STUDIES ON LIGHTING DESIGN SOLUTIONS OF DIFFERENT TYPES OF LIGHTING APPLICATION AND COMPARISON WITH CONVENTIONAL SOLUTIONS AND THEIR ENERGY EFFECTIVENESS

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Submitted by
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To Whom It May Concern

This is to certify that Ankit Ghosh, pursing M. Tech in Illumination Technology and Design from Jadavpur University has successfully completed his internship **from June 01, 2018 to March 31, 2019** at Crompton Greaves Consumer Electricals Limited in Lighting B2B division under the guidance of Mr. Pinaki Chowdhury, Sr. Manager – Business Development.

His project was **"Studies on Lighting Design Solutions of Different Type of Lighting Application & Comparison with Conventional Solutions and Its Energy Effectiveness"**.

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

All The Best.

P. V. Venkatesh

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Abstact

With rapid industrialization, energy consumption has been increased drastically. As most of the Lighting Application still prefers conventional lighting scheme, which is both unhealthy and consumes considerable amount of lighting load, therefore light emitting diodes (LEDs) are used for industrial lighting designs as a solution to reduce the energy consumption.

This project is based on the energy efficient lighting solution for Road, Thermal Power Plant, Oil Refinery, Metro Railway Station and Office Building. Case studies have been carried out for different cases and the best possible lighting scheme has been proposed. The illumination level for the different area is selected as per the Indian Standards where lighting levels are mentioned for cases.

Lighting simulation has been carried out using various lighting simulation software like AGI32, DIALux 4.13 and DIALux evo 8.0. A section of this thesis work has been dedicated to compare the cost analysis of LEDs with conventional fixtures by comparing their Payback Period.

The lighting design and simulation works in the subsequent chapters are performed in Crompton Greaves Consumer Electricals Limited, Kolkata branch during the internship period of the author of the thesis.

Contents **Page Number**

Chapter 1: Introduction **1-2**

1.1 Introduction 1

1.2 Aims and Objective 1-2

Chapter 2: Background Theory **3-11**

2.1 Conventional Light Sources 4

2.2 Light Emitting Diode 5

2.3 Ingress Protection Rating 5

2.4 CCT and CRI 6

2.5 Maintenance factor 7

2.6 Utilization Factor 7

2.7 Types of Light Fixture 8

2.8 Lighting Systems 10

Chapter 3: Modern Technology on LED Luminaire **12-31**

3.1 Introduction 13

3.2 Working Principle 13

3.3 RGB LED (White Light) 14

3.4 LED Chip Technology 14

3.4.1 DIP Chip 14

3.4.2 SMD Chip 14

3.4.3 COB Chip 15

3.5 LED Binning 16

3.6 Measurement Standards for LED 16

3.6.1 LM 79-08 16

3.6.2 In Situ Temperature Measurement Test (ISTMT) 17

3.6.3 LM80-08 17

3.6.4 TM 21-11 18

3.6.5 Photo- biological Safety Report 18

3.7 LED Driver 19

3.7.1 Potted Driver 20

3.8 Low Power LED Chip 21

3.9 Mid Power LED Chip 21

3.10 High Power LED Chip 21

3.11 Lumen Maintenance in LED Luminaire 21

3.12 Types of LED Luminaire 22

3.13 Selection Criteria for LED luminaires 29

3.14 Advantages of LED 29

3.15 LED Market in India 30

Chapter 4: Lighting Design Objectives and Criteria 32-36

4.1 Introduction 33

4.2 Lighting Design Objectives 33

4.2.1 Safety and Health 33

4.2.2 Performance 33

4.2.3 Appearance and Comfort 33

4.2.4 Visual Amenity 33

4.2.5 Architectural Integration 34

4.2.6 Energy Efficiency and Sustainability 34

4.2.7 Maintenance 34

4.2.8 Costs 35

4.3 Lighting Design Criteria 35

4.3.1 Average Illuminance 35

4.3.2 Overall Uniformity 35

4.3.3 Glare 35

4.3.3.1 Disability Glare 36

4.3.3.2 Discomfort Glare 36

4.3.4 Upward Light Output Ratio 36

Chapter 5: Lighting Design Methodology 37-53

5.1 Introduction 38

5.2 Input Data 38

5.3 Method of Lighting 38

5.4 Selecting the Lighting Equipment 38

5.5 Choice of Luminaire 39

5.6 Lighting Calculation Method 39

5.6.1 Manual Calculation Method 40

5.6.1.1 Lumen Method 40

5.6.1.2 Lumen Output of source 41

5.6.1.3 Calculation of Luminaires 41

5.6.2 Three Dimensional Modeling 42

5.6.3 Visualization 43

5.6.3.1 Flux Transfer or Radiosity Calculation 43

5.6.3.2 Ray Tracing Calculations 43

5.7 Design Tools 43

5.7.1 Lighting Design Software 43

5.7.2 Autocad 2017 48

5.7.3 Limiter 48

5.8 Design Methodology 48

5.9 Design Process 49

5.9.1 Indoor Area 49

5.9.2 Street 50

5.9.3 Exterior Area 52

Chapter 6: Basics of Illumination on Road, Industrial Area, Metro Railway and Office Building **54-99**

6.1 Basics of Illumination on Road 55

6.1.1 Introduction 55

6.1.2 Highway Related Terms 55

6.1.3 Geometry of Road Lighting System 56

6.1.4 Lighting Arrangements 59
6.1.4.1 Single Sided Arrangement 59
6.1.4.2 Staggered Arrangement 59
6.1.4.3 Opposite Arrangement 59
6.1.4.4 Axial Mounting 59
6.1.5 Fundamental Criteria of Road Lighting 60
6.1.5.1 Luminaire 60
6.1.5.2 Illuminance 60
6.1.5.3 Uniformity 60
6.1.5.4 Glare 61
6.1.5.5 Surround Ratio 62
6.1.5.6 Visual Guidance 62
6.1.6 Road Lighting Luminaires 63
6.1.6.1 Photometrical Characteristics 64
6.1.6.1.1 Light Distribution and Light Output Ratio 64
6.1.6.1.2 Relative and Absolute Photometry 66
6.1.6.1.3 Luminaire Classification System 67
6.1.6.2 Optical Characteristics 74
6.1.6.2.1 Reflectors 74
6.1.6.2.2 Refractor and Lens 75
6.1.6.2.3 Diffusers 76
6.1.6.3 Mechanical Characteristics 76
6.1.6.3.1 Material 76

6.1.6.3.2 Strength 77

6.1.6.3.3 Dirt and Humidity Depreciation 77

6.1.6.3.4 Installation and Maintenance 78

6.1.6.4 Electrical Characteristics 79

6.1.6.5 Thermal Characteristics 79

6.2 Basics of Illumination in Industrial Area 80

6.2.1 Introduction 80

6.2.2 General Features in Industrial Area 80

6.2.3 Criteria for Industrial Lighting Practices 81

6.2.3.1 Quality of Illumination 81

6.2.3.2 Maintenance Factor 81

6.2.3.3 Glare 81

6.2.3.4 Luminance and Luminance Ratios 82

6.2.3.5 Distribution, Shadow and Stroboscopic Effect 82

6.2.3.6 Colour of Light 82

6.2.3.7 Veiling Reflectance 82

6.2.3.8 Brightness Consideration 82

6.2.4 Lighting Related to Structure of Industrial Premises 83

6.2.4.1 Lighting of Factory spaces with Skylights 83

6.2.4.2 Lighting of Factory spaces with Closed ceiling 83

6.2.4.3 High-bay Lighting 83

6.2.5 Factors for special consideration 84

6.2.5.1 Lighting and Space Conditioning 84

6.2.5.2 High Humidity or Corrosive atmosphere and Hazardous Location Lighting 84

6.2.5.3 Abnormal Temperature Condition 84

6.2.6 Light Sources in Industrial Lighting 85

6.2.7 Luminaires for Industrial Lighting 85

6.3 Basics of Illumination in Metro Railway 86

6.3.1 General Features of Metro Railway Lighting 86

6.3.2 Metro Railway System 86

6.3.3 Metro Railway Application Area 87

6.3.3.1 Public Area 88

6.3.3.2 Non- Public Area 87

6.3.4 General Requirement of Metro Railway Lighting 88

6.3.5 Different Areas in Metro Railway and Lighting Requirement 88

6.3.5.1 Public Areas 88

6.3.5.2 Non Public Areas 89

6.3.6 Criteria for Selecting Lighting Equipment 90

6.3.7 Lamps used in Metro Railway 90

6.3.7.1 Linear Tubular Fluorescent Lamps 91

6.3.7.2 Compact Fluorescent Lamp 91

6.3.7.3 High Pressure Sodium Vapour Lamps 91

6.3.7.4 Metal Halide Lamps 92

6.3.8 Luminaire 92

6.3.9 Ballast and Control Gear 93

6.3.10 LED Luminaire 93

6.3.11 Ingress Protection 94

6.3.12 Light Loss Factor 95

6.3.13 Working Level 95

6.3.14 Reflectance Factor 95

6.3.15 Uniformity 95

6.3.16 Glare 95

6.3.17 Mounting Arrangement and type of Luminaires 95

6.3.18 Emergency Illumination 96

6.4 Basics of Illumination in Office 96

6.4.1 Lighting Layout 96

6.4.2 Light Sources 97

6.4.3 Illumination Level 97

6.4.4 Switching 97

6.4.5 Dimming 97

6.4.6 Daylight Integration 97

6.4.7 Colour 97

6.4.8 Glare 97

6.4.9 Vertical Illumination 97

6.4.10 Reflectivity 98

6.4.11 LG7 Guideline 98

6.4.12 Human Centric Lighting 99

Chapter 7: Various Lighting Codes and Standards under Design Consideration 100-110

7.1 Introduction 101

7.2 Codes and Standards for Road Lighting 101

7.2.1 National Lighting Code 102

7.2.1.1 Lighting Recommendations for different road types- IS classification 102

7.2.1.2 Lighting Recommendation for Junctions 102

7.2.1.3 Lighting Measurement Methods 102

7.2.2 IS: 1944(Parts I and II) – 1970: Code of Practice for Lighting of Public Thoroughfares 103

7.2.2.1 Basis of Lighting Requirements 104

7.2.2.2 Classification of Lighting 104

7.2.3.3 Recommended Values of Illumination 104

7.3 Codes and Standards for Industrial Lighting 105

7.3.1 IS 6665: Codes of Practice for Industrial Lighting 105

7.3.1.1 Basis of Lighting Requirement 105

7.3.1.2 Recommended Values of Illumination 106

7.4 Codes and Standards for Metro Railway Station Lighting 106

7.4.1 DMRC Guideline 106

7.4.2 Energy Conservation Guideline in Metro Railway Station 107

7.5 Codes and Standard for Commercial Office Lighting 107

7.5.1 IS-3646 (Part 1): Codes of Practice for Interior Illumination 108

7.5.2 IS-3646 (Part 2): Scheduled for values of Illumination and Glare Index 108

7.5.3 Energy Conservation Building Guideline in Commercial Office Area 108

Chapter 8: Case Studies **111-368**

8.1 Introduction 112

8.2 Case Study on Road Lighting 112

8.2.1 Simulation by using Conventional Fixtures 114

8.2.1.1 Choice of Lamps and Luminaires 114

8.2.1.2 AGI32 Simulation Results 115

8.2.2 Simulation by using LED Luminaire 116

8.2.2.1 Choice of Luminaire 117

8.2.2.2 AGI32 Simulation Results 118

8.3 Case Studies on Industrial Lighting 119

8.3.1 Case Study on Thermal Power Plant 119

8.3.1.1 Design Input 119

8.3.1.2 Area-wise Description 120

8.3.1.3 Simulation by using Conventional fixtures 128

8.3.1.3.1 Choice of Lamps and Luminaires 129

8.3.1.3.2 DIALux 4.13 Simulation Results 134

8.3.1.4 Simulation by using LED fixtures 148

8.3.1.4.1 Choice of Luminaires 149

8.3.1.4.2 DIALux 4.13 Simulation Results 155

8.3.2 Case Study on Oil Refinery 171

8.3.2.1 Design Input 171

8.3.2.2 Area-wise Description 172

8.3.2.3 Simulation by using Conventional Fixtures 177

8.3.2.3.1 Choice of Lamps and Luminaires 177

8.3.2.3.2 DIALux 4.13 Simulation Results 177

8.3.2.4 Simulation by using LED Fixtures 186

8.3.2.4.1 Choice of Luminaires 186

8.3.2.4.2 DIALux 4.13 Simulation Results 186

8.4 Case Study on Metro Railway Station 195

8.4.1 Platform and Staircase Area 195

8.4.1.1 Autocad Drawing 195

8.4.1.2 Simulation by using Conventional Luminaires 196

8.4.1.2.1 Choice of Lamps and Luminaires 196

8.4.1.2.2 DIALux 4.13 Simulation Results 199

8.4.1.3 Simulation by using LED Luminaires 203

8.4.1.3.1 Choice of Luminaires 203

8.4.1.3.2 DIALux 4.13 Simulation Results 208

8.4.2 Concourse Area 212

8.4.2.1 Autocad Drawing 212

8.4.2.2 Simulation by using Conventional Luminaires 213

8.4.2.2.1 Choice of Lamps and Luminaires 213

8.4.2.2.2 DIALux 4.13 Simulation Results 219

8.4.2.3 Simulation by using LED Luminaires 254

8.4.2.3.1 Choice of Luminaires 254

8.4.2.3.2 DIALux 4.13 Simulation Results 259

8.5 Case Study on Office Lighting 296

8.5.1 Autocad Design 296

8.5.2 Simulation by using Conventional Luminaires 296

8.5.2.1 Choice of Lamps and Luminaires 297

8.5.2.2 DIALux evo 8.0 Simulation Results 299

8.5.3 Simulation by using LED Luminaires 331

8.5.3.1 Choice of Luminaires 332

8.5.3.2 DIALux evo 8.0 Simulation Results 336

Chapter 9: Result and Cost Analysis **369-596**

9.1 Introduction 370

9.2 Result Analysis and Cost Analysis of Case Study on Road Lighting 370

9.2.1 Result Analysis of Case Study on Road Lighting 370

9.2.2 Economic Comparison between Conventional and LED Solution of Case Study on Road Lighting 390

9.3 Result Analysis and Cost Analysis of Case Study on Thermal Power Plant 392

9.3.1 Result Analysis of Case Study on Thermal Power Plant 392

9.3.2 Economic Comparison between Conventional and LED Solution of Case Study on Thermal Power Plant 426

9.4 Result Analysis and Cost Analysis of Case Study on Oil Refinery 429

9.4.1 Result Analysis of Case Study on Oil Refinery 429

9.4.2 Economic Comparison between Conventional and LED Solution of Case Study on Oil Refinery 448

9.5 Result Analysis and Cost Analysis of Case Study on Metro Railway Station 451

9.5.1. Result Analysis of Case Study on Metro Railway Station 451

9.5.1.1 Platform and Staircase Area 451

9.5.1.1.1 Platform Area 451

9.5.1.1.2 Staircase Area 455

9.5.1.2 Concourse Area 465

9.5.2 LPD Evaluation of Metro Railway Station 522

9.5.3 Economic Comparison between Conventional and LED Solution of Case Study on Metro Railway Station 522

9.6 Result Analysis and Cost Analysis of Case Study on Office Building 526

9.6.1 Result Analysis of Case Study on Office Building 526

9.6.2 LPD Evaluation of Office Building 592

9.6.3 Economic Comparison between Conventional and LED Solution of Case Study on Office Building 592

Chapter 10: Conclusions **598-601**

10.1 Introduction 599

10.2 Conclusions 599

10.3 Challenge Faced 600

10.4 Further Study 600

References **602**

Annexure I **604**

Annexure II: List of Lamps and Luminaires **605**

Annexure III: Case Study on Road Lighting by using Conventional Luminaire **606**

