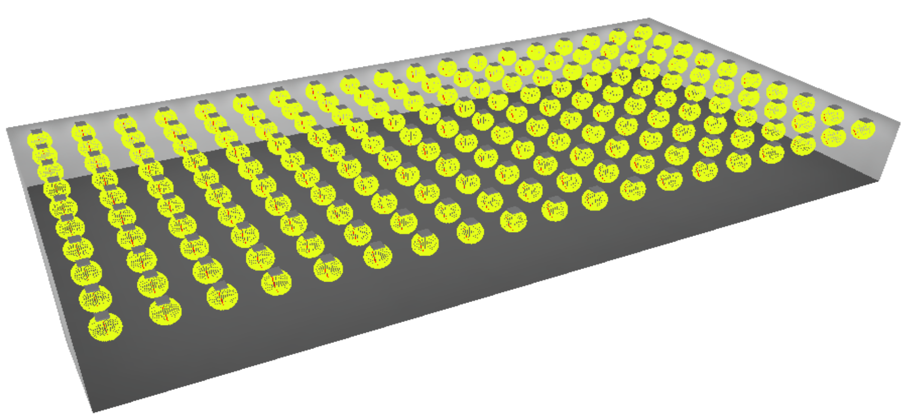
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.592, Ceiling / Working Plane: 0.233.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	190	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 800535	Total: 800546	6011.6

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 500 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Luggage Handling:



5.6.6: Passport control office

Description:

Visitors expect their documents to be checked quickly and efficiently with the minimum of hassle. At the same time, custom staff must appear authoritative and professional. The right lighting can aid their concentration and improve facial recognition.

Design Requirements:

- Average illuminance required: 400 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2'X2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 3m
- Luminaire Mounting height: 3m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the retail area has been shown below in Fig 5.12. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting is height 5m. The result overview as shown below is obtained by taking all the obstructions into design simulation.

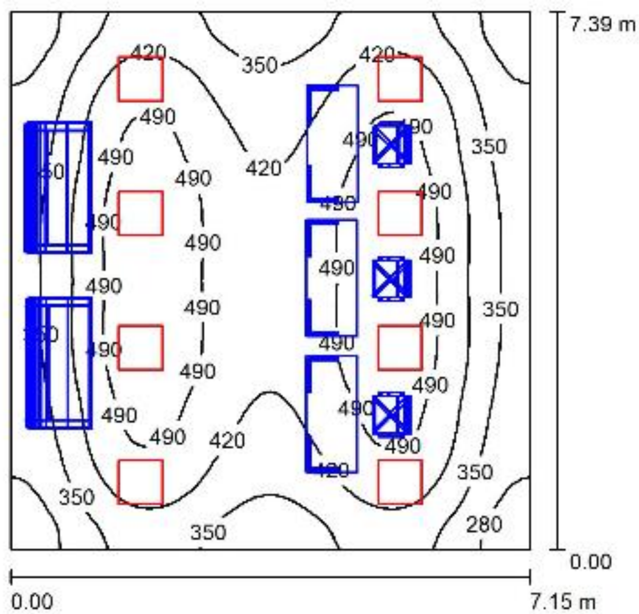


Fig 5.12: DIALux Simulation view of Passport control office

Result overview:

Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:95

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	417	237	540	0.569
Floor	20	296	43	441	0.144
Ceiling	70	114	82	178	0.722
Walls (4)	50	231	55	527	/

Workplane:

Height:	0.760 m
Grid:	64 x 64 Points
Boundary Zone:	0.000 m

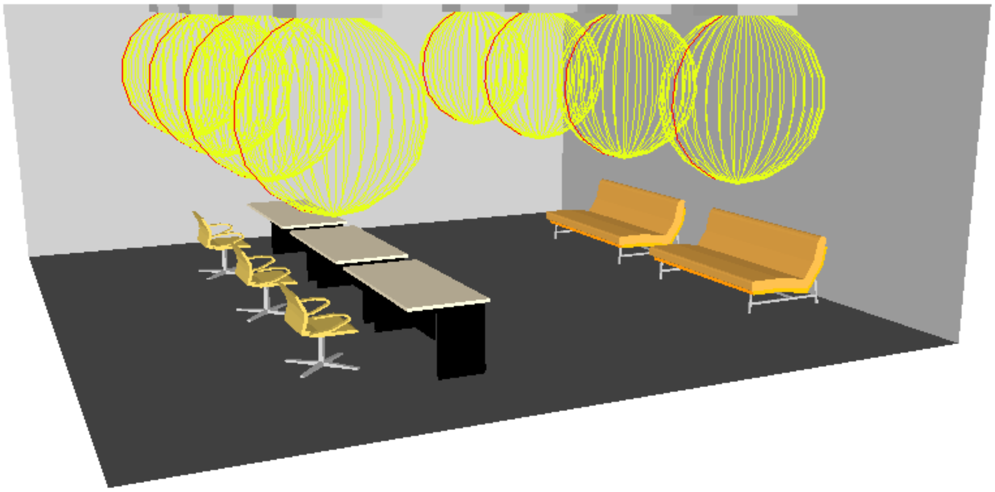
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.593, Ceiling / Working Plane: 0.273.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 33707	Total: 33707	253.1

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 400 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Passport Control Office:



5.6.7: Connection areas and Travelators

Description:

For an airport, which is often open 24 hours a day, connection areas and travelators are the arteries of the airport. They link the different areas together logistically.

Design Requirements:

- Average illuminance required for the passageway areas is 150 Lux whereas the required value of illuminance for Travelators is 200 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

70 W Clear Downlighter:

- Luminous flux (Luminaire): 7017 lm
- Luminous flux (Lamps): 7243 lm
- Luminaire Wattage: 70 W

Round LED Downlighter:

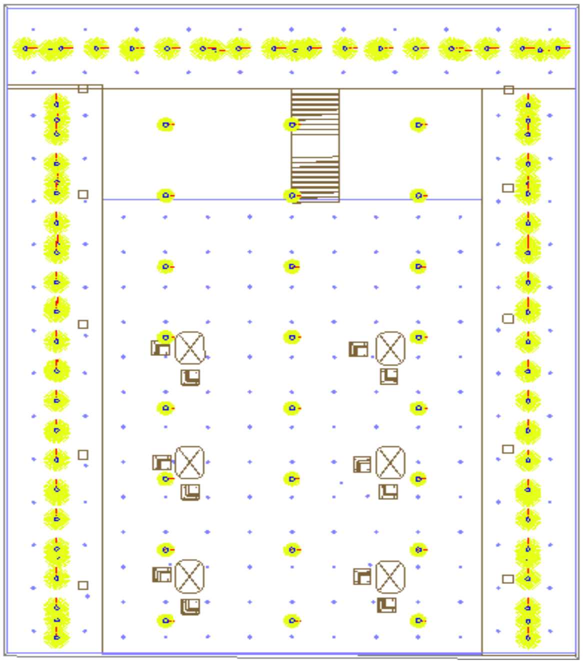
- Luminous flux (Luminaire): 1994 lm
- Luminous flux (Lamps): 1989 lm
- Luminaire Wattage: 18 W

Design Consideration:

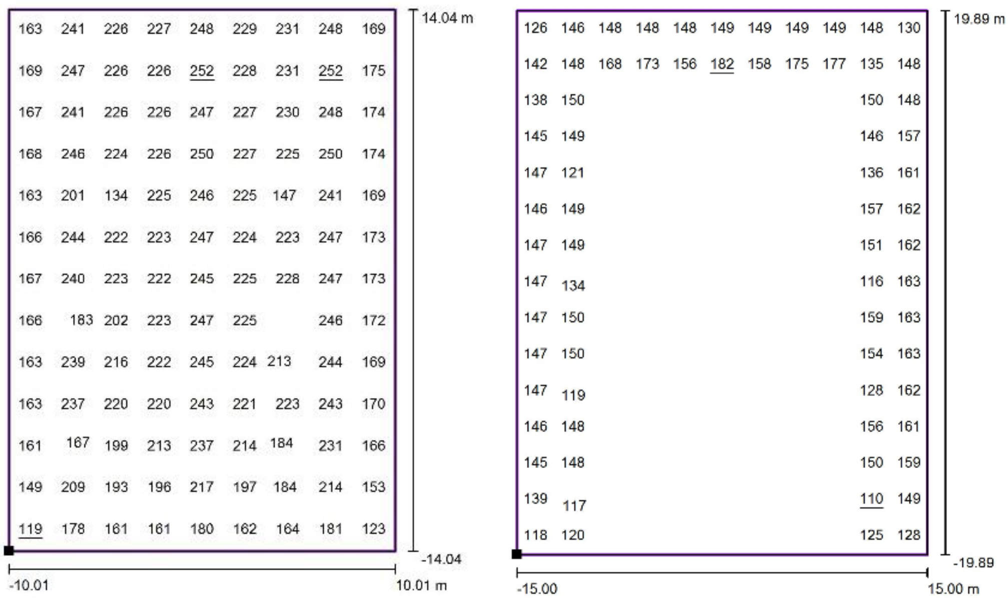
- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 6.5m
- Boundary zone: 0m

Design Simulation:

DIALux simulations are shown in Fig 5.13 (a) below consists of both the ground level and corridor areas of mezzanine floor. The Luminaire mounting height for the ground level which is hall is 6.5m, whereas the mounting height of the luminaire for the mezzanine floor is 3m which is linked by the staircase inclined as shown in the fig 5.13 (a). A field arrangement with 70W clear glass luminaire is done focusing the hall and the mezzanine floor along with the passage areas cover 18W downlighter as shown. The positioning of the calculation grids on both the hall and passageway have been shown in Fig 5.13 (b).