Annexure IV: Case Study on Road Lighting by using LED Luminaire **615**

Annexure V: Case Study on Thermal Power Plant by using Conventional Luminaire **623**

Annexure VI: Case Study on Thermal Power Plant by using LED Luminaire **641**

Annexure VII: Case Study on Oil Refinery by using Conventional Luminaire **659**

Annexure VIII: Case Study on Oil Refinery by using LED Luminaire **669**

Annexure IX: Case Study on Metro Railway Station by using Conventional Luminaire **679**

Annexure X: Case Study on Metro Railway Station by using LED Luminaire **744**

Annexure XI: Case Study on Office Building by using Conventional Luminaire **809**

Annexure XII: Case Study on Office Building by using LED Luminaire **848**

Annexure XIII: Installation Pictures **886**

Annexure XIV: Internship Details **889**

Chapter 1
Introduction

1.1 Introduction

Light is critical to human functioning in that it allows us to see things and perform activities. But it is also important because it affects human beings psychologically and physiologically. Lighting can influence human emotions and feeling of well-being. The lighting needs of a space must be design to optimize with proper allocation and management of energy. Lighting needs may range from simple orientation to complex visual tasks. Satisfaction and performance of the worker is totally dependent on Lighting in task area. In most of cases lighting system are installed for primary purpose of facilitating the performance of the visual task are not satisfactory and objective of the lighting system will not be met. Conversely illumination in excess of the required amount does wastage of energy and needlessly increases the cost of lighting system, not only that for outdoor application over illumination produces light pollution and for indoor application it is more harmful due to the biological effect of light. The medical research on the effects of excessive light on human body suggests that a variety of adverse health effects may be caused by excessive light exposure. The health issues due to over illumination and improper spectral composition of light may include increase of headache, visual and physical fatigue, medically defined stress, increment of anxiety or excitement etc.

With modern urbanization and expansion of industrial growth, energy shortage has become a serious concern and energy saving has become a hot topic recently. "Green Lighting" or "Energy Efficient Lighting" is listed one of the solution to save energy. By energy efficient lighting systems we mean use of LEDs, lamps with high efficacy, use of daylight, use of sensor and long life lamps.

India is shifting towards energy efficient lighting as it can improve the efficiencies of energy utilization and not harmful to human health and it does not impairs environment. Energy efficient lighting means to obtain an adequate lighting and consume less electricity and should be free from polluting the environment.

1.2 Aims and Objective

As India uses 19% of its total generation power in illumination application [1], demand increases to use energy efficient luminaires which in turns give the idea of retrofitment i.e. to use energy efficient lighting products instead of existing conventional luminaires.

Here different areas are taken for simulation purposes i.e. Road, Thermal Power plant, Oil Refinery, Metro Railway Station and Office Building Area and here illumination as well as energy parameters are compared by using conventional luminaires and energy efficient LED lumianaires.

The designs must have to be energy efficient and the results must meet the recommended values defined by the Authority or Client.

The main objectives of this study are

- To study illumination design criteria of different areas like Road, Thermal Power Plant, Oil Refinery, Metro Railway Station and Office Building.
- To study relevant codes regarding Illumination as well as energy parameters.
- To study new energy efficient technology in the field of illumination.
- To study about different lighting design simulating softwares like DIALux 4.13, DIALux evo and AGI32.

- To run design simulation by using conventional luminaires and energy efficient LED luminaires and compare the results based on illumination and power consumption parameter and calculated cost savings.

Chapter 2
Background Theory

2.1 Conventional light sources

2.1.1 Incandescent Lamps

Incandescent lamps give light output on the basis of incandescence principle. An incandescent lamp is an electric light which produces light with a wire filament heated to a high temperature by an electric current passing through it. The hot filament is protected from oxidation with a glass or quartz bulb that is filled with inert gas or evacuated leading to a significant extension in life and reduction in bulb blackening through life.

2.1.2 Halogen lamps

The halogen lamp is a type of incandescent lamp which uses halogen gases (iodine or bromine; not fluorine due to high reactive characteristics) in order to increase both light output and rated life. Unlike typical incandescent lamps halogen lamps are largely able to eliminate the problem of lamp blackening because the halogen gas reacts chemically with the evaporated tungsten to prevent it from affixing to the glass. [3]

2.1.3 High-intensity discharge lamps

High-intensity discharge lamps (HID lamps) are a type of gas-discharge arc lamps which create light by means of an electrical discharge between two electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. The tube is filled with an amalgam of gas and metal salts.

High Pressure Sodium Vapour (HPSV): In a high-pressure sodium lamp, a compact arc tube contains a mixture of xenon, sodium and mercury. The xenon gas which is easily ionized facilitates striking the arc when voltage is applied across the electrodes. The heat generated by the arc then vaporizes the mercury and sodium. The mercury vapor raises the gas pressure and operating voltage, and the sodium vapor produces light when the pressure within the arc tube is sufficient. [2]

Metal Halide Lamps: 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). [5]

2.1.4 Low-pressure sodium vapour (LPSV)

A Low-pressure sodium vapor lamps contains borosilicate glass gas discharge tube containing solid sodium, a small amount of neon, and argon gas in a Penning mixture to start the gas discharge. When the lamp is first started, it emits a dim red or pink light to warm the sodium metal; within a few minutes as the sodium metal vaporizes, the emission becomes the common bright yellow. This type of lamp uses sodium in presence of mercury in low pressure to emit monochromatic yellow light.

2.1.5 Fluorescent Lamp

Fluorescent lamps are low pressure mercury vapour lamps which emit Ultra-Violet radiation after discharge which converts to visible spectrum in presence of phosphor coating. This phenomenon is known as fluorescence. It requires a ballast and starter for operation. Starter provides stating high voltage pulse to initiate the discharge and ballast maintains the current through lamp during operation.

Compact Fluorescent lamps (CFL): Miniature version of fluorescent lamps which is made to replace incandescent lamp. They are made of glass tubes filled with gas and a small amount of mercury. CFLs produce light when the mercury molecules are excited by electricity running between two electrodes in the base of the bulb. [6] It can have integral ballast and can be retrofitted directly.

2.2 Light Emitting Diodes (LED)

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light 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 colour of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. [7] In normal p-n junction diodes, silicon is most widely used because it is less sensitive to the temperature.
Details on LEDs are discussed on Chapter 4.

2.3 Ingress Protection (IP) Rating

Ingress Protection (IP) ratings are developed by the European Committee for Electro Technical Standardization (CENELEC) (NEMA IEC 60529 Degrees of Protection Provided by Enclosures - IP Code), specifying the environmental protection the enclosure provides. The IP Code consists of the letters IP followed by two digits and an optional letter. 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. [8]
The IP rating normally has two numbers:
Number 1 indicates Protection from solid objects or materials (detailed in Table 2.1)
Number 2 indicates Protection from liquids (water) (detailed in Table 2.2)

Table 2.1: Values of first characteristic numerical and its protection level

First Characteristic numerical	Object size protected against	Effective against
0	_____	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, slender screws, ants 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.
6	Dust tight	No ingress of dust; complete protection against contact (dust tight). A vacuum must be applied. Test duration of up to 8 hours based on air flow.

Table 2.2: Values of second characteristic numerical and its protection level

Second Characteristic Numerical	Protected against	Effective against
0	Not protected	_____
1	Dripping water	Dripping water (vertically falling drops) shall have no harmful 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.
	Spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.
4	Splashing of water	Water splashing against the enclosure from any direction shall have no harmful effect.
5	Water jets	Water projected by a nozzle (6.3 mm) against enclosure from any direction shall have no harmful effects.
6	Powerful water jets	Water projected in powerful jets (12.5 mm nozzle) against the enclosure from any direction shall have no harmful effects.
7	Immersion up to 1 m	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 1 m or more	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. 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. The test depth and/or duration are expected to be greater than the requirements for IPx7.

2.4 CCT AND CRI

2.4.1 Correlated Colour Temperature (CCT)

The absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source [10] is known as CCT of that light source. The correlated color temperature (CCT) is a specification of the color appearance of the light emitted by a lamp, relating its color to the color of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K). [9] The CCT rating for a lamp is general "warmth" or "coolness" measure of its appearance. CCT of white light can be varied to get different appearance.

2700-3500 K white light is termed as _Warm White colour.

4000 K white light is termed as ―Natural White colour.
5000 K white light is termed as ―Daylight.
6000-6500 K white light is termed as ―Cool Daylight.

2.4.2 Colour Rendering Index (CRI)

The colour rendering index [11] defines the ability of a light source to identify colours. In other words Color rendering describes how a light source makes the color of an object appear to human eyes and how well subtle variations in color shades are revealed. It is measured on a scale of 1 - 100. On this scale a rendering of 1 is monochromatic light, and a rendering of 100 is natural sunlight, so you can think of the scale as a measure of the quality of light produced by the source. Higher the CRI value, better the color rendering ability. Light sources with a CRI> 70 are generally have outdoor applications such a floodlighting and street lighting. Light sources with CRI>80 have indoor applications.

Light sources with a CRI of 85 to 90 are considered good at color rendering used in shopping mall and retail applications. Light sources with a CRI of 90 or higher are excellent at color rendering and should be used for tasks requiring the most accurate color discrimination. [10]

2.5 Maintenance Factor (M.F.)

Maintenance factor 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. [11]

MF = LLMF x LSF x LMF x RSMF

Where,

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.

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 up light is far more onerous than on a sealed downlight.

LSF (Lamp Survival Factor): takes account of the effect of the failure of light sources during the maintenance period.

LLMF (Lamp Lumen Maintenance Factor): takes account of the effect of the lumen depreciation of the light sources during the maintenance period.

$$E_{maintained} = E_{initial} \times \text{Maintenance Factor}$$

Where,

$E_{maintained}$: maintained illuminanace at working level.

$E_{initial}$: Initial lumen from luminaire.

2.6 Utilization Factor

Utilization Factor 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 [12]

2.7 Types of Light Fixtures

Various types of light fixtures are designed to distribute light in different ways. These fixtures are known as:

1) Direct.
2) Direct-indirect.
3) Indirect.
4) Shielded (various types).

The effect of rooms, areas and objects greatly depends on the types of lighting. No single type of light fixture is appropriate in every situation. The amount and quality of lighting required for a particular workstation or task will determine which light fixture is most suitable. [13]

Direct light fixtures produce an even illumination on the horizontal working plane. Light structures with direct light have an axially symmetric light distribution emitted downwards for illuminating the usable surfaces. It projects 90 to 100 percent of their light downward toward the work area. Direct lighting tends to create shadows. The directed light produces good modeling and brilliance. The uniformity on the working plane increases as the room height increases or as the beam angle widens. Directed light enables good appreciation of form and surface texture. The visual comfort increases as the cut-off angle increases. A feature of direct illumination is its highly efficient use of energy. [13] At the work place, secondary glare must be taken into consideration. Schematic diagram for direct lighting is shown in Fig. 2.1.

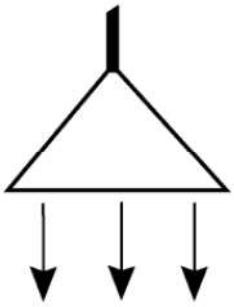


Fig. 2.1: Direct Lighting

Direct-indirect light fixtures refer to a combination of direct and indirect illumination with respect to the horizontal working plane. The ceiling or walls serve here as reflection surfaces. It distributes light equally upward and downward. They reflect light off the ceiling and other room surfaces. Little light is emitted horizontally meaning direct glare is often reduced. They are usually used in "clean" manufacturing areas. Schematic diagram for direct-indirect lighting is shown in figure 2.2. [13]

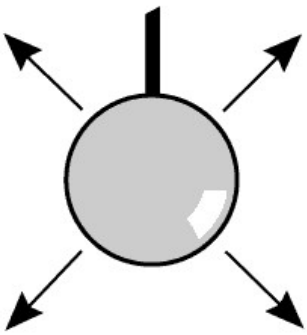


Fig. 2.2: Direct - Indirect Lighting

Indirect light fixtures use a ceiling, wall or other surface as a secondary reflector. It distributes 90 to 100 percent of the light upward. The ceiling and upper walls must be clean and highly reflective to allow the light to reach the work area. They provide the most even illumination of all the types of fixtures and the least direct glare. Indirect light fixtures are usually used in offices. Compared to direct illumination, a considerably higher luminous flux is necessary for achieving the same illuminance on the working plane. [13] Schematic diagram is shown in figure 2.3.

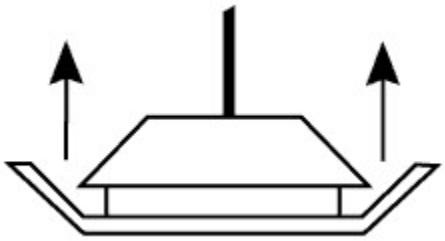


Fig 2.3: Indirect Lighting

Shielded light fixtures use diffusers, lenses and louvers to cover bulbs from direct view; therefore, helping to prevent glare and distribute light. Figure 2.4 shows different types of louvers. [12] Diffusers are translucent or semi-transparent (see-through) covers made usually of glass or plastic. They are used on the bottom or sides of light fixtures to control brightness. Lenses are clear or transparent glass, or plastic covers. The lens design incorporates prisms and flutes to distribute light in specific ways. Louvers are baffles that shield the bulb from view and reflect light. The baffles can be contoured to control light and decrease brightness. Parabolic louvers are specially shaped grids that concentrate and distribute light.

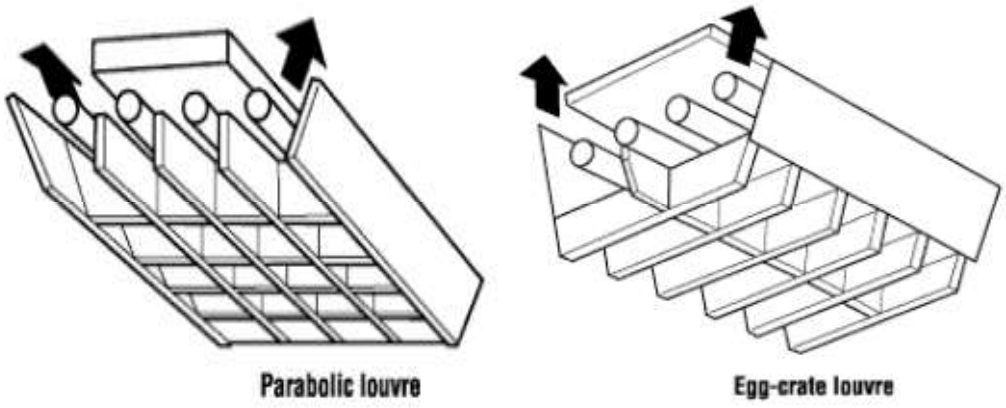


Fig. 2.4: Shielded Lighting

2.8 Lighting Systems

Commercial lighting can be done by adopting 3 general options:

1. General Lighting
2. Localized General Lighting
3. Local Lighting

1. General Lighting

In this type of system, lighting is provided by a regular array of luminaries. In majority of installations general direct lighting is employed. It gives the required horizontal illumination level and uniformity in the entire areas. In such a system any place in office can be used as a workstation. The lighting arrangement need not be changed due to changes in office layout. Figure 2.5 shows a general lighting scheme.

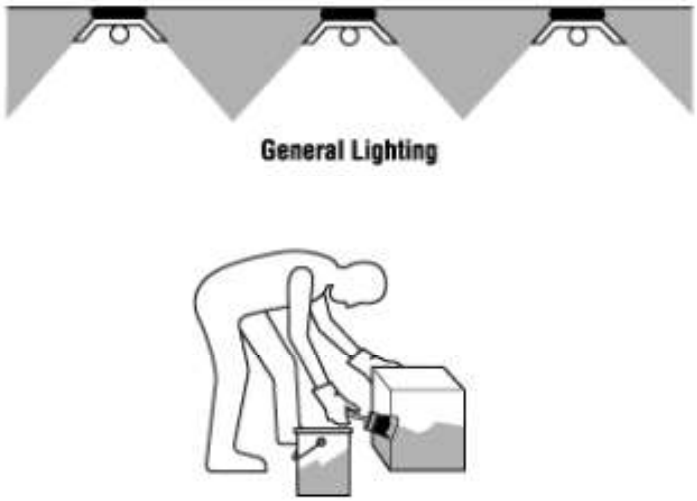


Fig 2.5: General Lighting

2. Localized General Lighting

In this type of system, lighting is provided by an irregular pattern of luminaries related to the working zones in offices; savings can be done by using localized general lighting. Localized-general lighting uses overhead fixtures in addition to ceiling fixtures to increase lighting levels for particular tasks.

This type of illumination consists of ceiling sources distributed with two things in mind—the illumination characteristics of the equipment and the illumination needs of each work station. This type of illumination is indicated for those spaces or work areas that will require a high level of illumination, and it requires knowing the future location of each work station in advance of the design stage. The luminaries should be designed in such a way that it should give the recommended illumination level at workstation and correspondingly lower luminance in non-working areas/circulation areas. In circulation areas the lighting level can be reduced to 50% of level of illumination for visual task. Though this system can give substantial savings over general lighting, it has certain disadvantages. The major disadvantages is that, as the layout in office changes the lighting arrangement must anticipate all futuristic changes and adapt to it with less changes. Figure 2.6 shows a localized general lighting scheme. [15]

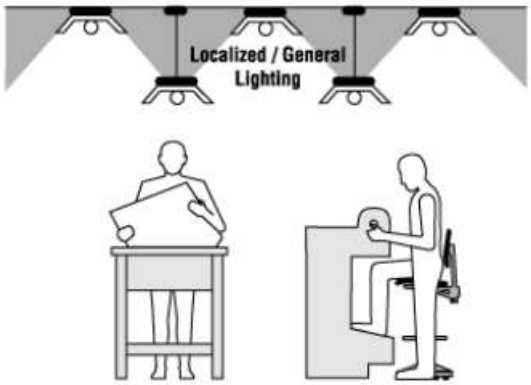


Fig 2.6 Localized General lighting

3. LOCAL LIGHTING

In this type of system, lighting is provided by additional luminaries placed at a small distance from a visual task, which illuminate only a limited area. Local (or task) lighting increases light levels over the work and immediate surroundings. Local lighting often allows the user to adjust and control lighting and provides flexibility for each user. Figure 2.7 shows a local lighting scheme. [16]

Fig 2.7: Local Lighting

Chapter 3
Modern Technology on LED Luminaire

3.1 Introduction

A **light-emitting diode** (**LED**) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. This effect is called electroluminescence.[17] The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor.[18] White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.[19]

3.2 Working Principle

A P-N junction can convert absorbed light energy into a proportional electric current. The same process is reversed here (i.e. the P-N junction emits light when electrical energy is applied to it). This phenomenon is generally called electroluminescence, which can be defined as the emission of light from a semi-conductor under the influence of an electric field. The charge carriers recombine in a forward-biased P-N junction as the electrons cross from the N region and recombine with the holes existing in the P-region [20]. Free electrons are in the conduction band of energy levels, while holes are in the valence energy band. Thus, the energy level of the holes will be lesser than the energy levels of the electrons. Some portion of the energy must be dissipated in order to recombine the electrons and the holes. This energy is emitted in the form of heat and light. Figure 3.1 shows the recombination process.

Semiconductor materials used for producing different colours:

(i) Red: Aluminium gallium arsenide (AlGaAs)
(ii) Orange: Gallium arsenide phosphide (GaAsP)
(iii) Yellow: Aluminium gallium indium phosphide (AlGaInP)
(iv) Green: Indium gallium nitride (InGaN)
(v) Blue: Zinc selenide (ZnSe)
(vi) Ultraviolet: Aluminium gallium nitride (AlGaN)
(vii) Infrared: Gallium arsenide (GaAs)

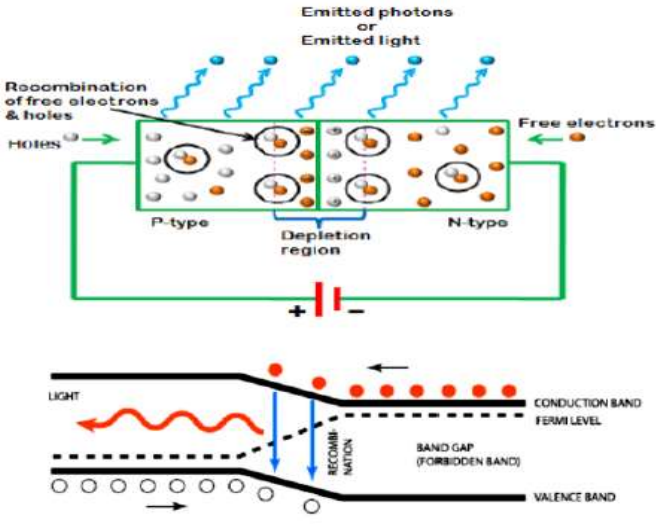


Figure 3.1: Working Principle of LED

3.3 RGB LED (White Light)

RGB LEDs consist of one red, one green, and one blue LED. By independently attenuating each of the three, RGB LEDs are capable of producing a wide colour gamut. There are two primary ways of producing white light-emitting diodes (WLEDs); LEDs that generate high-intensity white light [21]. One is to use individual LEDs that emit three primary colours - red, green, and blue- and then mix all the colours to form white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad spectrum white light, much in the same way a fluorescent light bulb works.

There are three main methods of mixing colours to produce white light from an LED:

- Red LED + Green LED + Blue LED (colour mixing; can be used as backlighting for displays).
- Near-UV or UV LED + RGB phosphor (an LED producing light with a wavelength shorter than blue's is used to excite an RGB phosphor).
- Blue LED + yellow phosphor (two complementary colours combine to form white light; more efficient than first two methods and more commonly used).

3.4 LED Chip Technologies

3.4.1 DIP Chip

DIP (Dual In-Line Package) LEDs are the traditional LED lights. It is what most people think of when they picture LED lights [21]. They look the most like a traditional light with the chip encased in hard plastic generally used with two straight parallel connecting pins. Figure 3.2 shows a DIP chip.

Fig. 3.2: DIP LED Chip

3.4.2 SMD Chip

SMD stands for Surface mounted diode and are much smaller and efficient LEDs than the previous DIP chips. They have become popular due to their versatility and are typically mounted and soldered onto a circuit board. SMD chips have become very important for the development of the LED industry as three diodes are able to be put on the same chip. As well as the brightness being significantly better, they have the capacity to change colour. Some of the chips are made small in order to be used in high end electronics such as laptop computer indicator lights. They are also standalone chips predominantly used LED strips or LED recessed downlights [21]. Figure 3.3 shows a SMD LED downlighter.

Fig. 3.3 SMD LED

3.4.3 COB Chip

Chip on Board (COB) is the most recent development in LED technology. It uses multiple diode chips typically around 9 or more. There is no casing with COB technology which enables a much denser LED array of light compared to SMD. COB chips are being used in an array of different devices. The great advantage of COB modules lies in the highly homogeneous light they emit. That means a consistent light beam is given off, without any visible individual light points. By then adding a ceramic substrate, the best conditions are created for optimal cooling, which in turn serves to increase efficiency and lengthen service life [21]. Typically, in small devices such as cameras and Smartphone, this is due to a high amount of lumens created for a very small amount of energy. Figure 3.4 shows a COB chip.

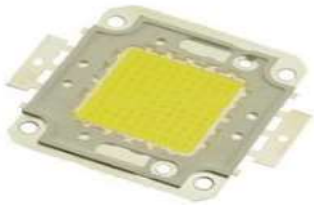


Fig 3.4: COB LED Chip

Comparisons of SMD and COB LED chip

- Compared to SMD, COB LED are small in size. But the temperature gets as high as 74 degree which requires a bigger heat sink. In case of SMD large LED spacing on the board helps heat to dissipate faster.
- SMD chips have higher luminous efficiency than COBs.
- With good performance of heat dissipation, SMD chips could pass the LM80/TM21test. While, few COB chips could pass that.

LIGHT EMISSION: The homogeneous light emitted by COB LED modules unaffected by individual light points or multi shadows. Fig. 3.5 shows the light output comparison of SMB and COB LED.

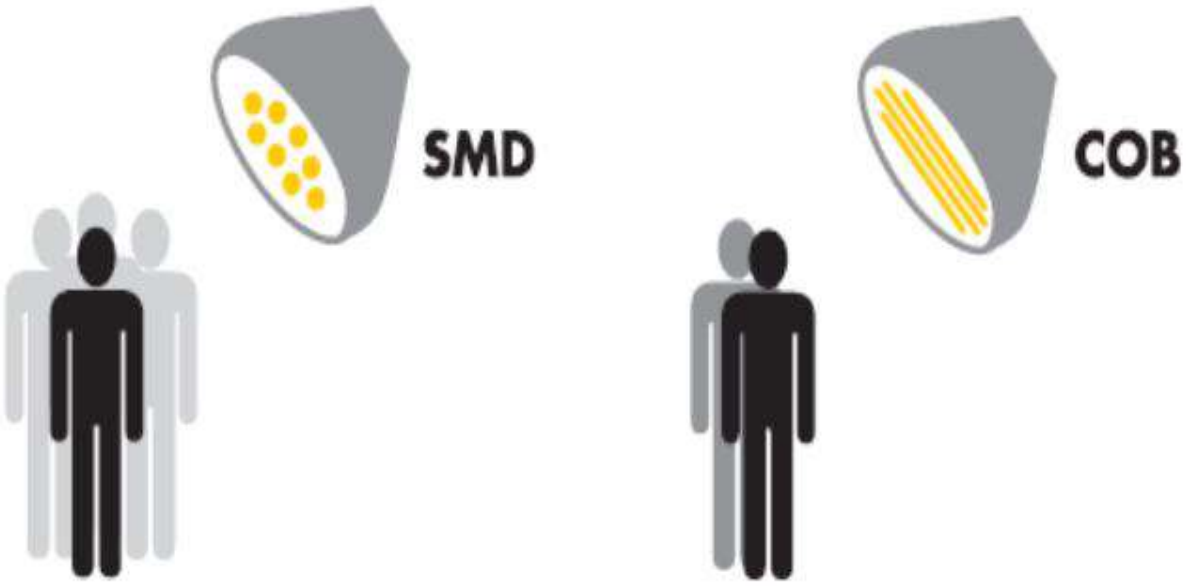


Fig. 3.5: Light Output comparison of SMB and COB LED [19]

3.5 LED BINNING

LED components vary from each other during production. Their difference can manifest in color, forward voltage, and flux. Even within the same production batch, LEDs will be prone to quite large differences. In the SSL field, stable and homogenous light from products is extremely important. For this reason the binning system was implemented. The binning of LEDs means they are measured on a variety of factors. For each individual component this is done under the exact same conditions regarding temperature voltage etc. Measurement data is divided into classes, which we call bins, and the LED components are divided accordingly [23]. This results in batches of LEDs that have only the slightest deviations in performance from one another.