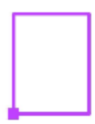
(a)



(b)

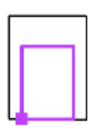
Fig 5.13 (a) & (b) DIALux Simulation view and calculation grid overview of the Connection areas and travelators

Result overview:



Grid: 74 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
147	110	182	0.75	0.60

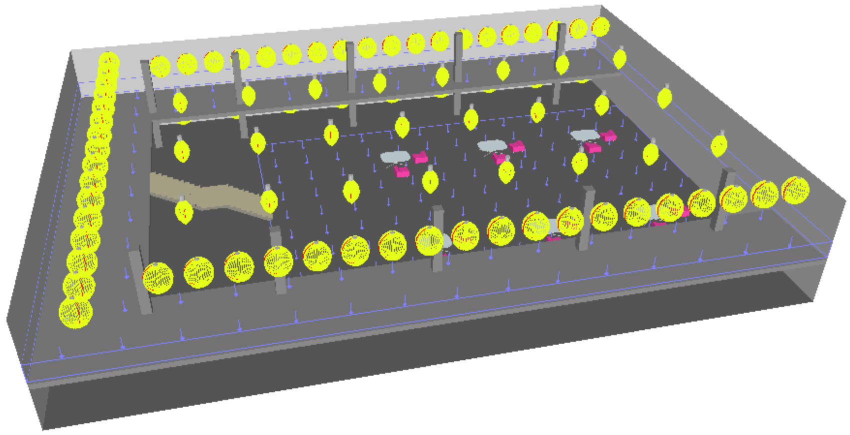


Grid: 117 Points

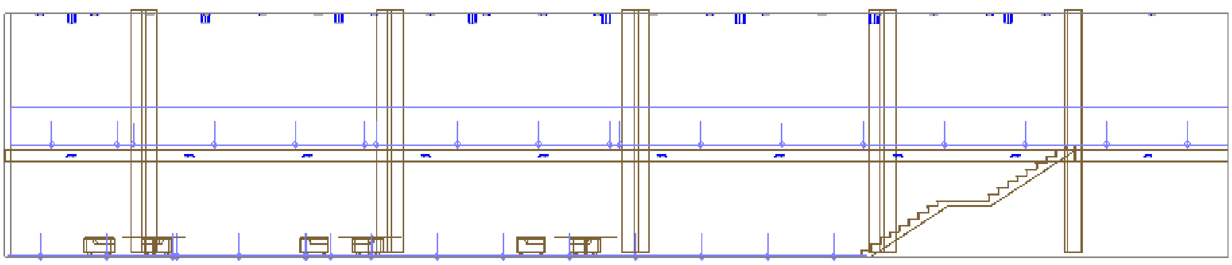
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
208	119	252	0.57	0.47

For ground level passageway areas, the illuminance value is 150 Lux maintained and for travelator area the illuminance value is 200 Lux as achieved. In the section elevation of the design is also shown from one side which depicts luminaire location and the location of chairs as well as tables from east side elevation.

3D View of Connection areas and travelators:



Section Elevation of Connection areas and travelators:



5.6.8: Departure Hall

Description:

Good lighting can guide people effortlessly to their destination and therefore the departure environment should be comfortable and calm, easing the burden of waiting, especially in the case of delays.

Design Requirements:

- Average illuminance required: 300 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- 70 W Clear Downlighter
- Luminous flux (Luminaire): 7017 lm
- Luminous flux (Lamps): 7243 lm
- Luminaire Wattage: 70 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height:
- Luminaire Mounting height:
- Working Plane:
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the departure hall has been shown below in Fig 5.14. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting height is 6.2m.

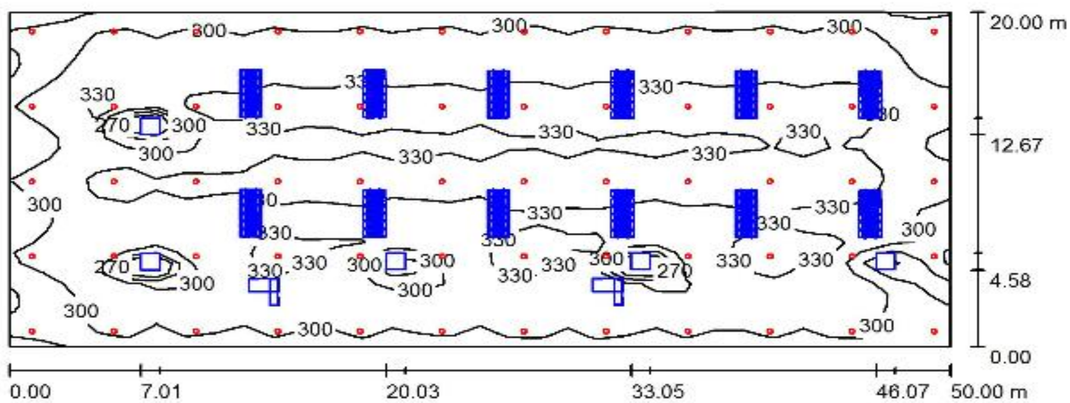


Fig 5.14: DIALux Simulation view of Departure Hall

Result overview:

Height of Room: 6.200 m, Mounting Height: 6.200 m, Light loss factor: 0.80 — Values in Lux, Scale 1:358

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	317	229	362	0.720
Floor	20	294	44	349	0.149
Ceiling	70	64	50	166	0.773
Walls (4)	50	149	52	683	/

Workplane:
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m

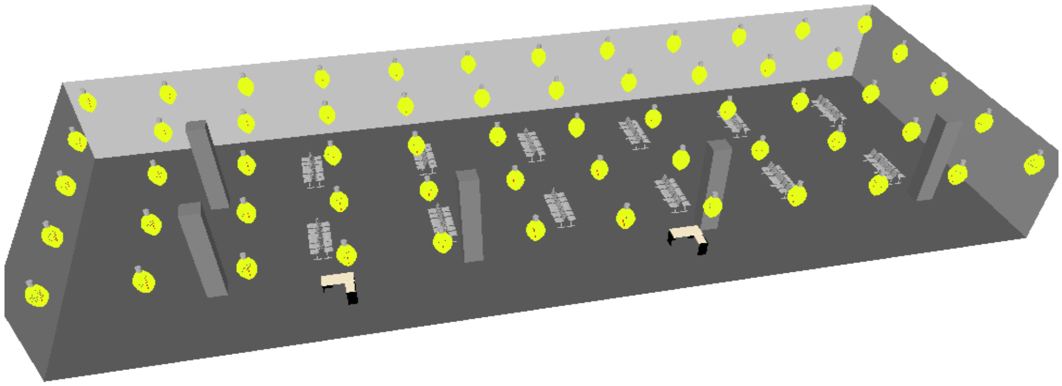
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.488, Ceiling / Working Plane: 0.203.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	60	Crompton Greaves Ltd. 01 LCDR-70-CDL/C (1.000)	7017	7243	71.2
			Total: 420996	Total: 434574	4273.8

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 300 Lux and recommended overall uniformity above 0.5 respectively.

3D View of the Departure Hall:



5.6.9: Baggage Claim area

Description:

A typical baggage claim area contains baggage carousels or conveyor systems that deliver checked baggage to the passenger. Waiting to be reunited with our baggage after a flight can be an anxious time for passengers. A natural lighting solution that mimics daylight will enhance guidance and comfort for the traveler to quickly find the right baggage carrousel and collect its baggage as fast as possible.

Design Requirements:

- Average illuminance required: 200 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2'X2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 5m
- Luminaire Mounting height: 5m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the baggage claim area has been shown below in Fig 5.15. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting height is 5m.

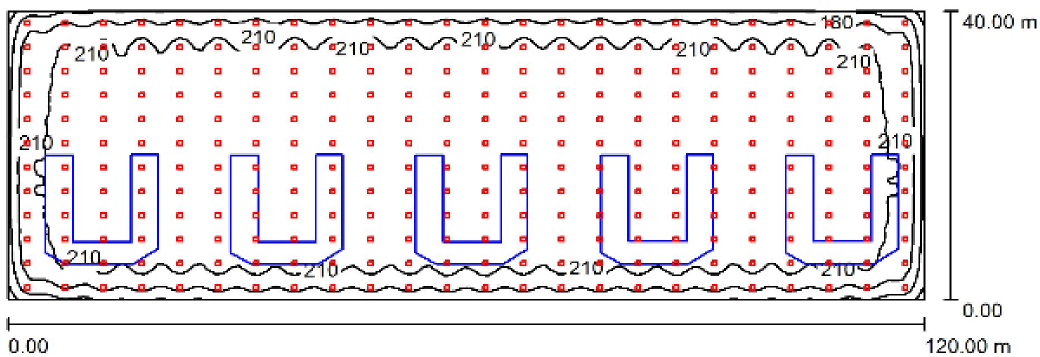


Fig 5.15: DIALux Simulation view of Baggage claim area

Result overview:

Height of Room: 5.000 m, Mounting Height: 5.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:858

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	214	111	241	0.520
Floor	20	179	12	233	0.068
Ceiling	70	50	41	111	0.807
Walls (4)	50	126	65	205	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

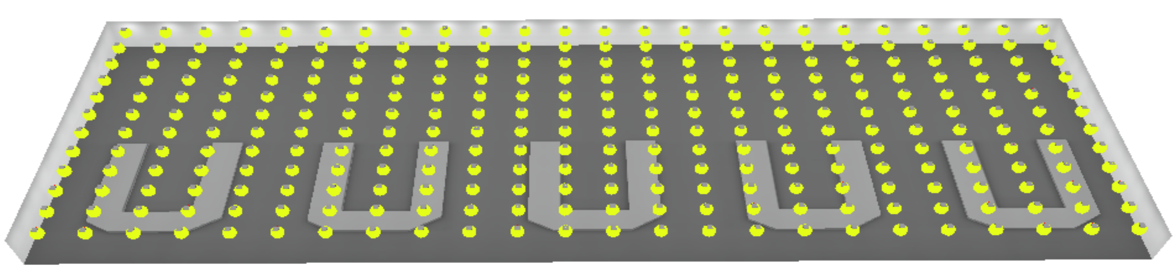
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.585, Ceiling / Working Plane: 0.235.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	288	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 1213442	Total: 1213459	9112.3

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 200 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Baggage claim area:



5.6.10: Security Check areas

Description:

Body checks and scans must be conducted in a dignified way that ensures passengers feel respected and the actions of staff are beyond question.