NEED OF LED BINNING:

- LED-to-LED differences after production, is their maximum current and power. As the variations between individual LEDs are big, the current needed to power one led, might overload another. For this reason, the first selection made to divide LEDs is applied forward voltage [23].
- The color of light might vary drastically per LED die; in many applications a multitude of LED components are used to create a single lighting image. For this, the LEDs cannot vary too much in color from their neighbors [23].

3.6 Measurement Standards for LED

3.6.1 LM 79-08

It is the Illuminating Engineering Society of North America (IESNA) approved method for the Electrical and Photometric Measurements of Solid-State Lighting. It measures an LED luminaries or integral lamp as a whole system according to a standard process using specified equipment [24].

The testing report issued according to a standard format will provide the following photometric parameters:

- Total Luminous Flux.
- Luminous Intensity Distribution.
- Electrical Power Characteristics.
- Luminous Efficacy (calculated).
- Colour Characteristics (CRI, CCT).

Now in 2012, BUREAU OF INDIAN STANDARDS comes up with IS-16106 which contains **"METHOD OF ELECTRICAL AND PHOTOMETRIC MEASUREMENTS OF SOLID STATE LIGHTING (LED) PRODUCTS"**. It contains same experiment procedures which are required to generate the photometric parameters of LED luminaire.

3.6.2 IN SITU TEMPERATURE MEASUREMENT TEST (ISTMT)

It is the measurement of the LED source case temperature within the LED system (luminaries or lamp). The measurement is done when operating in it designed position. The measurement is performed at the temperature measurement point (TMP) indicated by the LED package manufacturer. Once ISTMT is known, we check if the temperature within the luminaries is within the temperature of the LM-80-08 LED source report. It is then the basis for lifetime interpolation either based on TM-21-11 or other method.

LED In-Situ Testing Information:

- LED chip or package manufacturer and model number.
- LED chip spec sheet and if possible LM-80 report information.
- Diagram showing where to attach thermocouple; usually in the LED chip or package specification sheet or LM-80 reports.
- Test voltage, current and Power Consumption.
- Driver model number and specification.
- Additional measurement information required (additional thermocouples or driver measurement points.

3.6.3 LM-80-08

It is the Illuminating Engineering Society of North America (IESNA) approved standard for measuring lumen maintenance of LED light sources. LM-80 apply to the LED package, array, or module alone, not a complete system, it is testing a component level. The standard does not provide guidance for extrapolation of testing results [24]. The testing report issued according to a standard format will provide luminous flux for a given current over a 6,000 hours period with interval measurements. Luminous flux will be measure for 3 different LED case temperatures: 55ºC, 85ºC and a third temperature to be selected by manufacturer. Besides, the lumen maintenance, the chromaticity shifts over the measured period.

This report provides

- Luminous Flux Maintenance over 6000Hrs. Testing
- LIFE OF LED
- Maximum chromaticity shift

3.6.4 TM 21-11

It is the Illuminating Engineering Society of North America (IESNA) approved method for Measuring Lumen Maintenance of LED Light Sources. This document provides recommendations for projecting long term lumen maintenance of LED light sources using data obtained when testing them per IES LM-80-08. The results can then be used to interpolate the lifetime of an LED source within a system (luminaries or integrated lamp) using the in-situ LED source case temperature. There is not such a thing as testing, it is a mathematical method based on LM-80-08 collected data.

Among another thing, TM-21-11 will consider:

- If total LM-80 data period is between 6,000 and 10,000 hrs, we consider the last 5,000 hours.
- If total data period is above 10,000 hours, we use the last half of collected data.
- In situ case temperature interpolation using Arrhenius equation between LM-80 temperatures.
- Projections are limited to 6 times the available LM-80 data period so projected and reported lifetime may or not be the same.

The method will provide a projected lifetime for the LED source or system. Life notation results will then use the following standardized nomenclature: Lp (Yk) P: Lumen maintenance percentage. For LED luminaries we consider L70 to be the standard.

After 30% lumen depreciation, we consider the system is not performing its duty anymore and should be replaced (see Lifetime section of Lighting Guide for more details) Y: Length of LM-80 data period in thousands of hours Example: L70 (6k) = 36,000 hours.

3.6.5 Photo-biological Safety Report

In 2006, the IEC adopted the existing CIE S009/E-2002 guidelines, to publish IEC62471:2006 "Photo-biological Safety of Lamps and Lamp Systems" as a dual-logo standard with the CIE. The scope of this standard is to provide guidance for the evaluation of the photo-biological safety of lamps and lamp systems, excluding lasers, emitting light in the spectral region 200-3000 nm.

A measurement methodology and exposure limit values (based on ICNIRP data) are given in the consideration of the six hazards (Fig. 3.5) to the skin and eye for exposure duration of up to eight hours, taken as a working day. No consideration is taken of the potential effects of long-term exposure.

Hazard	Wavelength Range (nm)	Principle Bio-effects	
		Skin	Eye
Actinic UV skin and eye†	200-400	Erythema (sunburn) Elastosis (ageing, wrinkles)	Photokeratitis Cataractogenesis
UVA eye	315-400	-	Cataractogenesis
Retinal blue-light†	300-700	-	Photoretinitis
Retinal thermal†	380-1400	-	Retinal burn
Infrared radiation eye	780-3000	-	Corneal burn Cataractogenesis
Thermal skin	380-3000	Skin burn	-

Fig. 3.5 Six Photo-biological Hazards

A four-tier classification structure, based on permissible exposure time before exceeding the EL of each hazard, is defined, ranging from "Exempt" to "Risk Group (RG) 3" (Fig. 3.6).

Risk Group	Philosophical Basis
Exempt	No photobiological hazard
RG1	No photobiological hazard under normal behavioral limitation
RG2	Does not pose a hazard due to aversion response to bright light or thermal discomfort
RG3	Hazardous even for momentary exposure

Fig. 3.6: Risk Group and their Philosophical Basis

In the case of retinal hazards, the aversion-response time of the eye is taken into account. It should be noted that this classification system is different from the class system used for lasers.

The evaluation consists of a complex series of measurements of spectral irradiance (200-3000 nm) in consideration of hazards to the skin and front surfaces of the eye, and spectral radiance (300-1400 nm) in consideration of hazards to the retina. Measurements are performed in specific geometrical conditions which replicate biophysical phenomenon, such as the effect of eye movements on retinal irradiation, and at a measurement distance dependant on the application of the source in consideration i.e. general lighting service (GLS) or non-GLS.

In 2012, BIS also created their own Photo-biological standards i.e. IS-16108 which adopts the IEC62471:2006.

3.7 LED Driver

In electronics, an **LED circuit** or **LED driver** is an electrical circuit used to power a light-emitting diode (LED). The circuit must provide sufficient current to light the LED at the required brightness, but must limit the current to prevent damaging the LED. The voltage drop across an LED is approximately constant over a wide range of operating current; therefore, a small increase in applied voltage greatly increases the current. Very simple circuits are used for low-power indicator LEDs. More complex, current source circuits are required when driving high-power LEDs for illumination to achieve correct current regulation. So, basically LED is a constant current source.

The internal circuit of a LED driver can be simplified in Fig. 3.7

Fig.3.7: Simplified internal circuit of LED Driver

The circuit operation as follows:

- In India, there is standard voltage supply is 240 V, 50 Hz AC. But the driver is made so that it can operate on various voltage range,
- Then a Surge Protector is connected. The Surge Protection Device **(SPD)** is a component of the electrical installation protection system. This device is connected in Series or parallel on the

power supply circuit of the loads that it has to protect. Surge protector is used to protect the driver from Undervoltage condition.

- Then there is Rectifier which converts the AC current into DC Current.
- After the conversion, the output DC current is not pure DC current. There some harmonics are present. So, a PFC filter is used to eliminate the harmonics which in turn reduce losses in installations, reduce electricity bills and provide extra electrical capacity for increased production.
- After that, Step down Chopper is used to reduce the input DC current.
- Then a Pi or T filter is used to make that DC current from Step down Chopper to ripple free DC current. The filter is basically arrangement of capacitor which in turn improves the Power Factor.

3.7.1 Potted Driver

In electronics, **Potting** is a process of filling a complete electronic assembly with a solid compound for resistance to shock and vibration, and for exclusion of moisture and corrosive agents. Generally thermosetting plastics or silicone rubber gels are used.[25] Many sites recommend using a potting product to protect sensitive electronic components from impact, vibration, and loose wires. [26]
In the potting process, an electronic assembly of the driver is placed inside a mold (i.e. the "pot"[27]) which is then filled with an insulating liquid compound that hardens, permanently protecting the assembly. The mold is part of the finished article and can provide shielding or heat dissipating functions in addition to acting as a mold. [28]
When potting a circuit board that uses surface-mount technology, low glass transition temperature (T_g) potting compounds such as polyurethane or silicon are used, because high T_g potting compounds may break solder bonds through solder fatigue as they harden and shrink at low temperatures.[29]
The potted driver gives advantage on

1. Vibration proof performance i.e. in case of outdoor luminaire especially luminaire arrangement on bridge, there is so much vibration which in turn damages the shouldering component.
2. Better thermal and heat dissipation i.e. in a driver, the junction temperature rises due to electrical cause which in turn generates heat. This heat comes to the driver surface through the silicone gel potting and from there heat dissipates.
3. Electrical safety of the driver component i.e. if in case a water molecule enters into the driver then it cannot go to the driver junction due to silicone gel potting.

Fig. 3.8 shows a picture of potted driver where the driver compartment is filled with silicon gel.

Fig: 3.8: Potted Driver

3.8 Low Power LED Chip

Low power LED Chips are initial LEDS. It covers the ranges from 0.05 – 0.10 Watt. Its only application is limited on indicator lights. [30]

3.9 Mid Power LED Chip

Mid power LED chips covers the range from 0.25 – 0.50 Watt. The diodes in these LEDs are packed more densely relative to high power white LEDs and give more uniform appearance. It delivers 35-45 Lumens per LED. Driving current is 100-150 mA and Forward voltage is 2.85-3.0 V_{dc}.

Their low power consumption often allows standard PCB materials, such as FR-4 printed circuit boards, to be used. It comprises of polyphthalamide plastic substrate that supports both royal blue LED die as well as Yttrium Aluminium Garnet that combines with white light and forms a beam. Junction temperature of mid-power LEDs varies from 25 – 60 ºC.

Mid power LEDs occupies the most of the market. Now a day, CREE, OSRAM are investing more in making this LED chip due to their cost effectiveness. [30]

3.10 High Power LED Chip

High power LEDs covers the range from 1.0 – 2.5 Watt and they allows higher levels of current to be applied to the semiconductor junction itself, making for explosive growth in the areas of high power LEDs.

High power LEDs are used for better brightness. LEDs with higher current rating 700mA are considered as high power LED. High power LEDs are mainly used when highest efficacy and highest light output is required as these LEDs are alternative for longer lasting and more efficient traditional lamps. Now a day's incandescent and halogen conventional technology is replaced by high power LEDs.

But there is a difference between High Brightness LED and High Power LED. High brightness LED produces 50 Lumen and High power LED consumes more than 1W Power.

Advantage of High power LEDs are that they generates sufficient lumens output (125-140 Lumen/Watt) which are ideal for lighting applications and high colour rendering capabilities. [30]

Disadvantages are they dissipate more heat. Their junction temperature rises more than 85ºC which in turn makes them more expensive.

3.11 Lumen Maintenance in LED Luminaire

Typical Luminous efficacy of High power LED chip is 160 Lumen/Watt. But due to the thermal loss in LED, the luminous efficacy reduces up to 148 Lumen/Watt, considering typical 7% thermal loss. This thermal loss can be improved by thermal management of LED.

Then a secondary optics is put on the LED chip for beam distribution. Considering the lens loss approx 10%, the system luminous efficacy now becomes 135 Lumen/Watt.

A toughened glass is then put to protect the entire module to make them protected from external particles. Considering 10% toughened glass loss, system luminaire efficacy now becomes 123 Lumen/Watt and after considering driver loss which is approx 12%, the total system efficacy now

becomes 112 Lumen/Watt which varies in different ambient conditions and becomes 100 Lumen/Watt as overall system luminous efficacy of the LED luminaire. [30]

3.12 Types of LED Luminaire

Depending upon applications, below mentioned LED luminaires is generally available in market [30].

❖ **Panel Light**

Panel lights are generally used office and education places. Their dimension varies depending upon the ceiling design, false ceiling dimension and required lux level. They are generally available in 2ft x 2ft, 1ft x 4 ft. They can be recessed, surface or pendent mounted depending upon their application. Generally their body is made of CRCA with white powder coated and beam angle distribution is 120 degree. In India, now a day, 100 Lumen/Watt LED panel light is common. Technologies are improving to increasing luminous efficacy in respective to energy savings concern. Fig. 3.9 shows typical panel light.

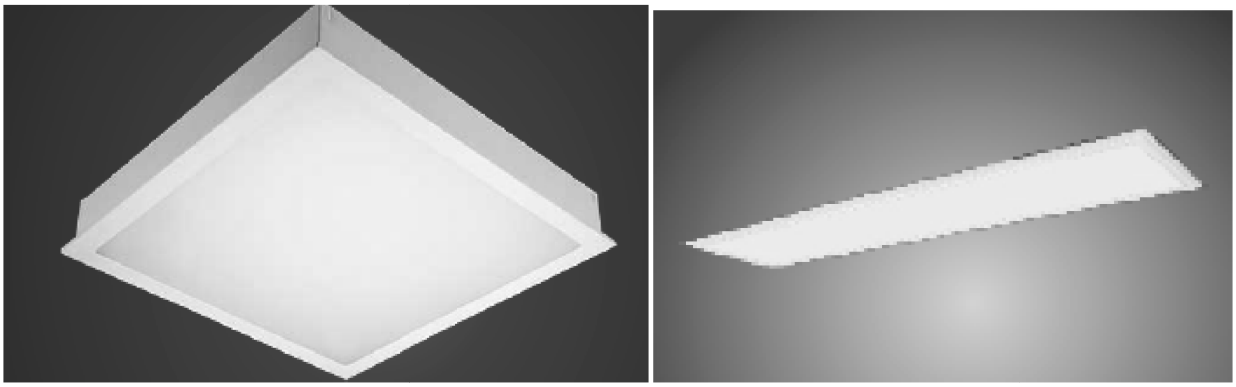


Fig. 3.9: Typical Panel Light

❖ **Downlighter**

LED Downlighters are light fixtures that can be easily installed into a hollow space in the ceiling. They are brilliant energy-saving lighting solutions that are designed for a plethora of

applications. **LED Downlighters** emit light in a downward direction with an accurate and narrow beam. They can be square or round with various dimensions depending upon their applications. Their mounting can be recessed or surface with minimum IP20 protection.

Fig. 3.10 shows typical LED Downlighters.

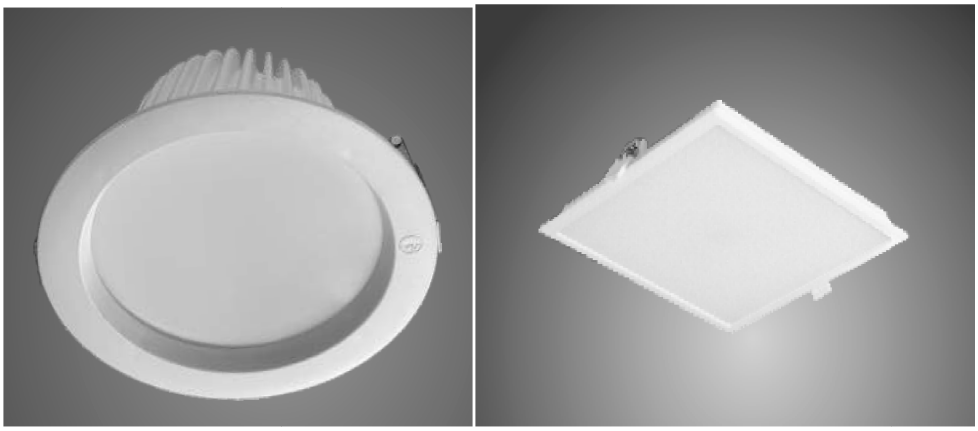


Fig. 3.10: Typical LED Downlighter

❖ **Track Spot**

Track lighting is a method of lighting where light fixtures are attached anywhere on a continuous track device which contains electrical conductors.[1] This is in contrast to directly routing electrical wiring to individual light positions. Tracks can either be mounted to ceilings or walls, lengthwise down beams, or crosswise across rafters or joists. They can also be hung with rods from especially high places like vaulted ceilings.

For Lighting from Track, LED Spot lights are used which consists of COB LED chip which allows to produce 4-19 degree beam angle. The Power Consumption of the spot lights varies from 3-12 Watt depending upon the application. Fig. 3.11 shows typical Track Spot Luminaires.

Fig 3.11 Typical LED Track Spot

❖ **Linear**

Linear LED lights are generally 1ft x 4ft dimension lights which can be recessed mounted or suspended depending upon application. It allows the ceiling to look continuous linear lighting arrangement. They are generally used in modern office spaces.

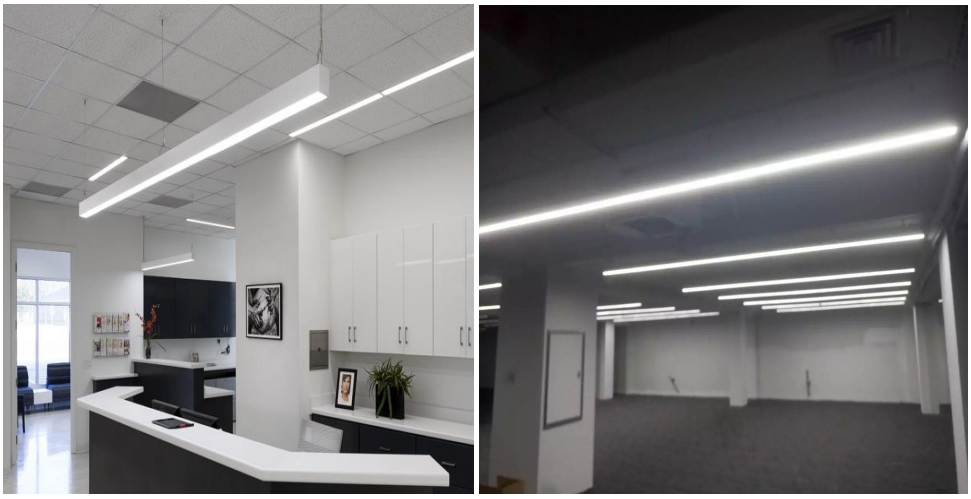


Fig. 3.12 Typical LED Linear Light

❖ **LED Integrated Batten**

The Integrated **LED batten** is a lighting fixture with one or two **LED** tubes built in. They offer many advantages over traditional fluorescent fixtures. They are light weight and slim line providing an unobtrusive and stylish look also gives compact looks. Depending their application they can be IP20 (Indoor) or IP65 (Industrial and Outdoor) or higher. Generally T8 and T5 LED battens are available in Indian Market. Fig. 3.13 shows typical LED integrated batten.

Fig. 3.13 Typical LED Integrated Batten

❖ **Tube**

LED tube is a type of LED lamp used in fluorescent tube luminaires with G5 and G13 bases to replace traditional fluorescent tubes. As compared to fluorescent tubes, the most important advantages of LED tubes are energy efficiency and long service life.

LED tubes are usually produced using a large number of low or medium-power LEDs. With the help of these, light output and heat conduction are balanced out across the entire tube length. The operating temperature of LED tubes is lower as compared to traditional lighting technologies, and a LED tube produces less heat than traditional fluorescent lamps.

Among the most important properties of LED tubes is the possibility of light direction – the entire luminous power of a LED tube can be directed in a narrower beam to wherever the light is required. Fig. 3.14 shows typical LED tube.

LED tubes are typically made of durable plastic and aluminium, which means that they will not break easily. Due to Technological improvement, 150 Lumen/Watt LED Tube light are available in market.

In general, the control gear i.e. driver is integrated into the LED tube, but it can also be located outside the actual light source.

Fig. 3.14 Typical LED Tube

❖ **Post-top**

Post Top LED has a vintage and classy look which makes the ambience aesthetically appealing. They are mounted on 1.5 m poles to 2 m poles depending upon beautification. Post-top luminaires must have proper IP and IK protection. Post-top luminaires not only acts as a luminous source also acts as a landscape material. Fig. 3.15 shows typical LED Post-top.

Fig 3.15 LED Post-top

❖ **Bollards**

Bollard lights are a type of architectural outdoor lighting fixture comprising short, upright ground-mounted units, typically giving off light from the top or the sides, and used to illuminate walkways, steps or pathways. As outdoor luminaire, Bollards must have proper IP and IK Protection. Fig. 3.16 shows typical LED bollard.

Fig. 3.16 Typical LED Bollard

❖ **Footlight**

A **footlight** or Step light is that type of luminaires which is used to illuminate steps. Footlight is an outdoor luminaires which requires proper IP and a higher IK protection. Fig. 3.17 shows typical Footlight.

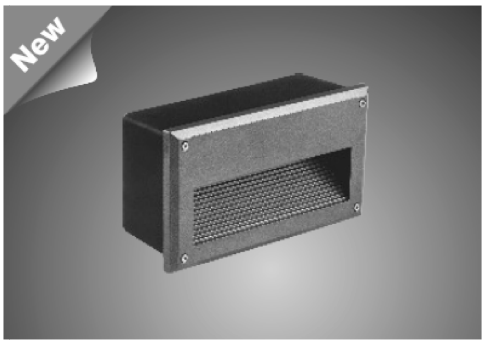


Fig. 3.17 Typical LED Footlight Luminaire

❖ **Floodlight**

A floodlight is a broad-beamed, high-intensity artificial light. They are often used to illuminate outdoor playing fields while an outdoor sports event is being held during low-light conditions. LED floodlights are bright enough to be used for illumination purposes on large sport fields or large areas. The main advantages of LEDs in this application are their lower power consumption, longer life, and instant start-up (the lack of a "warm-up" period reduces game delays after power outages). When designing a floodlighting installation, the weight of each floodlight is crucial as it decides the load on high mast which in turn requires designing the high mast mechanics. As outdoor device, floodlight must have proper IP protection.

Fig. 3.18 shows typical LED Floodlight.

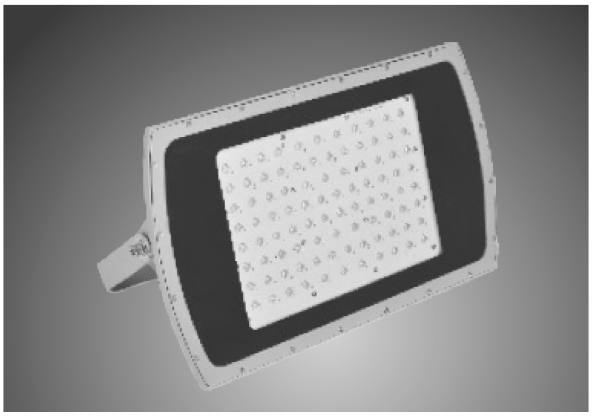


Fig. 3.18: Typical LED Floodlight Luminaire

❖ **Well glass**

A transparent lighting device used as a main lighting device in mines. Its distribution characteristics are simple, since there is no control of light other than that provided by the interior of the upper part of the fitting, which absorbs a large proportion of the upward flux component from the lamp and reflects the remainder. Generally Well glass Luminaire made of Pressure die cast aluminium body, Well glass luminaires have proper IP and IK protection as their application is in Industrial areas. Fig. 3.19 shows typical LED Well glass Luminaire.

Fig. 3.19: Typical LED Well Glass Luminaire

❖ **Highbay**

Typically, High Bay Lights apply to any large area with a ceiling height greater than 20 ft. it is often find bay lights that are 150W or above referred to as High Bay with a beam angle of 90 degrees or narrower. They focus light more directly to create powerful illumination at a long range High Bay lights are usually found in warehouses, factories, and hangars with proper IP and IK protection depending upon application.

Fig. 3.20 shows typical LED Highbay Luminaire.

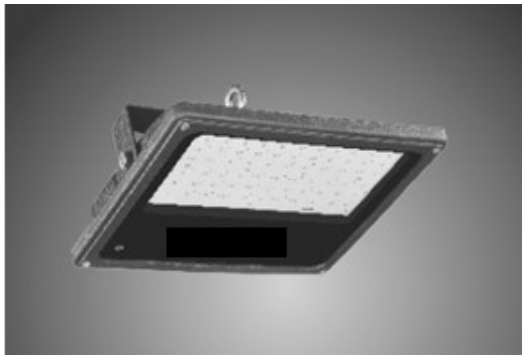


Fig. 3.20 Typical LED Highbay Luminaire

❖ **Canopy**

LED canopy lights are ideal lighting solutions for a variety of applications, especially outdoor locations such as parking garages, covered strip mall walkways and gas stations. The right outdoor canopy lighting fixtures are unobtrusive and make the space feel welcoming, safe and attractive. Canopy lights should have proper IP and IK protection. Fig. 3.21 shows typical LED Canopy Luminaire.

Fig 3.21 Typical LED Canopy Luminaire

❖ **Streetlight**

A street light, light pole, lamppost, street lamp, light standard, or lamp standard is a raised source of light on the edge of a road or path. An LED street light is an integrated light that uses light emitting diodes (LED) as its light source. These are considered integrated lights because, in most cases, the luminaire and the fixture are not separate parts. In manufacturing, the LED light cluster is sealed on a panel and then assembled to the LED panel with a heat sink to become an integrated lighting fixture. Most LED street lights have a lens on the LED panel, which is designed to cast its light in a rectangular pattern, an advantage compared to traditional street lights, which typically have a reflector on the back side of a high-pressure sodium lamp.

A drawback of new trends LED Street light is that most light is directed to the road, and less light to the footpaths and other areas. This can be addressed by the use of specialized lens design and adjustable mounting spigots.

The beam distribution of the LED Streetlight is like batwing shape i.e. the light distributes more along the road rather than across the road. They must have proper IP and IK protection. Fig. 3.22 shows typical LED Street light Luminaire

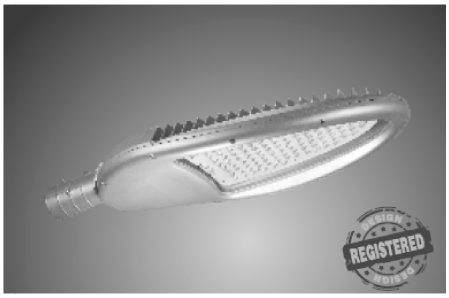


Fig. 3.22 Typical LED Street Light Luminaire

❖ **Clean-room Application**

Clean-room application luminaires are sealed enclosure which separates its internal lighting components from the surrounding environment, protecting them from dirt, dust, moisture and other contaminants. It also protects the surrounding environment from out-gassing, heat, arcing, air pressure leakage, electromagnetic Interference (EMI) and other conditions that could negatively affect process integrity or personal safety. Hospitals, laboratories and production environments like the food industry require lighting solutions that offer pure light, are easy to clean, dust free and leave no room for errors. Fig. 3.23 shows typical LED clean-room application Luminaire. They must have proper IP value to protect from proper dust and liquid particles.

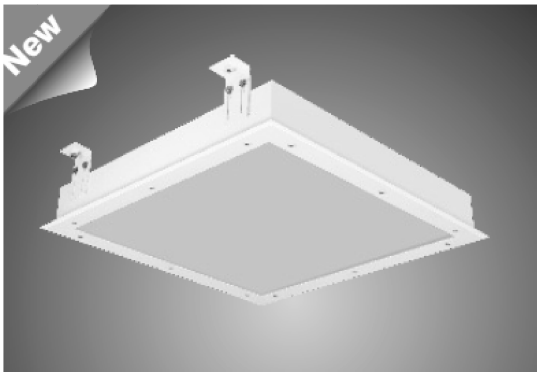


Fig. 3.23: Typical LED Clean-room Application Luminaire

❖ **Tunnel Light**

Tunnel lighting is necessary to solve the problem of abrupt adaptability of the environment inside the tunnel. It is necessary to balance the adaptability of the inside and outside luminance for the person entering or exiting the tunnel. This design is based on certain critical length of the tunnel. At night a tunnel may be lighted in such a way that it would be similar to a stretch of open road. The selection criteria of tunnel LED luminaire is proper IP value (preferred IP67 or higher) and a proper IK value (generally IK10). Fig. 3.24 shows typical LED Tunnel Light Luminaire.