Design Requirements:

- Average illuminance required: 500 Lux
- Overall Uniformity: 0.5

Luminaire used:

- 70 W Clear Downlighter
- Luminous flux (Luminaire): 7017 lm
- Luminous flux (Lamps): 7243 lm
- Luminaire Wattage: 70 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 6.2m
- Luminaire Mounting height: 6.2m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the security check area has been shown below in Fig 5.16. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting height is 6.2m.

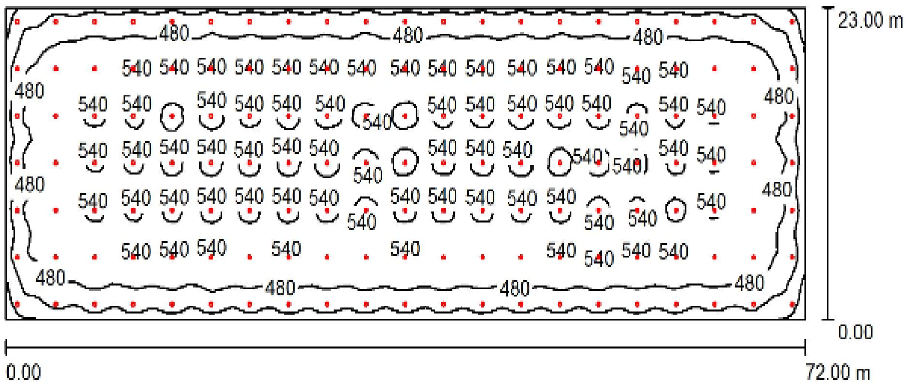


Fig 5.16: DIALux Simulation view of Security check area

Result overview:

Height of Room: 6.200 m, Mounting Height: 6.200 m, Light loss factor: 0.80

Values in Lux, Scale 1:515

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	503	309	564	0.614
Floor	20	495	295	556	0.595
Ceiling	70	101	86	252	0.846
Walls (4)	50	214	80	594	/

Workplane:

Height:	0.760 m
Grid:	128 x 128 Points
Boundary Zone:	0.000 m

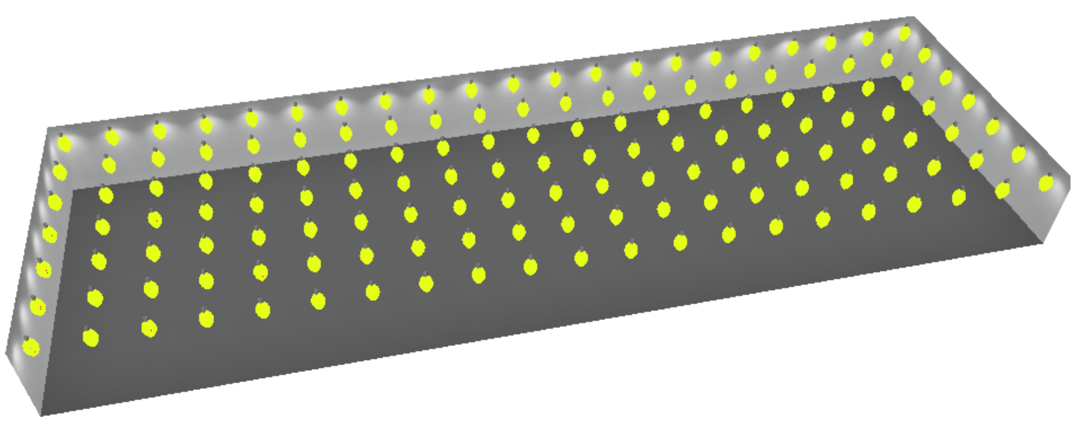
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.433, Ceiling / Working Plane: 0.201.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	147	Crompton Greaves Ltd. 01 LCDR-70-CDL/C (1.000)	7017	7243	71.2
			Total: 1031439	Total: 1064706	10470.8

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 500 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Security Check area:



5.6.11: Office

Description:

LED lighting supports sustainability goals and occupant well-being, while our connected lighting systems provide a firm base for the growing push towards smart buildings.

Design Requirements:

- Average illuminance required: 500 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2'X2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 2.7m
- Luminaire Mounting height: 2.7m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of a typical office area has been shown below in Fig 5.17. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting height is 2.7m.

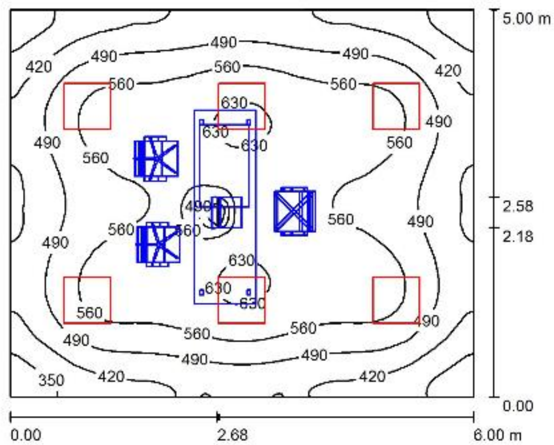


Fig 5.17: DIALux Simulation view of Office area

Result overview:

Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 — Values in Lux, Scale 1:65

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	514	307	643	0.598
Floor	20	373	93	486	0.249
Ceiling	70	138	98	192	0.710
Walls (4)	50	296	146	491	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

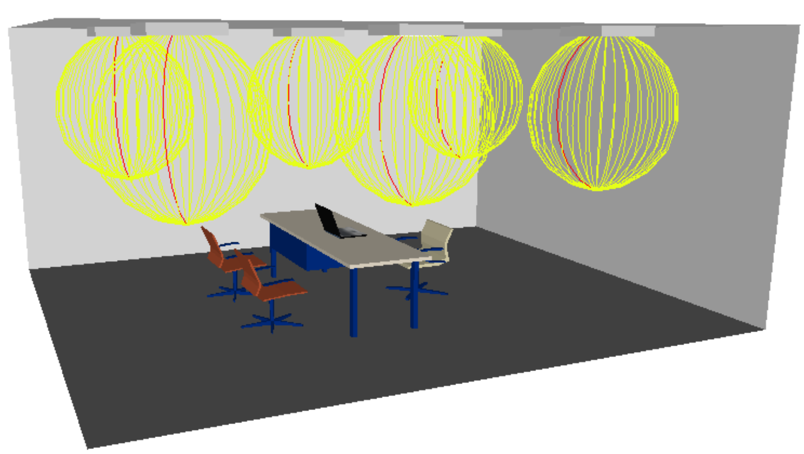
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.612, Ceiling / Working Plane: 0.268.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 25280	Total: 25280	189.8

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 500 Lux and recommended overall uniformity above 0.5 respectively.

3D View of the Office area:



5.6.12: Conference Room

Description:

Once single-use spaces, conference rooms are now often multi-use facilities that depend on the availability of sophisticated and dynamic resources — especially lighting.

Design Requirements:

- Average illuminance required: 500 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2'X2' Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 2.7m
- Luminaire Mounting height: 2.7m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of a conference office has been shown below in Fig 5.18. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting height is 2.7m.

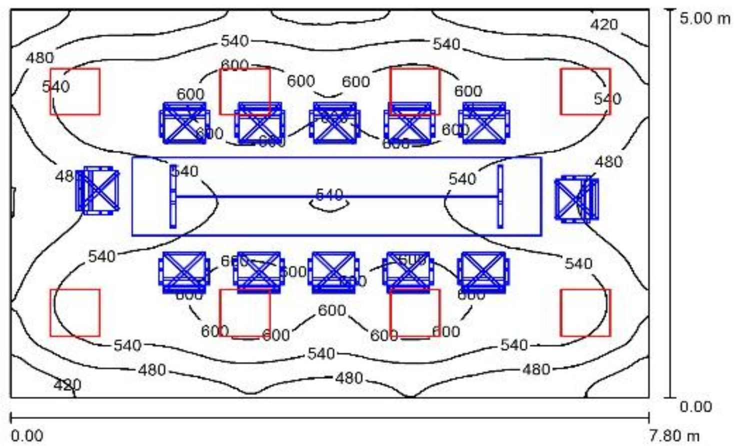


Fig 5.18: DIALux Simulation view of Conference room

Result overview:

Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 — Values in Lux, Scale 1:65

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	537	367	640	0.684
Floor	20	335	70	449	0.208
Ceiling	70	160	127	228	0.790
Walls (4)	50	332	185	723	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

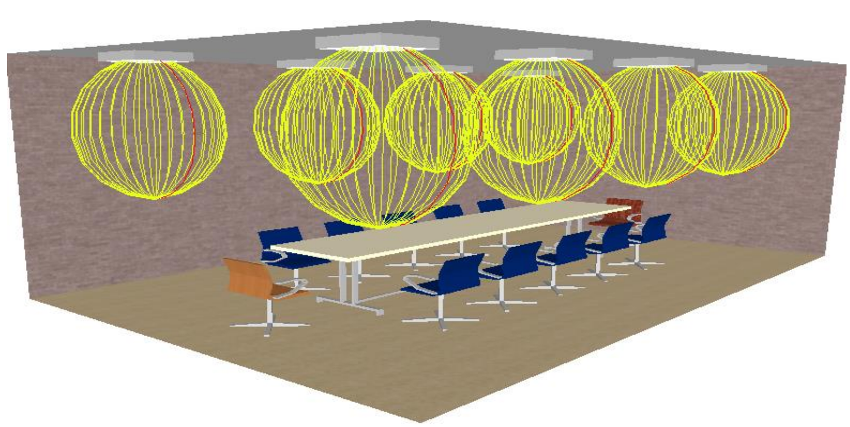
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.676, Ceiling / Working Plane: 0.298.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 33707	Total: 33707	253.1

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 500 Lux and recommended overall uniformity above 0.5 respectively.