Fig. 3.24: Typical Tunnel LED Light Luminaire

3.13 Selection criteria for LED luminaires

There are some specific criteria which may helps to choose better LED luminaires. The criteria are:

1. System Luminous Efficacy
2. System Luminous Flux
3. Power Consumption
4. CCT
5. CRI
6. Power Factor
7. Total Harmonic Distortion
8. Housing and Glass or Diffuser material
9. Operating Voltage Range
10. IP value
11. IK value
12. Surge protector
13. Photo-biological Safety Report availability
14. LED chip lifetime (LM80 Report)
15. BIS Certification

3.14 Advantages of LED

1. Efficiency: LEDs produce more lumens per watt than incandescent bulbs. LEDs are capable of 135 lumens per watt.

2. Lifetime: LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer.
3. Colour: In LED technology, we are able to obtain each illumination light color. LEDs can emit light of an intended colour without using any colour filters as traditional lighting methods need. This is more efficient and can lower initial costs.
4. Size: LEDs can be very small (smaller than 2 mm2) and are easily populated onto printed circuit boards.
5. Warm up time: The warm up time is the time required for the bulb takes to reach full brightness. LED Light Bulbs are described as being instant on, meaning that they will reach full brightness as soon as they are turned on. LED lights turned on within nanoseconds. One of the major strengths of using LED technology to illuminate your environment is that they will be able to provide you with little to no warm up time.
6. Dimming: LEDs can very easily be dimmed either by analog dimming and pulse-width modulation. Analog dimming simply controls the drive current fed to the LEDs. Full brightness uses the full drive current, and the current is linearly reduced to achieve dimming, reaching zero in the off condition. In pulse-width modulation (PWM) dimming, the LEDs are driven with full amplitude pulses of current and (as the name implies) the width of the pulses is varied to control the apparent brightness.
7. Cycling: LEDs are ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or HID lamps that require a long time before restarting.
8. Slow failure: LEDs mostly fail by dimming over time, rather than the abrupt failure of incandescent bulbs.
9. Shock resistance: LEDs, being solid-state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs, which are fragile.
10. Environment friendly: LED lights contain no toxic elements. Most offices currently use fluorescent strip lights which contain noxious chemicals such as mercury. This will contaminate the environment when disposed of in landfill waste. Disposal has to be arranged through a registered waste carrier so switching to LED avoids the cost and time implications required for compliant disposal – and helps to protect the environment from further toxic waste.

3.15 LED Market in India

From Ken Research Report 2015 [31], it is shown that LED market growing at compound annual growth rate up to 48.1% in financial year 2019-20. LED Commercial segment growing at compound annual growth rate of 49.3% and LED market expected to be at INR 22000 crores by financial year 2019-20. Commercial lighting i.e. IT, commercial offices, education shop and hospitals is the fastest growing segment with in Lighting. Fig. 4.25 shows Ken Research Report.

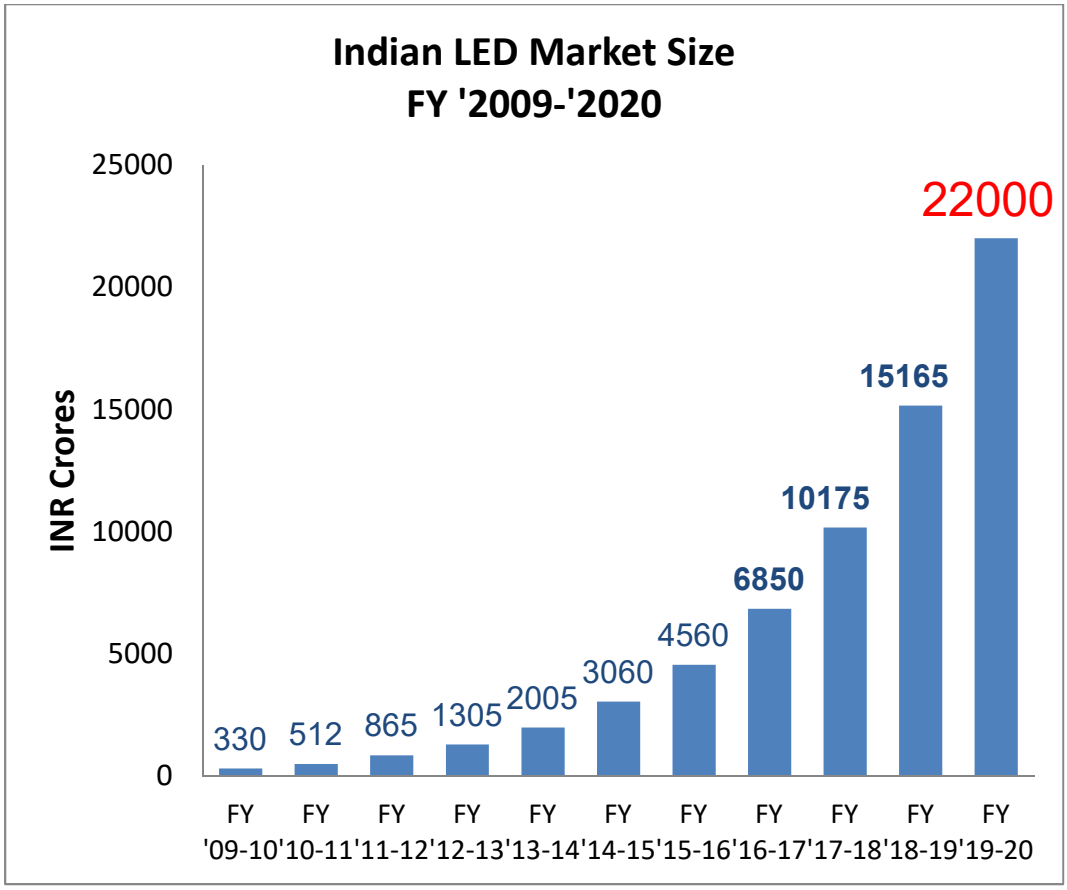


Fig. 3.25: Ken Research Report [31]

Chapter 4
Lighting Design Objectives and Criteria

4.1 Introduction

In recent years the field of lighting has been struggling with two prominent forces energy efficiency and lighting quality. Just as the profession of lighting design began to emerge in which the quality of lighting is held in high esteem, energy efficiency also became a concern in the design of buildings [32]. Lighting designers initially faced the choice between attractive, well- lighted spaces and spaces that used a minimum of energy. Lighting design can have a number of objectives. Merely facilitating to carryout out the work is rather a limited view of what a lighting installation can serve. Ideally these objectives are decided by the collaboration between the clients and the designers. For traffic routes priority would be given to ensure the rapid movement of the vehicles and safety. In urban areas safety is the sheer important factor although the appearance of the people and building are also important. Business sectors use lighting for attracting more customers and promotion of their respective brands. Therefore, when designing it is always a good practice to know the expectations that the lighting has to be fulfilled. To prevent loss of money and resources for failing to reap the benefits, remedial solution would be a holistic lighting strategy for lighting design. This approach starts with in-depth conversation with the client and the other members of the design team to chalk out a design brief. There should be clear cut idea regarding the demands of the client and function of the space.

4.2 Lighting Design Objectives [33]

4.2.1 Safety and Health

Interior lighting should enable the occupants to see sufficiently well to work and move about in safety, both under normal condition and in the event of an emergency involving power failure. Lighting must not create conditions, which are injurious to people's health.

4.2.2 Performance

The type of work that takes place and the characteristics of the workforce together define the nature and variety of visual task in an interior. The quality and quantity of lighting required to achieve satisfactory visual conditions depends upon these tasks.

4.2.3 Appearance and Comfort

The way in which the space is illuminated can affect its character and appearance of objects within it. Where the creation of mood or atmosphere is predominant this must be the prime lighting objective.

4.2.4 Visual Amenity

Undoubtedly the lighting can bring a visual amenity to space but it cannot be measured whether it can aid in improving the performance. Studies have shown that people respond to the lit appearance of a room on two independent dimensions: visual lightness and visual interest. Visual lightness describes the overall lightness of the space, which is related to the average luminance of vertical surfaces. Visual interest refers to the non-uniformity of the illumination pattern or the degree of light and shade. Depending on the application, people prefer some modulation in the light pattern rather than an even pattern of illumination. Although variation in the light pattern is desirable, it has to

be seen as meaningful in terms of the application and the architecture. Examples could be like highlighting displays within are tail outlet, or a floral display in a hotel lobby. There are two further areas of visual amenity that are needed to be considered and these are colour rendering and colour appearance of the lighting. The required colour rendering will depend on the functions the lighting is designed to fulfill. Where fine colour discrimination is crucial, light sources with a CIE general colour rendering index of at least 80 should be used. Where a natural appearance is required for people and objects, light sources with a CIE general colour rendering index of at least 60 or higher should be used. Where such functions are not important, poorer colour rendering light sources can be used. As for colour appearance, a light source with a Correlated Colour Temperature (CCT) ≤ 3000 K will appear warm and if it has a CCT ≥ 5300 K it will appear cool. Choice of the CCT of the lamp will depend on the nature of the space. In quasi-domestic situations, such as hotels, a warm colour appearance will be required whereas, in commercial interiors a CCT of around 4000 K is appropriate. Personal observation and trial installations are the two things that help in understanding of the visual amenity.

4.2.5 Architectural Integration

Understanding the space plays an important role in arriving at a decision on what lighting is to be employed. All the staffs ranging from the dimensions, finishes, texture and colour of the materials forming the space and the appearance of the luminaires, lit and unlit should be considered if the desired atmosphere is to be attained. A good option is to start with the day lighting. This means considering the amount and pattern of daylight required for the particular application, and hence the size and positions of windows and roof lights. But windows cannot be designed on the basis of the day lighting alone because at the same time other visual, thermal, acoustic and privacy issues are needed to be met. After making decision on day lighting, the artificial lighting can be planned. Integration of the artificial lighting with the architecture is not limited to considering only its operation with respect to the day lighting, but the appearance of the luminaires and controls and the way they are incorporated into the fabric of the building, as well as the lighting effect produced.

4.2.6 Energy Efficiency & Sustainability

It is always encouraged to use energy as efficiently as possible without compromising with the visual function that the lighting has to serve. Efficient lamps, luminaires and control circuits are helpful in achieving energy efficiency. Design option such as task/ambient lighting may further aid in attaining energy efficiency. Automatic control of lighting is another strategy for an energy lighting efficient solution. It is also necessary for the lighting industry and its customers to use equipment that is sustainable. This means that the materials used are wherever possible from renewable sources and that at the end of life the redundant equipment can be disposed of safely with most of the base materials being recycled.

4.2.7 Maintenance

It is known that both daylight and artificial light depreciate with time. A maintenance program is needed to be designed and implemented so as to arrest that effect. As the maintenance programme plays a significant role in lighting design, the designer will need to state the maintenance programme on which the design has been based; otherwise there could be problems when a client is comparing

different design proposals. It will also be important for the client to be provided with a maintenance schedule so that they know what will need to be done. [34]

4.2.8 Costs

Cost of a project is a very important factor. Cost of every project has basically two parts capital costs and running costs. Capital costs are the first thing that needed to be agreed by the client otherwise lot of time will be wasted. The operational costs include the cost of the electricity consumed, which comprises items such as standing charges, maximum demand charges and electricity unit costs. They will also include the cost of maintenance, which includes cleaning and re lamping throughout the life of the installation. In some cases charges may have to be budgeted for the disposal of redundant equipment although this may be borne by the supplier. The two cost elements are to be considered together in terms of life cycle costing to avoid any kind of inconsistency.

4.3 Lighting Design Criteria

It is not possible to express all the design objectives as measurable quantities. The quantitative criteria can be done in terms of illumination level, uniformity and glare.

4.3.1 Average Illuminance (E_{avg})

The lighting of any work place should be both sufficient and suitable in terms of:

1) Adequate quantity of light on the work tasks and surrounding area.

2) The light should be such that it should not have any harmful effect on people's health and performance.

The code of practice for interior and industrial recommends illumination levels according to the tasks involved. They are mentioned in terms of the mean illumination levels throughout the maintenance cycle of lighting system and averaged over the relevant area. Relevant area may be the whole interior or just that occupied by tasks and immediate surroundings. [35]

4.3.2 Overall Uniformity (U_O)

Code of practice recommends that the uniformity of illuminance should be measured as the ratio of minimum illuminance to the average illuminance over the task area. It is important for three basic reasons:

i) An excessive variation in illuminance means that certain parts receive fewer illuminations than desired.

ii) Illuminance in the immediate surrounding can affect the visual performance and comfort.

iii) Uneven lighting can be termed as unsatisfactory lighting.

4.3.3 GLARE

Glare can be defined condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both due to an unsuitable distribution or range of luminance or to extreme contrasts in space or time. [35]

Glare in the installation is defined by two different terms:

1) Disability Glare

2) Discomfort Glare

4.3.3.1 Disability Glare

Disability Glare is the glare, which impairs the vision of objects without necessarily causing discomfort.

4.3.3.2 Discomfort Glare

Discomfort Glare is the glare, which is distracting, annoying or uncomfortable but does significantly reduce the ability to perform visual tasks.

Degree of discomfort glare is measured by **Unified Glare Ratio (UGR)** [35]. It is expressed by the formula –

$$\mathbf{UGR = 8 \log (0.25/L_b) \Sigma_n (L^2 \omega / P2)}$$

Where,

L_b: Luminance in the field of view (cd /m2) (not including luminaire luminance).

L: Luminance of a luminaire in the direction of an observer.

ω: Solid angle of a luminaire subtended to the observer.

P: Position index of a luminaire.

4.3.4 Upward Light Output Ratio (ULOR)

It is a prime considerable parameter for outdoor lighting. ULOR is the ratio of upward flux of luminaire measured under specified practical conditions with its own lamp and equipment to the sum of own individual fluxes of the same lamps when operated outside of the luminaire with same equipment under specified condition [35].

ULOR shows the efficiency of the luminaire. Less the ULOR, luminaire is more efficient. As per IGBC, Green Building Ratting System, version 3.0, Design exterior lighting such that no external light fixture emits more than 5% of the total initial designed fixture Lumens, at an angle of 90 degrees or higher from nadir (straight down).

Chapter 5
Lighting Design Methodology

5.1 Introduction

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 [36]. The use of a structured design process helps to avoid this. This chapter explains in detail the methodology used in the successful completion of the project. The assumptions made, the luminaire specifications and the tools used have also been mentioned in this chapter.