3D view of the Conference room:



5.6.13: Cargo Storage area

Description:

Special procedures have been prescribed for handling of human remains, live animals and unaccompanied baggage for quick clearances.

Design Requirements:

- Average illuminance required: 300 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- LED Wellglass Luminaire
- Luminous flux (Luminaire): 3693 lm
- Luminous flux (Lamps): 3730 lm
- Luminaire Wattage: 35 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 3.5m
- Luminaire Mounting height: 3.5m
- Working Plane: 0.760m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of a Cargo storage area has been shown below in Fig 5.19. Horizontal calculation grid has been taken on 0.76m above the ground level, as shown. Luminaire mounting height is 3.5m.

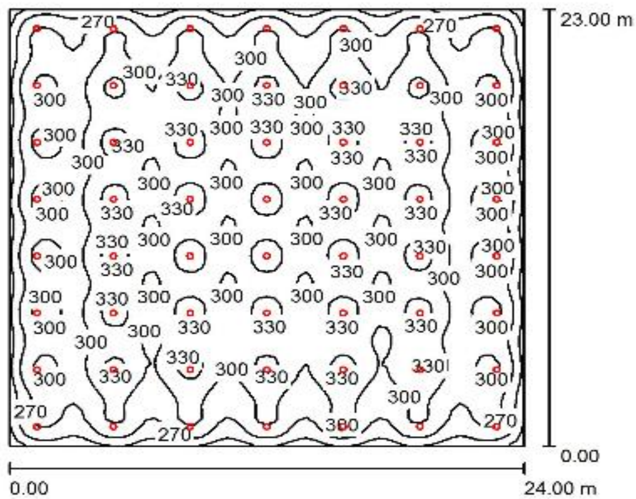


Fig 5.19: DIALux Simulation view of Cargo Storage area

Result overview:

Height of Room: 3.500 m, Mounting Height: 3.500 m, Light loss factor: 0.80 — Values in Lux, Scale 1:296

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	300	204	343	0.681
Floor	20	288	189	323	0.656
Ceiling	70	65	58	115	0.888
Walls (4)	50	165	61	384	/

Workplane:

Height:	0.760 m	**UGR**	Lengthways-	Across	to luminaire axis
Grid:	64 x 64 Points	Left Wall	23	23	
Boundary Zone:	0.000 m	Lower Wall	23	23	
		(CIE, SHR = 0.25.)			

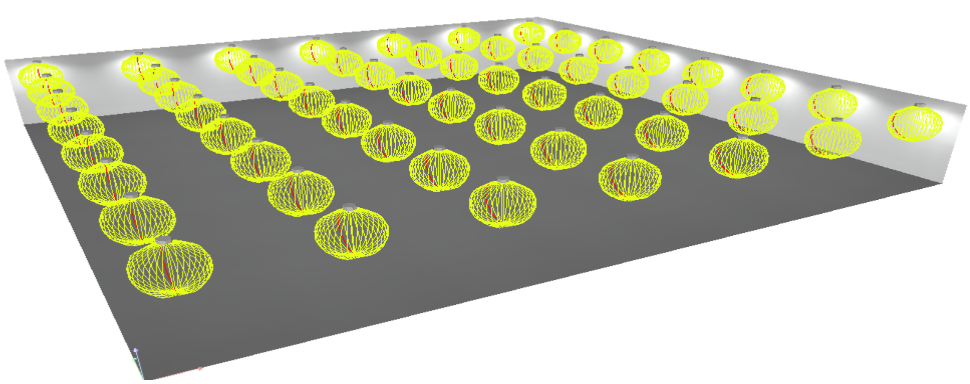
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.557, Ceiling / Working Plane: 0.217.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	56	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 206790	Total: 208852	1954.4

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 300 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Cargo Storage area:



5.6.14: Corridor

Design Requirements:

- Average illuminance required: 150 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Round LED Downlighter
- Luminous flux (Luminaire): 1994 lm
- Luminous flux (Lamps): 1989 lm
- Luminaire Wattage: 18 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 3m
- Luminaire Mounting height: 3m
- Working Plane: 0m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of corridor has been shown below in Fig 5.20. Horizontal calculation grid has been taken at the ground level, as shown. Luminaire mounting height is 3m.

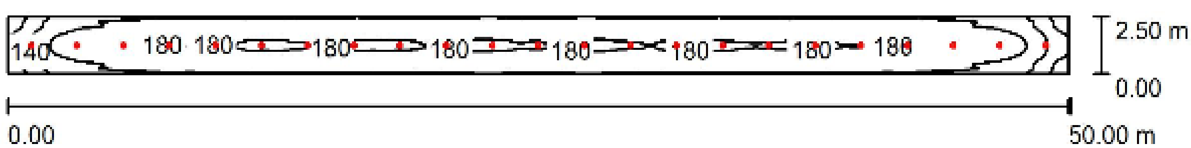


Fig 5.20: DIALux Simulation view of Corridor

Result overview:

Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:358

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	167	112	183	0.668
Floor	20	167	110	183	0.655
Ceiling	70	49	45	59	0.910
Walls (4)	50	114	47	183	/

Workplane:
Height: 0.000 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m

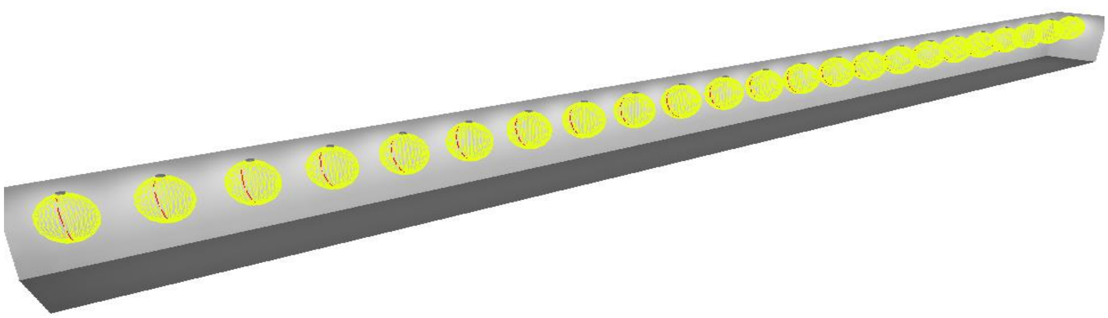
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.692, Ceiling / Working Plane: 0.294.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	23	Crompton Greaves Ltd. 01 LCDE-18-CDL (1.000)	1994	1989	18.2
			Total: 45870	Total: 45740	418.8

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 150 Lux and recommended overall uniformity above 0.5 respectively.

3D View of the Corridor:



5.6.15: Leisure Area

Description:

Customized lighting designs that attract travelers and keep them engaged while they are in the terminal. Targeted, engaging experiences stimulate shoppers, highlight key locations throughout the area.

Design Requirements:

- Average illuminance required: 150 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- **Round LED Downlighter**
- Luminous flux (Luminaire): 1994 lm

- ➢ Luminous flux (Lamps): 1989 lm
- ➢ Luminaire Wattage: 18 W

Design Consideration:

- ➢ LLF: 0.8;
- ➢ Room Surface Reflectance: 70%, 50% and 20% respectively.
- ➢ Room height: 3m
- ➢ Luminaire Mounting height: 3m
- ➢ Working Plane: 0.760m
- ➢ Boundary zone: 0m

Design Simulation:

DIALux simulated view of Leisure area has been shown below in Fig 5.21. Horizontal calculation grid has been taken at 0.76m above the ground level, as shown. Luminaire mounting height is 3m.

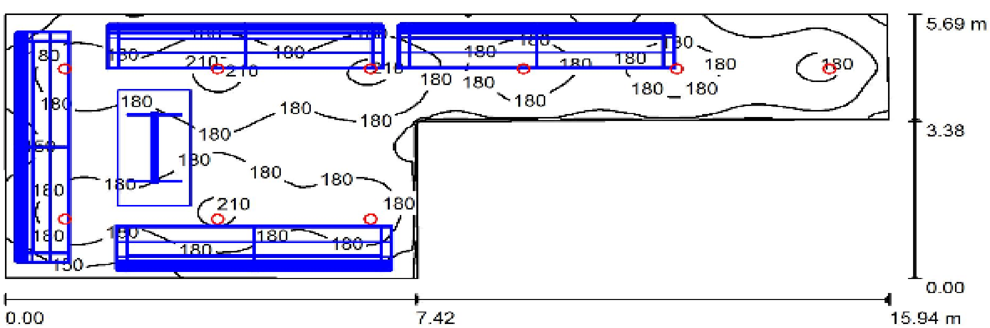


Fig 5.21: DIALux Simulation view of Leisure area

Result overview:

Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:114

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	173	108	218	0.622
Floor	20	88	8.84	174	0.100
Ceiling	70	50	38	65	0.759
Walls (6)	50	101	23	270	/