5.2 Input Data

➢ Drawing of the area giving plan and elevation

This detail helps in deciding the length, width and height of the area. It also gives information about the type of ceiling and any constraints in locating the luminaires [36]. If AutoCAD layout drawing is not available direct site survey can be conducted to get these details.

➢ Reflection Properties of Surroundings

This data helps in deciding the reflection factors of the ceiling, walls and floor. Normally the client does not specify this data. In such cases, the environmental condition prevailing in the area and experience of the designer helps in deciding the reflection properties [36].

➢ Required Illumination Level

This will help in deciding the illumination level for the particular type of application from Indian Standards.

➢ Layout and Heights of Machine and Tools

This will help in location of luminaires and also determining the working plane height. From AutoCAD layout we have idea of elevation [36].

5.3 Method of Lighting

At this stage, consideration is given to how the light is to be delivered. The lighting may be recessed, surface mounted, wall 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 [36].

5.4 Selecting 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 [36]:

- Light output (lumens)
- Total input Power Consumption
- Efficacy (lumens per Watt)
- Surface brightness / glare
- Colour characteristics
- Electrical characteristics

- Requirement for control gear
- Compatibility with existing electrical system
- Suitability for the operating environment

A number of factors also affect luminaires choice [36]

- Characteristics of the light source and control gear
- Luminaire efficiency (percentage 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
- IP rating and IK rating
- Surge Protection in KV
- Compatibility with existing electrical system
- Ambient temperature for operation
- Diffuser/Optical compartment material
- Thermal management

5.5 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 [37]:

- 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.

5.6 Lighting Calculation Methods

Lighting calculations methods fall into three broad categories:

I. Manual Calculation Method

II. Three-Dimensional Modeling

III. Visualization

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

5.6.1 Manual Calculation Methods

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 wide variety of shapes of luminous objects. The majority of these now have been superseded by computer programs [36].

5.6.1.1 LUMEN METHOD

The Lumen method was the mainstay for interior lighting and has remained in use as a quick and relatively accurate method of calculation interior illuminance. The Lumen Method calculates the average illuminance at a specific level in the space, including allowance for the light reflected from the interior surfaces of the room. The calculation method has a set of assumptions that, if allowed gives a reasonable visual environment. Inadequate attention to the assumptions will produce poor result.
The basic assumptions are [36]:

- 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 factors.

Lumen Method Formula

The number of luminaires required to achieve the desired average illumination level for an interior is calculated by the Lumen method using the formula:

$$E = (n*N*\varphi*UF*MF)/A$$

Where,
E =average illuminance over the horizontal working plane
n = number of lamps in each luminaire
N = number of luminaire
φ =initial bare lamp luminous flux
UF = Utilization factor for the horizontal working plane
MF=Maintenance factor
A=Area of the horizontal working plane

Utilization Factor (UF)

The Utilization factor or Coefficient of Utilization (COU) of a luminaire is the percentage of the light emitted by the light source, which contributes in illuminance on the surface. As this factor takes into account the direct as well as indirect component of light, it is dependent on the shape and size of the room, mounting height and also the reflection properties of the surroundings.
The room indices generally specified in the UF chart is 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0 &5.0. The reflectance generally given are R_f=10, 20, 30%, R_w=10, 20, 30, 50% and R_c=30, 50, 70%. For finding the UF, first the Room Index is to be calculated.

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 floor and ceiling surfaces to the area of the width .For rectangular rooms room index is given by

$$\textbf{Room Index (RI)} = (L*W)/ (L+W) *H_m$$

Where,

L= length of the room in meter.

W= width of the room in meter.

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

$H_m = H-H_s-H_{wp}$

Where

H= Height of the room

H_s= Suspension Height

H_{wp}= Working Plane Height

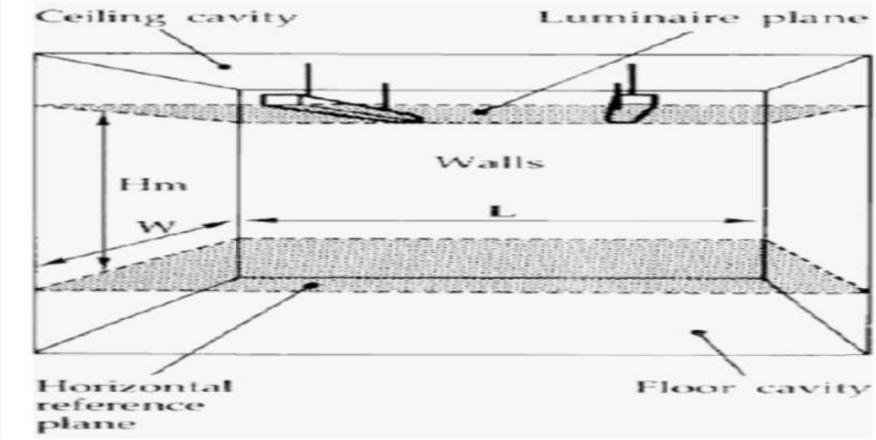


Fig 5.1.Room Index Calculation

The formula for room index is applicable only for the areas the length of the areas where the length of the area is less than or equal to five times the width of the area. If the room is re-entrant in shape, for example L shaped, and then it must be divided into two or more non-re-entrant sections, which can be treated separately. Fig. 5.1 shows Room index calculation.

5.6.1.2 Lumen Output of source

The lumen output of sources varies with Power Consumption and type of lamp. Normally, the lumen output of lamp specified in any catalogue is the initial lumen output (after 100 burning hours). However, for the lighting design the lumen output after 2000 burning hours is taken. In case while calculation if initial lumen output is considered then the maintenance factor should be taken considering the lamp lumen depreciation factor. If the lighting design lumen output is considered then the maintenance factor should be without lamp lumen depreciation factor.

5.6.1.3 Calculation of Luminaires

After finding out all the variables, number of luminaires is calculated by using the formula given below. The no. of luminaries calculated is round off to the nearest digit for practical layout.

Once the no. of luminaries are finalized then as a final check the effective spacing to mounting height ratio is found out. The spacing to mounting height ratio varies with each luminaire depending on the light distribution generated by the luminaire. The spacing to mounting height ratio given in manufacturer's catalogue indicates the maximum spacing that can be provided for the luminaire giving the uniform lighting in the interior. The effective spacing to mounting height ratio for the installation can be calculated by the following formula:

$$\textbf{Effective } S/H_m = (1/H_m) * \sqrt{A_f}/N$$

Where,

A_f = Area of the floor

H_m= Mounting height in meters.

N= Number of Luminaires

5.6.2 Three-Dimensional Modeling

Although it was possible to calculate the luminance of all the surfaces in the room, the calculations were extremely laborious and could only be justified in the most special cases. However, the advent of computer modeling 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 [36]:

- A mixture of luminaires can be used.
- The luminaires no longer have to be arranged in a regular array.
- Directional luminaries 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.

Fig. 5.2 shows DIALux software workplane where a 3D modeling is shown.

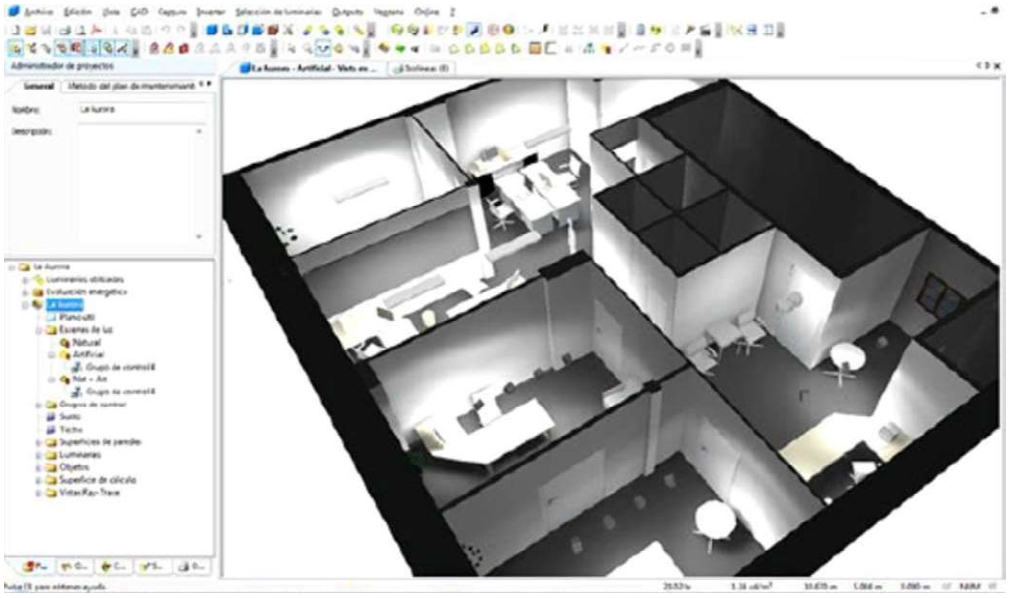


Fig 5.2 DIALux work plane

5.6.3 Visualization

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

The programs fall into two basic types:

5.6.3.1 Flux transfer or radiosity calculations

5.6.3.1 Ray Tracing Calculations

5.6.3.1 Flux transfer or radiosity calculations

A flux transfer or radiosity program treats all surfaces as diffuse as a result there rendering tends to appear flat with soft shadow details. It will tend to overestimate the uniformity.

5.6.3.2 Ray Tracing Calculations

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 the specular component of the surfaces [36].

Visualization programs are a useful tool in the presentation of a design, as a tool for the designer to check that the design is consistent with his own visualization of the space, and to model specific lighting solutions. The programs are still calculation tools and not design programs. The Programs can show the designer how a specific design will perform but they cannot reliably be used the acceptability of a design. Irrespective of the form of the visualization output, it is important that the program provides adequate information to enable the construction and verification of the lighting design.

The output should include:

- **Installation information:** The type and location of all luminaries 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 reflectance that were assumed, light loss factors, lumen output of lamps and mounting and aiming locations.

5.7 Design Tools

5.7.1 Lighting Design Software

There are different types of lighting simulation software as described in Table 5.1.

Table 5.1: Lighting design software

Sl. No.	Title	Description
1	DIALux	DIALux is free light planning software for both indoor and outdoor lighting with daylight and artificial light scenarios.
2	OptiWin 3D pro	A free lighting design program for a building or renovation project by importing large 3D models for LENI (Lighting energy numeric indicator) calculations, lux level calculation and also simple calculation of emergency lighting.
3	Vectorworks Spotlight	It is the industry-leading design software for the landscape lighting, urban lighting and entertainment business i.e. for stage lighting with 2D and 3D capabilities.
4	TracePro	A software tool for modeling the propagation of light in imaging and non-imaging opto-mechanical systems. The models are created by importing from a design or CAD program, or through directly creating the solid geometry in TracePro. The source rays propagate through the model with portions of the flux of each ray allocated for absorption, specular reflection and transmission, fluorescence, and scattering. Designers can analyze from the model: - Light distributions in illumination and imaging systems - Lumens exiting, absorbing, and incident at the component and system levels - Candela distributions - Optical efficiency, luminance, and radiance metrics - Photorealistic rendering - Fluorescence effects of phosphors
5	LiteStar 4D	A software for interior and exterior lighting design

6	MA Lighting software	Lighting design software for indoor and outdoor stage lighting
7	Visual 3D	This type of lighting design is used for many outdoor lighting scenarios e.g. parking lots and exterior facade lighting. Visual design tools can be used to quickly calculate scenarios with simple geometrics where inter-reflected light will not significantly affect the resulting illuminance.
8	Wysiwyg	Lighting design software for indoor and outdoor stage lighting.
9	AGi32	Lighting design software for providing numeric and rendered solutions for almost any lighting application, interior or exterior, including roadway and day-lighting.
11	Relux	Free lighting design software for indoor, outdoor and tunnel lighting.
12	OptisWorks	This type of software is for scientific simulation of light effect- light levels, light distribution, photometric performance and light colour with respect to human visualization within a virtual reality environment. Users use this software to simulate and optimize lighting performance, product appearance, as well as the visibility of information, taking into visual angle, various ambient light conditions, and glare on human product interfaces. Applications are in automotive lighting, aerospace lighting, traffic light, illuminated road signs, LED backlight and indoor lighting (for Museum and hotel). In automotive lighting system intelligent automated adaptive lighting effect can be created by using this software to enhance driver safety, good mood and visual comfort.
13	Radiance	Radiance is a free open-source suite of programs for the analysis and visualization of lighting in design. Its input files specify

		the scene geometry, materials, luminaires, time, date, and sky conditions (for daylight calculations). Calculated values include illuminance values; luminance values include and glare indices. Simulation results may be displayed as colour images, numerical values, and contour plots
14	Rayfront	This type of software is used for lighting design in educational institutions and industries with daylight to compute daylight factors, work-plane illuminance and evaluate glare distribution.
15	LX Series software	Lighting design software for indoor stage lighting that helps to display beam of spotlight in particular area, lux values on stage by using DMX controlling software and glare distribution with respect to visual effect of spectators.
16	Microlux	Lighting design software for indoor stage lighting
17	Lighting Reality	Lighting software for street and outdoor area lighting
18	Capture	Capture is used for stage lighting design. Capture allows users to work with lighting, video/laser media state, motion control system and water jets. It supports a wide range of ethernet DMX protocols such as Art-Net and sACN
19	Lumicept	Lumicept is hybrid light simulation software that simulates the behaviour of light, allowing the user to know how light propagates and is distributed in space.
20	LD Assistant	Lighting design software for indoor and outdoor stage lighting as well as used entertainment industries. Users can insert lighting fixtures along camera, speaker, sound cabinets, and video projectors. It supports a wide range of ethernet DMX protocols such as Art-Net and sACN

21	LightCalc	Lighting design software for indoor areas with features that include the following: - It can be used to determine the overall reflectance in a room. - It can find the proper foot-candle level or lux level for general, task, and art lighting. - It helps the user determines the proper spacing needed. - It uses both inverse square law and lumen methods. - A grid layout is suggested for general lighting.
22	ElumTools	Lighting design software for interior lighting design with or without daylight and exterior lighting design for light level calculation
23	CalcuLuX	This type of software has been developed at Philips Lighting Design and Application Centre [LiDAC] and it is applied for illuminance value calculation in indoor and outdoor area
24	Light-in-Night Road	Lighting software for street lighting
25	Ulysse	Lighting design software by **Schreder** company, calculate the necessary lighting levels for road applications
26	CGLux	This type of software has been developed at Crompton Greaves Ltd. It is applied for illuminance value calculation in indoor and outdoor area. Now days it is used by Crompton Greaves Consumer Electricals Limited and it also simulates Facade Lighting.