Workplane:
- Height: 0.760 m
- Grid: 128 x 64 Points
- Boundary Zone: 0.000 m

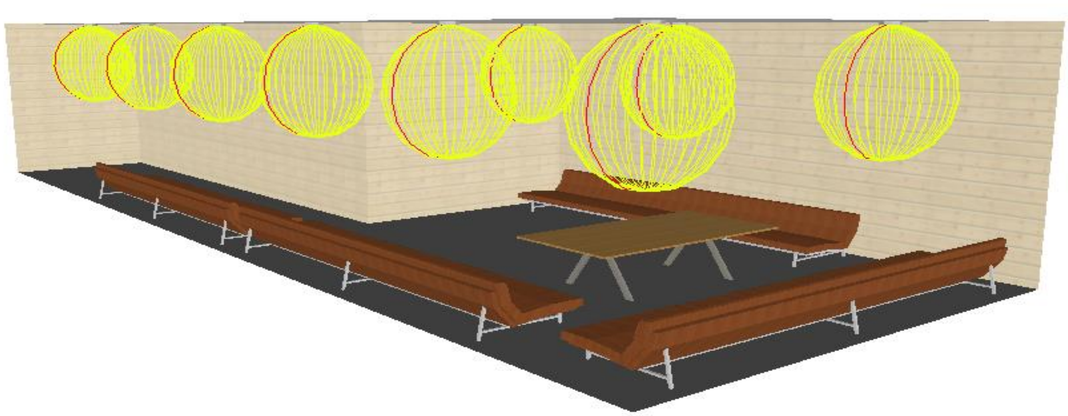
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.650, Ceiling / Working Plane: 0.288.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. 01 LCDE-18-CDL (1.000)	1994	1989	18.2
			Total: 17949	Total: 17898	163.9

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 150 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Leisure area:



5.6.16: Fire Control Room

Description:

The principal objective of an airport fire and rescue service is "to save lives in the event of an aircraft accident or incident". This also applies to any other incident where life and property can be saved.

Design Requirements:

- Average illuminance required: 300 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

- Sonic LED 2’X2’ Tile
- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively
- Room height: 3m
- Luminaire Mounting height: 3m

➢ Working Plane: 0.760m
➢ Boundary zone: 0m

Design Simulation:

DIALux simulated view of fire control room has been shown below in Fig 5.22. Horizontal calculation grid has been taken at 0.76m above the ground level, as shown. Luminaire mounting height is 3m.

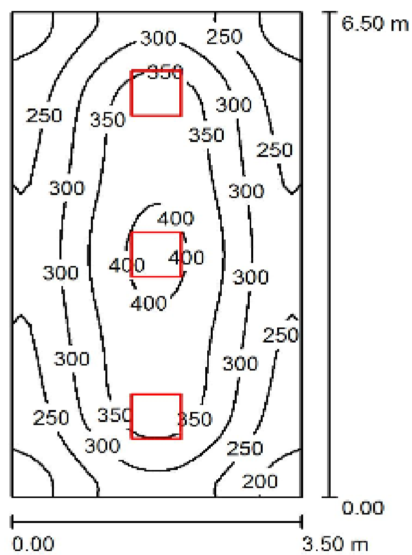


Fig 5.22: DIALux Simulation view of Fire control room

Result overview:

Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:84

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	301	177	416	0.586
Floor	20	245	158	309	0.645
Ceiling	70	79	55	140	0.699
Walls (4)	50	171	72	365	/

Workplane:		UGR	Lengthways-	Across	to luminaire axis
Height:	0.760 m	Left Wall	17	17	
Grid:	32 x 64 Points	Lower Wall	18	18	
Boundary Zone:	0.000 m	(CIE, SHR = 0.25.)			

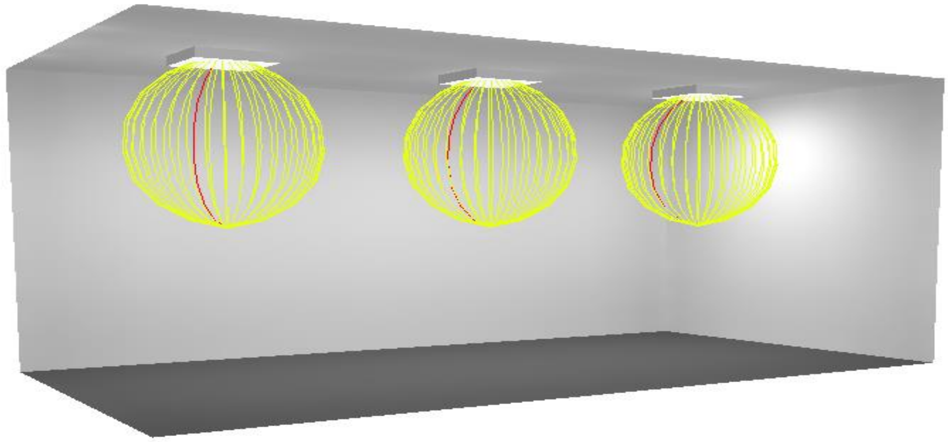
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.601, Ceiling / Working Plane: 0.263.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
			Total: 12640	Total: 12640	94.9

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 300 Lux and recommended overall uniformity above 0.5 respectively.

3D view of Fire control room:



5.6.17: Air Traffic Control room

Description:

Air traffic controllers are the heart of our airport and essential for its safe operation. To keep airplanes flying safely and on time, it is very much needed to guide pilots with precision accuracy, 24 hours a day.

Design Requirements:

- Average illuminance required: 500 Lux;
- Overall Uniformity: 0.5;

Luminaire used:

Round LED Downlighter

- Luminous flux (Luminaire): 1994 lm
- Luminous flux (Lamps): 1989 lm
- Luminaire Wattage: 18 W

Sonic LED 2'X2' Tile

- Luminous flux (Luminaire): 4213 lm
- Luminous flux (Lamps): 4213 lm
- Luminaire Wattage: 36 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 3m

- ➢ Luminaire Mounting height: 3m
- ➢ Working Plane: 0.760m
- ➢ Boundary zone: 0m

Design Simulation:

DIALux simulated view of the air traffic control room has been shown below in Fig 5.23. Horizontal calculation grid has been taken at 0.76m above the ground level, as shown. Luminaire mounting height is 3m. DIALux result is obtained considering all the obstructions in the lighting design as shown. The design simulation is carried out using combination of round downlighter along the edge of the room and 2'X2' tile is properly installed in the middle of the room as shown.

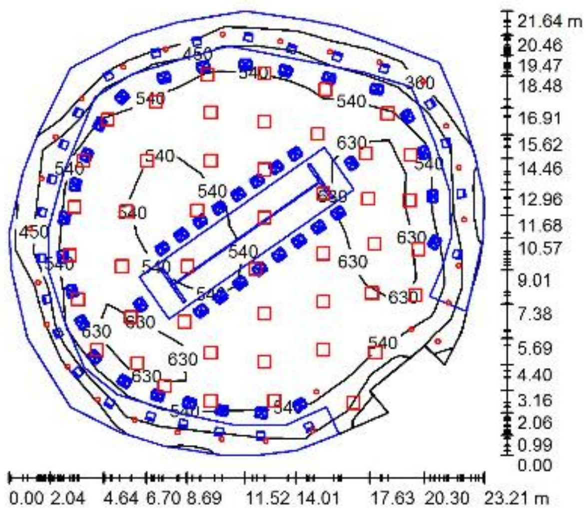


Fig 5.23: DIALux Simulation view of Air Traffic control room

Result overview:

Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:278

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	539	298	698	0.553
Floor	20	354	9.90	642	0.028
Ceiling	70	168	110	292	0.652
Walls (31)	50	280	52	619	/

Workplane:
Height: 0.760 m
Grid: 13 x 13 Points
Boundary Zone: 0.000 m

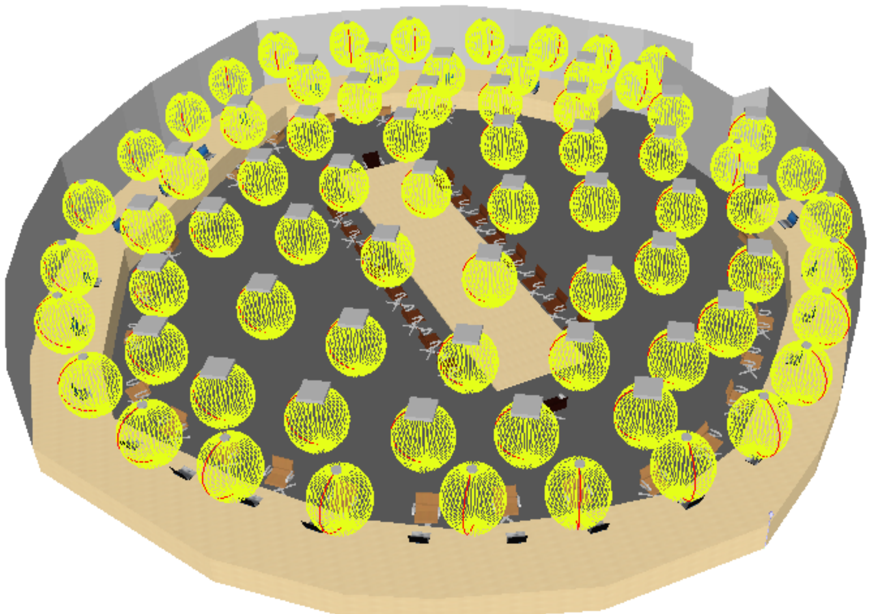
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.608, Ceiling / Working Plane: 0.311.

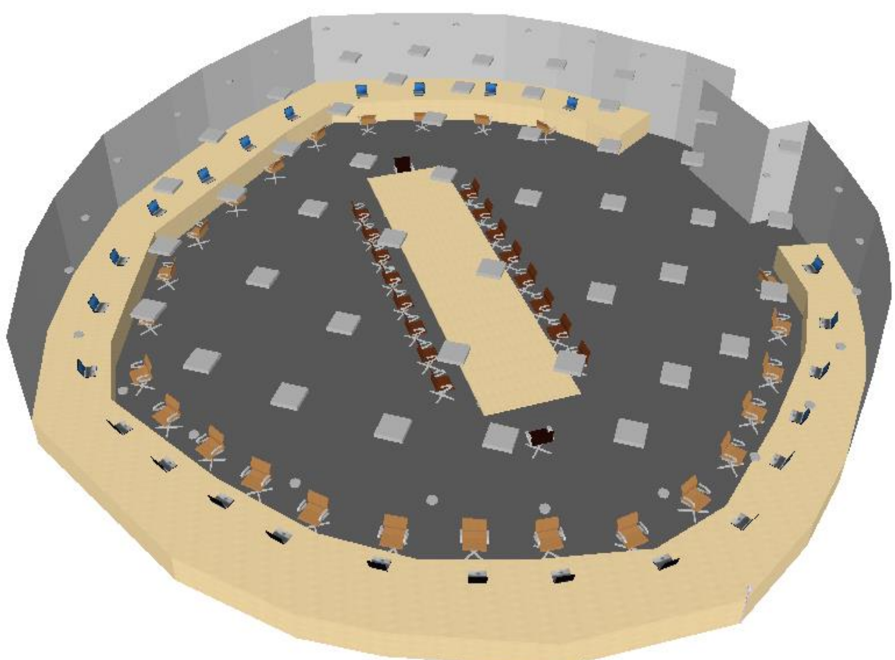
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	46	Crompton Greaves consumer electrcal Ltd. 01 LCTRS-36-CDL (1.000)	4213	4213	31.6
2	28	Crompton Greaves Ltd. 01 LCDE-18-CDL (1.000)	1994	1989	18.2
			Total: 249655	Total: 249500	1965.3

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 500 Lux and recommended overall uniformity above 0.5 respectively.

3D View of Air Traffic control room:

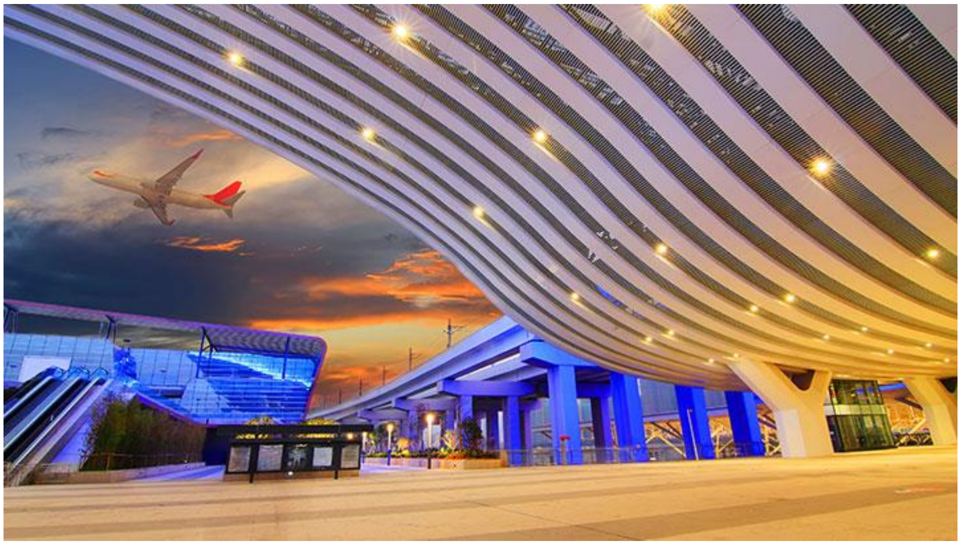




5.6.18: Facades and Architecture

Description:

LED lighting offers unprecedented design freedom in terms of color, dynamics, miniaturization, architectural integration and energy efficiency – opening up new possibilities in brand building and ambience creation, for instance by dynamically changing the lighting, using various highlighting and color effects. Architectural facade lighting can effectively turn the airport into a prominent landmark, a living symbol of hospitality.



(a)

(b)

Fig 5.24: (a) & (b) represent Façade lighting of Airport

5.7: Lighting design for Air Side area

5.7.1: Hangar Area

Description:

Effective lighting is essential for operational productivity and efficiency. Bright, white light not only improves visibility, it can also help those working late at night to stay alert and focused.

Design Requirements:

- Average illuminance required: 300 Lux
- Overall Uniformity: 0.5

Luminaire used:

- LED High bay Luminaire
- Luminous flux (Luminaire): 9307 lm
- Luminous flux (Lamps): 9359 lm
- Luminaire Wattage: 90 W

Design Consideration:

- LLF: 0.8;
- Room Surface Reflectance: 70%, 50% and 20% respectively.
- Room height: 6.5m
- Working Plane: 0m
- Boundary zone: 0m

Design Simulation:

DIALux simulated view of the hangar area has been shown below in Fig 5.24. Horizontal calculation grid has been taken at 0.76m above the ground level, as shown. Line arrangement of the luminaires with differential heights is shown in the section elevation. The space should be uniformly distributed by the luminaires.

165	330	221	298	304	253	304	220	283	274	223	335	158
195	393	266	339	334	328	409	287	324	326	279	395	188
182	329	230	329	339	341	432	291	330	325	229	331	174
211	433	300	351	344	341	438	292	341	340	316	436	203
184	322	222	335	348	349	430	306	338	327	219	322	173
218	457	315	355	347	345	435	299	346	346	332	459	209
187	316	219	337	346	348	443	294	344	329	214	314	174
219	455	314	355	349	348	433	303	348	347	331	460	210
185	324	224	336	347	351	434	306	343	328	219	323	174
211	430	298	354	346	341	442	286	347	344	314	438	205
185	336	235	332	344	347	430	302	341	323	229	334	176
197	389	265	345	339	336	418	294	339	334	278	399	192
175	343	231	306	315	277	342	242	310	293	229	339	169

15.00 m
-15.00
-15.21
15.21 m

Fig 5.24: DIALux simulation for Hangar area

Result overview:

Grid: 13 x 13 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
309	158	460	0.51	0.34

Thus, it can be concluded form the given result that a uniform illumination has been covered throughout the entire area of recommended average illuminance over 300 Lux and recommended overall uniformity above 0.5 respectively.

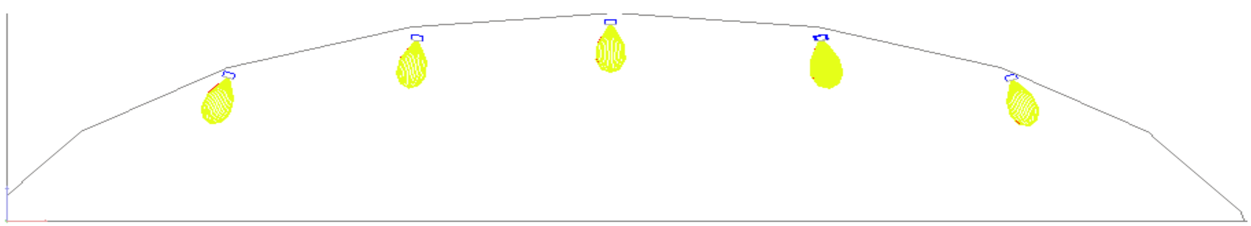
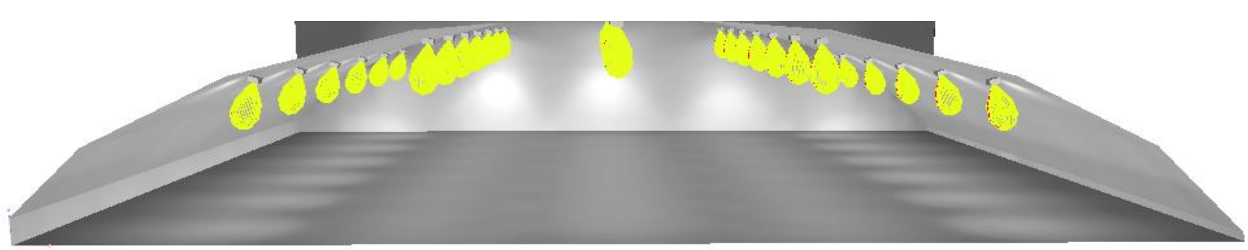


Fig 5.25: Sectional view of Highbay Luminaire arrangement

3D View of Hangar:



5.7.2: Apron Area:

Description:

The areas where airplanes park to load or offload cargo, passengers and luggage need to be lit effectively for essential operations to take place such as refueling or safety checks. Bright white light reassures passengers waiting at the gate to board because they can see that safety and security protocols are maintained at all times.

Design Requirements:

- Horizontal illuminance value required: 20 Lux;
- Overall Horizontal Uniformity: 0.25;
- Vertical Lux level required: 20 Lux at a height of 2m from the ground level.

Luminaire Used:

- LED Floodlight Luminaire
- Luminous flux(Luminaire): 45970 lm
- Luminous flux(Lamps): 46000 lm
- Luminaire Wattage: 400 W

Design Considerations:

- LLF: 0.8;
- High Mast height and locations are considered as per AutoCAD layout given;
- High Mast height: HM-1 to HM-5 have height of 30m from the ground level & HM-6 to HM-10 have height of 20m from the ground level respectively;
- Luminaire Mounting height: Luminaires of HM-1 to HM-5 has height of 30m from the ground level & HM-6 to HM-10 has height of 20m from the ground level respectively;
- No of High Mast: 10;
- No of Luminaires: 82 Nos of 30 degree beam angle 400 W LED Floodlight & 11 Nos of 10 degree beam 400 W LED Floodlight respectively;
- Taxiway has average horizontal illuminance of 10 Lux;
- No obstructions considered in the lighting design.

AutoCAD Layout:

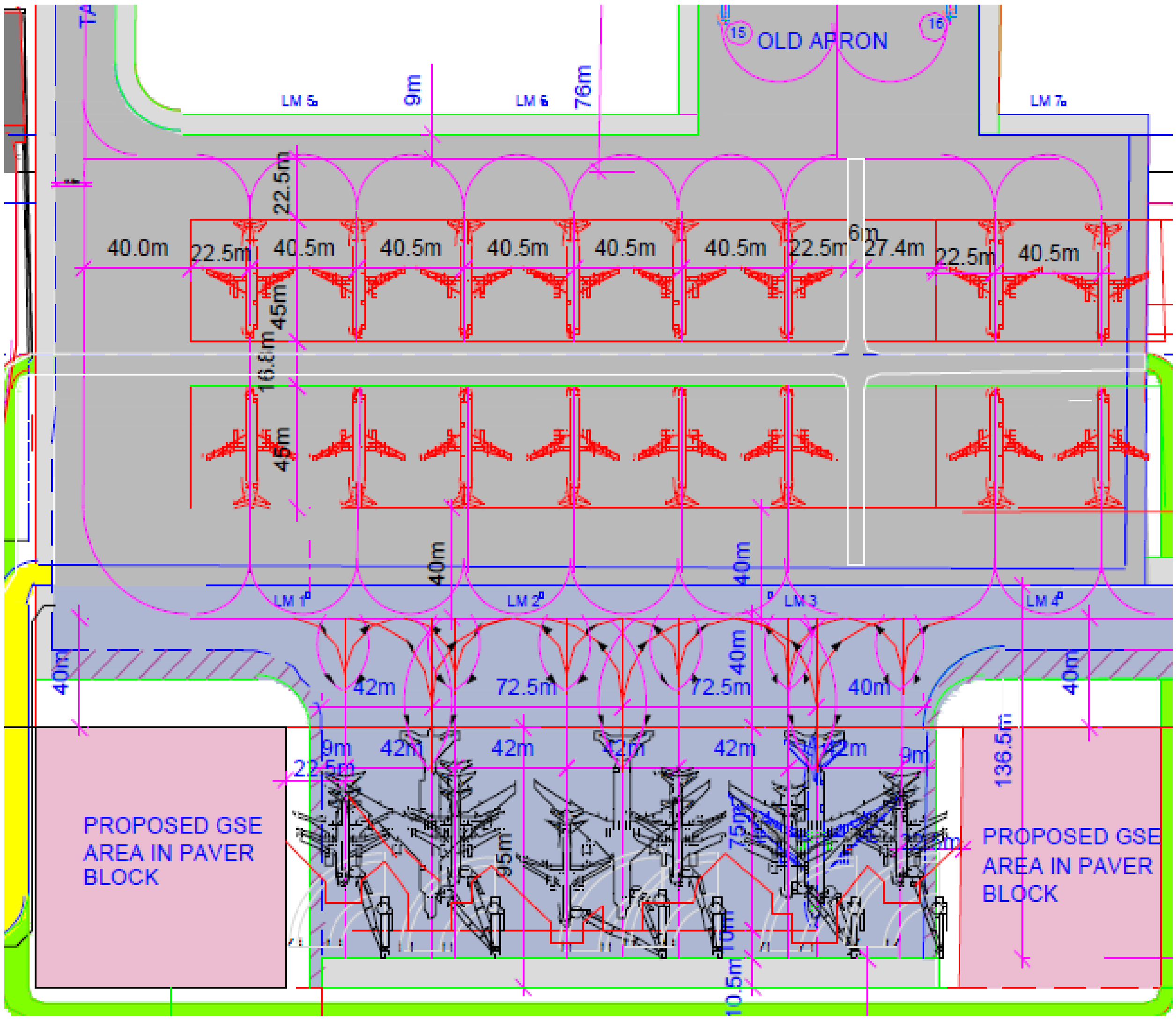


Fig 5.26: AutoCAD Layout of Apron area

Fig 5.29 depicts AutoCAD layout of Stand-wise Apron areas. The distance between the aircraft is maintained at a gap of 40.5m above and 42m below as shown. The taxiway region is in the middle of the two airport apron areas.

AGI32 Simulation:

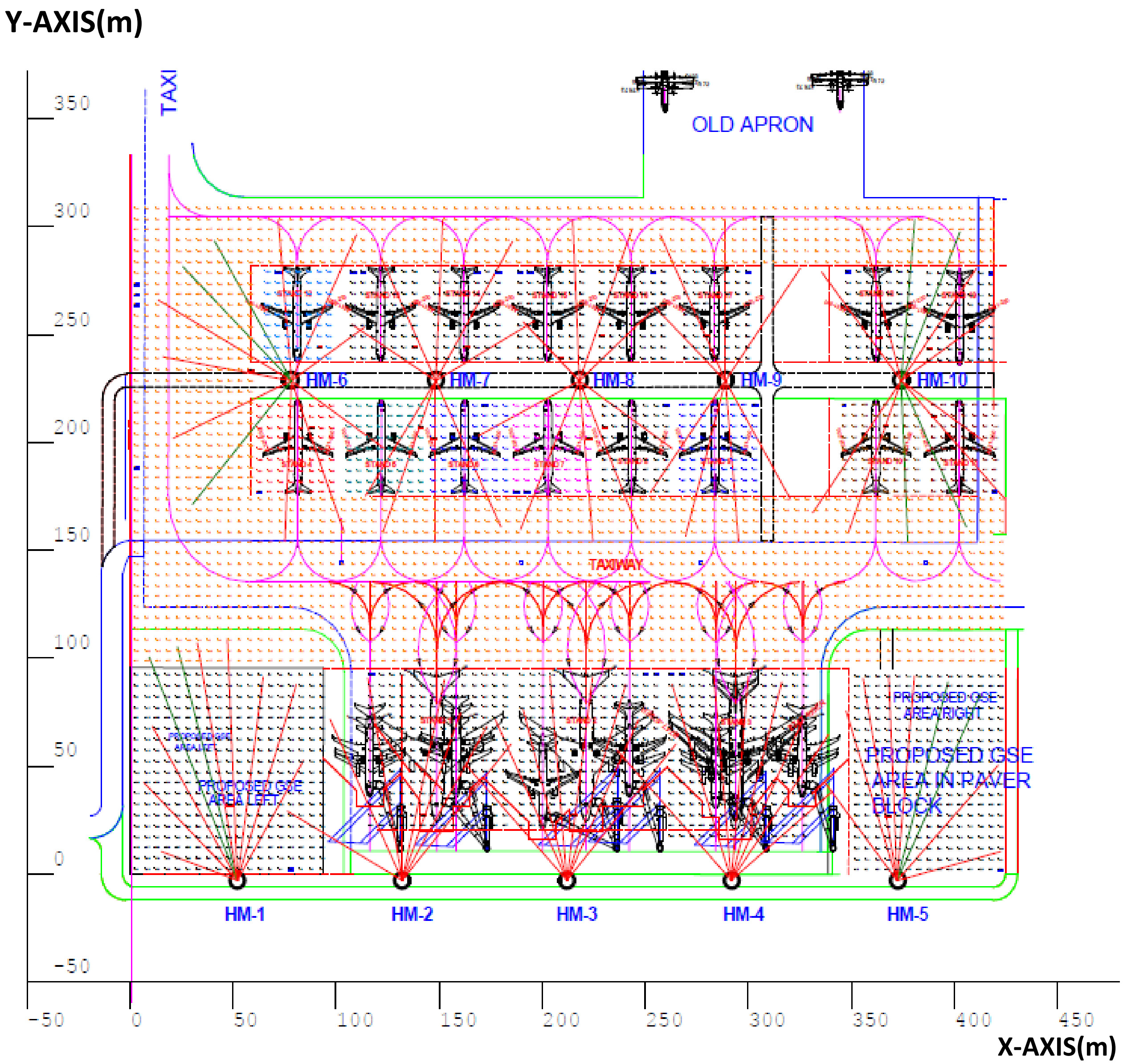


Fig 5.27: AGI Simulation view of Apron area

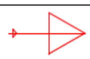
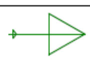
AGI32 Simulation of apron area is shown above where locations of high masts are marked as HM-1 to HM-10 respectively. Calculation grids are taken on stand wise apron areas and taxiway region separately. The High mast locations are selected with respect to the AutoCAD layout given by the Airport Authority. AGI32 is a very accurate and user friendly software simulation design tool which allow us to find out the results for large outdoor areas with higher level of accuracy. The high mast number with luminaire quantity per mast is shown in the table below.

Luminaire Details:

HM wise Luminaire Details

HM NO.	LUMINAIRE QTY.
HM-1	10
HM-2	08
HM-3	08
HM-4	08
HM-5	09
HM-6	12
HM-7	09
HM-8	09
HM-9	08
HM-10	12

Result Overview:

Luminaire Schedule				
Symbol	**Qty**	**Label**	**LLF**	**Description**
	82	LFLPI-400-CDL_30-HE	0.800	400w LED FL
	11	LFLPI-400-CDL_10-HE	0.800	400w LED FL

Hence, red colored symbol of luminaire represents 30 degree beam angle lens and green colored symbol represents 10 degree beam angle of 400 Watt each kind of luminaires as shown in the result. Here, high mast HM-1 consists of two numbers of 10 degree and eight numbers of 30 degree beam angle lens of 400 Watt LED Floodlight. Similarly, HM-5 consists of two numbers of 10 degree beam angle lens and 7 numbers of 30 degree beam angle lens of 400 Watt LED Floodlight as shown. In the same manner, HM-6 and HM-10 consists of three and four numbers of 10 degree beam angle lens of LED Floodlight. Remaining all other luminaires of total 82 numbers are 400 Watt LED Floodlight being used in the design as shown in Fig 5.27.

Horizontal Illuminance details:

Calculation Summary						
Label	**CalcType**	**Units**	**Avg**	**Max**	**Min**	**Min/Avg**
PROPOSED GSE AREA LEFT	Illuminance	Lux	21.09	46.8	7.8	0.37
PROPOSED GSE AREA RIGHT	Illuminance	Lux	21.10	47.9	7.9	0.37
STAND 1	Illuminance	Lux	23.35	48.6	10.3	0.44
STAND 10	Illuminance	Lux	22.31	38.9	6.4	0.29
STAND 11	Illuminance	Lux	22.11	46.3	8.3	0.38
STAND 12	Illuminance	Lux	25.00	43.9	11.9	0.48
STAND 13	Illuminance	Lux	23.97	42.3	12.8	0.53
STAND 14	Illuminance	Lux	24.70	39.7	12.6	0.51
STAND 15	Illuminance	Lux	23.95	41.3	12.2	0.51
STAND 16	Illuminance	Lux	24.05	44.9	14.2	0.59
STAND 17	Illuminance	Lux	25.72	46.9	11.7	0.45
STAND 18	Illuminance	Lux	22.31	36.9	9.9	0.44
STAND 19	Illuminance	Lux	22.89	46.7	7.8	0.34
STAND 2	Illuminance	Lux	23.67	48.9	11.0	0.46
STAND 3	Illuminance	Lux	23.18	49.3	10.9	0.47
STAND 4	Illuminance	Lux	21.24	35.6	8.8	0.41
STAND 5	Illuminance	Lux	23.65	51.0	14.3	0.60
STAND 6	Illuminance	Lux	22.80	49.5	12.3	0.54
STAND 7	Illuminance	Lux	22.40	40.4	12.5	0.56
STAND 8	Illuminance	Lux	22.47	41.6	13.8	0.61
STAND 9	Illuminance	Lux	27.09	45.9	15.1	0.56
Taxiway	Illuminance	Lux	10.15	42.1	4.1	0.40

Vertical Illuminance details:

Calculation Summary			
Label	**CalcType**	**Units**	**Avg**
PROPOSED GSE AREA LEFT	Illuminance	Lux	34.31
PROPOSED GSE AREA RIGHT	Illuminance	Lux	34.65
STAND 1	Illuminance	Lux	41.40
STAND 10	Illuminance	Lux	38.89
STAND 11	Illuminance	Lux	34.77
STAND 12	Illuminance	Lux	46.60
STAND 13	Illuminance	Lux	42.39
STAND 14	Illuminance	Lux	46.42
STAND 15	Illuminance	Lux	44.23
STAND 16	Illuminance	Lux	44.91
STAND 17	Illuminance	Lux	49.24
STAND 18	Illuminance	Lux	45.59
STAND 19	Illuminance	Lux	44.53
STAND 2	Illuminance	Lux	41.77
STAND 3	Illuminance	Lux	39.56
STAND 4	Illuminance	Lux	32.46
STAND 5	Illuminance	Lux	35.71
STAND 6	Illuminance	Lux	35.63
STAND 7	Illuminance	Lux	33.50
STAND 8	Illuminance	Lux	32.52
STAND 9	Illuminance	Lux	42.92

Hence, it can be said from the above results that average horizontal illuminance level for all apron stands marked are above 20 Lux and for Taxiway area the value of horizontal illuminance is 10 Lux respectively. The vertical illuminance level is also 20 Lux which has been obtained for all apron stand wise areas. The overall uniformity for all the apron stands is 0.25 as shown. These values obtained matches with that of the recommended airport standard and guidelines of **IS 11116** (1984).

CH-6

RESULT ANALYSIS

6.1: Introduction

The entire airport lighting design for indoor and outdoor has been covered by using SSL technology i.e., LED Systems. Conventional light sources are not considered here in the project. LED luminaires are energy efficient which solves many problems. During retrofitting, Point to point replacement of the conventional luminaires by using LED luminaires, it deals with the evaluation of LPD values. Care is taken to selectively choose the luminaires at the time of designing where the lighting design fulfils the criteria given by the Airport Authority. The IP and IK ratings of the luminaires are also matched with the respective values provided by the authority.

6.2: Evaluation of LPD

Energy efficiency has always been an integral part of lighting design. LPD is measured in watts per square foot, or energy consumed divided by the size of a space. LPD is calculated in the Building Area Method and the Space by Space method. The Building Area Method lists approximately 30 different building types (Office, School, Hospital, etc.) and provides an LPD for the entire square footage of the building. This method is easy to implement and is hard to argue with – the energy consumption of all fixtures in the building are added up and then divided by the overall area of the building.

6.3: LPD Evaluation of Terminal Building

Area type	*Total Wattage of Lighting Systems (W)*	*Total Floor area (m^2)*	*LPD (W/m^2)*
Arrival Hall	4986.1	1266.07	3.94
Departure Hall	4273.8	999.38	4.28
Check-in and Information desks	9758.5	1865.67	5.23
Passport Control office	253.1	52.80	4.79
Baggage Claim area	9112.3	4797.02	1.90
Corridor	418.8	125	3.35
Security Check area	10470.8	1654.97	6.33
Office	189.8	29.98	6.33
Conference room	253.1	38.98	6.49
Retail area	284.8	17.06	16.69
Leisure area	163.9	61.59	2.66
Connection and Travellator area	3148.1	1196.96	2.63
ATCT room	1965.3	399.40	4.92
Fine Lounge	316.4	55.56	5.70

Luggage Handling area	6011.6	1250	4.81
Total	**51606.4**	**13810.44**	**3.74**

Table 6.1: LPD Evaluation Table for Main Terminal Building

The American Society of Heating, Refrigeration and Air-Conditioning Engineers (**ASHRAE**) and the Illuminating engineering Society of North America (**IESNA**) have provided the recommended building code in the US (ASHRAE 2004). This code applies to all buildings except low rise residential buildings and has a lighting section which specifies maximum "lighting power density" limits, in units of Watts per square meter.

Therefore, an integrated research for architecture-based energy management in sustainable airports [9] defines the Airport guidelines in which the LPD values several areas for main terminal building are shown. The obtained result of LPD is 3.74 $\mathrm{W/m^2}$ in this project. So, this lighting design is feasible and energy efficient.

ANSI/ASHRAE/IESNA Standard 90.1–2001 elaborates lighting density of baggage area of airport must be lower than $11\mathrm{W/m^2}$ [10]. As per the airport guidelines authority, the LPD values of baggage claim area must be lower than or equal to $10.8\mathrm{W/m^2}$. From this project, the LPD obtained is $1.90\mathrm{W/m^2}$. For fire station, LPD value is $4.17\mathrm{W/m^2}$, which again states the lighting design for these areas is energy efficient and feasible.

LEDs are much more cost efficient with respect to Conventional luminaires. Since cost plays a pivotal role determining whether any project is feasible or not, point to point replacement of luminaires from conventional to LED can be done where the lumen value of the conventional luminaire matches with that of LED respectively. Hence, Retrofitting solution can be obtained in such manner in which results are well justified using Payback calculation methods.

CH-7

CONCLUSION & FUTURE SCOPE

Conclusion & Future Scope

7.1 Conclusion

1. This thesis is carried out considering several factors in mind which includes energy efficient, cost effective lighting design solutions. Various simulation results in DIALux and AGI32 software have been carried out where LED fixtures despite having higher initial investment prices, results in higher payback periods as compared to conventional fixtures.
2. The advantage of LED lighting is that LEDs do not contain toxic materials such as mercury and other metals dangerous for the environment, in contrast to the energy-saving lamps and are 100% recyclable, what helps to reduce carbon dioxide emissions. They contain chemical compounds responsible for the color of its light (phosphor), which are not harmful to the environment.

7.2 Future Scope

1. Moving with the new & renewable energy sources, this system can be upgraded by replacing ordinary LED modules with the solar based LED modules. With utilizing the latest technology and advance sensors, we could serve the same purpose of automatically controlling the street lights much more effectively both by cost and manpower.
2. Further energy savings can be achieved with smart lighting control strategies. Today, the most common form of control (the standard wall switch) is being replaced by automatic components which are based on occupancy or daylight harvesting. Examples of this technology are occupancy sensors which turn the lights off when the area is unoccupied.
3. The upcoming smart lighting systems are predicted to be equipped with highly robust sensors for both outdoor as well as indoor lighting. Using PWM technology (Pulse Width Modulation) LEDs can be accurately dimmed. Multiple sensors- lighting intensity and ultrasonic range sensors can be combined with LED dimming system to realize an automatically controlling LED lighting system.

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ANNEXURE

Details of Internship course:

Company: Crompton Greaves Consumer Electricals Ltd.
Branch: Mumbai (Head Office)
Duration: 10 months (01.06.2018 to 31.03.2019)
Reporting Head: Mrs. Uma Lanka, Associate Vice President, Design, Lighting Division.

Work Details:

- ❖ Worked as a lighting designer in LAB (Lighting Advisory Bureau).
- ❖ Includes client visiting, understanding the demands of the client and lastly to guide the client for better product technologies and to make a selection for the best lighting solution.
- ❖ As per BIS guidelines, proper and through design has been carried out for both indoor and outdoor lighting using LED as well as conventional fixtures.
- ❖ Finally, Results obtained which includes all the details regarding lighting design, on the basis of which, Bill of Quantity (BOQ) is prepared for Payback calculation chart.

Design Area:

i. Airport Indoor and Outdoor areas including several domestic and international airports inside India and abroad.
ii. Indoor and outdoor sports lighting like Cricket, Football, Basketball, Badminton, Kabbadi, Volleyball, hockey.
iii. Cement Plant Mine.
iv. Industry lighting and industrial Sheds.
v. Highmast lighting in Port area.
vi. Street, Highway and Flyover.
vii. Façade Lighting in government offices, schools and other large buildings.
viii. Hospital Lighting.
ix. Substation lighting.
x. Auditorium lighting.
xi. Highmast lighting in various applications like party lighting, area lighting etc.