Out of the above mentioned lighting design software **DIALux** software has been adopted for present study considering following aspects:

- Simple, effective and professional light planning.
- Latest luminaire data of the world's leading manufacturers.
- Latest state of the art software always available free of charge.
- Energy evaluation facility and lighting control system facility.
- Lux level calculation in presence of integrated daylight and electrical light sources.
- Coloured light scenes with LED or other colour changing luminaires.

5.7.2 AutoCAD 2017

AutoCAD is an architectural tool which provides complete information on the dimensions of the room like length, width and height of the room. And after the completion of the design, the same can be used to provide the lighting layout as well. AutoCAD drawings are saved using the DWG extension, and over the years this has become a standard format for exchanging technical drawings, to the extent that even programs such as Adobe Illustrator will recognize DWG files. AutoCAD also supports an even more widely recognized format called DXF which was specifically designed as an interchange format [2].

5.7.3 Limiter

It is an instrument used to measure the illumination level at different points in working area. There are two main conditions when a Lux meter is required

a) Post Installation Audit: This is mainly required when the client wants to verify the simulated report with the practically achieved result. This is known as post installation audit.

b) Refurbishment: When an existing installation needs to be replaced with a more efficient lighting scheme (i.e. LEDs).

A proper calibrated lux meter was used for carrying out the lighting audit.

5.8 Design Methodology

1. Client Meet & Discussion:

For any lighting designer, the foremost step is to have a formal discussion with the client or end user and other members of the design team, so as to get the essence of what function the space would serve for, and hence to have an idea about what needs to be done.

2. Obtaining the AUTOCAD layout:

After client meeting, we need AUTOCAD file of the project. AutoCAD layout provides us the exact length, width and height of particular area which help in proper selection and arrangement of the luminaire.

3. Study of guidelines:

Study the relevant codes, guide lines in detail. For indoor lighting design IS3646.1992 (Part I & Part II), National lighting code IS.SP.72.2010, Road lighting design IS1944, Industrial lighting design IS: 6665-1972 etc. For LPD calculation ECBC 2017 is referred.

4. Design Simulation with the Site layout:

After following the guidelines, we have to import the AUTOCAD layout in the lighting design software e.g. DIALux version 4.13, AGi32.During this import, one should take care about the dimension unit in the AUTOCAD File. For example, if the dimension is in millimeters or feet in the AUTOCAD layout then import that file into DIALux by selecting the dimension in millimeters or feet respectively. Here in this project DIALux 4.13 software is used for airport indoor areas of terminal building and AGi32 software is used for exterior areas of airport e.g. airport apron, entrance, car parking etc.

5. Selection of Luminaires:
Simulation is checked with different possible lamps and luminaires which could be used for lighting up the given facility. For example: Let us consider a Factory Shed which is to be lit up. We first check the height of the shed and the clear height where the luminaires can be mounted. Now, from our knowledge of Low bay, Midbay and Highbay luminaires and based on the mounting height, we can decide the appropriate luminaire suited for the purpose. Selection of the lamps and luminaires should be such that so that it meet the illumination level as per standard.

6. Analysis of result:
If the simulation does not comply with the standards, or if the client asks for a specific requirement, a review is done on that and redesigning is done until the standards are met, and the client is satisfied.

7. Analysis of LPD values:
The LPD value analysis of the spaces in the building is carried out using different luminaires and the one which gives the lowest LPD is suggested to the client as it has lowest Power Consumption**.**

5.9 Design Process

5.9.1 Indoor area

Indoor area design is done by DIALux4.13. The steps involved in indoor lighting are as under.

STEP I-Deciding the type of area and type of task to be performed
In the first step after having AutoCAD layout we have to identify the type of work to be done e.g. whether it is office area, industry shed area etc.

STEP II-Deciding the illuminance level required
Once the area type and task to be performed decided then as per IS 3646 recommendation illuminance level required can be found out.

STEP III – Finding out the dimension of the room
After import the AutoCAD we can find the length, width and height. Once of the dimension of the area is found out, then the type of lighting arrangement can be decided.

STEP IV - Finding out the ceiling type
In this step we have to decide whether true ceiling or false ceiling is there. If it is true ceiling surface/ suspended mounted luminaires are chosen. In case of false ceiling recess mounted luminaire should be chosen.

STEP VI – Selecting the luminaire
Luminaire is chosen based upon the task performed in the area, illumination level required, type of ceiling and level of protection required for the specified area.

STEP VII – Selecting Maintenance Factor
Maintenance factor is chosen as discussed earlier otherwise mentioned by the client. Generally, for conventional light sources we consider maintenance factor 0.7 and for LED light sources 0.8.

STEP VIII – Finding out the work plane height
Depending upon the task to be performed work plane height is to be considered for office area we consider table height say 0.76 meter above the floor and for industrial shed area we consider null value.

STEP IX – Selecting the reflectance factors
Depending upon the area we have to select the reflectance factors of the room. For office area reflectance factors for ceiling, walls and floor are to be considered 70%, 50% and 20% respectively. For industry shed area reflectance factors for ceiling, walls and floor 50%, 30% and 10% respectively.

STEP X – Software simulation
To find out luminaire quantity we have to simulate DIALux software after all the above steps done. In DIALux to simulate the software we have to select calculate option.

STEP XI-Output
After software simulation done we have to select output option in DIALux. In output we have to choose summary option to find out required illuminance levels and luminaire quantity for a particular task.

5.9.2 Street

In case of Street lighting, the area boundaries are not defined. The length normally varies from installation to installation. Hence the Lumen formula cannot be applied as it is. In case of street lighting instead of finding out the number of luminaires as in case of indoor or exterior lighting, the spacing between the luminaires is calculated. Once the spacing is known them the same is extrapolated to find out the number of luminaires for a stretch of road. The steps involved in street lighting design by DIALux 4.13 are as under

STEP I – Deciding the type of road as per IS 1944 recommendation
Based on the road location and type of traffic, whether the road belongs to Group A or Group B is decided.

STEP II – Deciding the illuminance level required
Once the road type is decided then as per IS 1944 recommendation illumination level and uniformity can be found out.

STEP III – Selecting Maintenance Factor

Maintenance factor is chosen as discussed earlier otherwise mentioned by the client. However, for normal use the maintenance factor normally varies from 0.7 to 0.8. Generally, for conventional light sources we consider maintenance factor 0.7 and for LED light sources 0.8.

STEP IV – Finding out the width of the road

From the drawing of the road the width of road can be decided. Once the road is found out, then the type of lighting arrangement can be decided.

STEP V- Street Arrangement

In the arrangement option in DIALux we can arrange the roadway, median, sidewalk, bicycle lane as per client's requirement or according to drawing layout.

STEP VI – Deciding the mounting height, angle of the tilt and outreach

Depending upon the width of the road, type of arrangement and geometry of road the mounting height required is decided. The mounting height should normally be equal to width of the road but should not exceed 10 meters. Normally the angle of tilt should be 0, 10 and 15 degrees depending upon requirement. The pole should be located as close as possible to the edge of road. Also, the outreach should be selected in such a way that the effective width after selecting outreach should match with the mounting height. However, the outreach should normally limit to 1.5 meters. If the arrangement selected is other than single side arrangement then the width of road for individual pole should be taken as equal to half of the actual road width.

STEP VII– Selecting the light source

There is no hard and fast rule for selecting the light source. Depending on the customers liking this is selected. Nowadays the LED luminaires, MHL & HPSV luminaires are the common light sources for street lighting.

STEP VIII– Selecting the luminaire

The selection of luminaire depends upon the designer's experience and customer's choice. Normally the standard luminaires with multifaceted reflectors are used. However, in certain cases for Group A1 and Group A2 the luminaires with POT Optics reflector and within tubular lamp can be suggested.

STEP IX – Deciding the pole arrangement

Followed by the above steps we have to decide the pole arrangement i.e. whether it is single sided, opposite, staggered or central verge. For doing this in DIALux we have to select street light arrangement option. For central verge arrangement we have select luminaires per pole quantity two unlike other arrangement and pole will be on median.

STEP X – Deciding the spacing between luminaires

To achieve good uniformity as per IS 1944 standard we have to decide spacing between two poles. Normally the spacing between poles is minimum three times to the mounting height.

STEP X – Software simulation
To find out luminaire quantity we have to simulate DIALux software after all the above steps done. In DIALux to simulate the software we have to select calculate option.

STEP XI- Output
After software simulation done we have to select output option in DIALux. In output we have to choose planning data option and value chart option in valuation field to find out required illuminance levels and uniformity for a particular task.

STEP XII- Luminaire quantity
In DIALux there is default length of the street for simulation. To find out actual luminaire quantity we have to use following formula for a single sided arrangement

$$\text{Actual Luminaries quantity} = \frac{\text{Total length of the road in meter}}{\text{Spacing between poles in meter}} + 1$$

If it is double sided, opposite or central verge then actual luminaire quantity should be multiplied by two.

5.9.3 Exterior area

Exterior area design is done by AGi32 software. Here airport exterior area e.g. apron, car parking, entrance has been done with software. The steps involved in indoor lighting are as under

STEP I- Deciding the type of area and type of task to be performed
In the first step after having AutoCAD layout we have to identify the type of work to be done e.g. whether it is apron area or car parking area etc.

STEP II-Finding out the dimension of the area
Once the area type and task to be performed decided then as per standard illuminance level required can be found out. To do this we have to import the AutoCAD layout into the AGi32 software by import option. During this import, one should take care about the dimension unit in the AUTOCAD File. For example, if the dimension is in millimeters in the AutoCAD layout then import that file into AGi32 by selecting the dimension in millimeters. And the AutoCAD should be taken into (x, y, z) 0, 0, 0 co-ordinates for measurement purposes in practical case.

STEP III – Selecting Maintenance Factor
Maintenance factor is chosen as discussed earlier otherwise mentioned by the client. Generally, for conventional light sources we consider maintenance factor 0.7 and for LED light sources 0.8.

STEP IV – Selecting the luminaire
Luminaire is chosen based upon the task performed in the area, area type illumination level required. Generally, in outdoor area we use flood light. Depending upon illuminance required we have to select suitable Power Consumption of the lamps. To select the luminaire, we have to select luminaire from luminaire selection option in the software.

STEP V- Mounting height

Depending upon illuminance required high mast height should be selected. After selecting mounting height, we have to choose lock mounting height option, so that all the luminaire in the high mast will be in same height.

STEP VI –Locating the High mast

After the above steps we have to locate the high mast as per drawing layout.

STEP VII- Luminaire tilt and aiming

To achieve good uniformity, we have to select suitable tilt. To do this we have to select edit luminaires under luminaire toolkit. To change luminaire aiming we have select rearrange luminaire. By selecting this we can give suitable tilt and aiming required for the luminaires to meet the standard.

STEP VIII-Software simulation

To simulate this software, we have to choose calculation option. In calculation option there are direct only method and radiosity method. We will select direct only method to simulate.

STEP IX-Output

Unlike DIALux in AGi32 software we can view simultaneously result in case of any change in high mast location, height or change of luminaries tilt. To view output, we have select statistics window. There we can find average illuminance, uniformity.

Chapter 6
Basics of Illumination on Road, Industrial Area, Metro Railway and Office Building

6.1 Basics of Illumination on Road

6.1.1 Introduction

Fixed lighting of public ways for both vehicles and pedestrians can create a night-time environment in which people can see comfortably and can quickly and accurately identify objects on the roadway being travelled. Roadway lighting can improve traffic safety, achieve efficient traffic movement, and promote the general use of the facility during darkness and under a wide variety of weather conditions.

As a supplement to vehicular headlight illumination, fixed lighting can enable the motorist to see details more distinctly, locate them with greater certainty, and react safely to roadway and traffic conditions present on or near the roadway facility. Pedestrians must be able to see with sufficient detail to readily negotiate the pedestrian facility and recognize the presence of other pedestrians, vehicles, and objects in their vicinity. When fixed-lighting principles and techniques are properly applied, the visibility provided on these public ways can provide economic and social benefits to the public, including [38]:

- Reduction in night-time accidents
- Aid to police protection
- Facilitation of traffic flow
- Promotion of business and industry during night-time hours
- Inspiration for community spirit and growth

6.1.2 Highway Related Terms

- ***Highway***

A highway is any public road or other public way on land. It is used for major roads, but also includes other public roads and public tracks. [39]

- **Carriageway**

A carriageway consists of a width of road on which a vehicle is not restricted by any physical barriers or separation to move laterally. A carriageway generally consists of a number of traffic lanes together with any associated shoulder, but may be a sole lane in width. [40]

A single carriageway road has one carriageway with 1, 2 or more lanes together with any associated footways /sidewalk and road verges/ green belt). A dual carriageway road has two roadways separated by a central reservation or median. A local-express lane system has more than two roadways, typically two sets of 'local lanes' and also two sets of 'express lanes'. "Cars only" lanes may be physically separated from those open to mixed traffic including trucks and buses.

- ***Median or Central Reserve***

The median strip or central reservation is the reserved area that separates opposing lanes of traffic on divided roadways, such as divided highways, dual carriageways, freeways, and motorways.

- ***Service Road***

A service road is a local road running parallel to a higher-speed, limited-access road and connected only at selected points with the principal road. A service road is often used to provide access to private driveways, shops, houses, industries or farms.

- ***Cycle Track***

Cycle Track is a way or part of a highway for use by pedal cycles only.

- ***Footway:***

Footway is that portion of a road reserved exclusively for pedestrians.

- ***Verge***

The unpaved area flanking a carriageway, forming part of the highway and substantially at the same level as the carriageway.

- ***Shoulder***

A strip of highway adjacent to and level with the main carriageway to provide an opportunity for vehicles to leave the carriageway in an emergency.

- ***Refuge:***

A raised platform or a guarded area so sited in the carriageway as to divide the streams of traffic and to provide a safety area for pedestrians.

- ***Kerb:***

A border of stone, concrete or other rigid material formed at the edge of a carriageway.

6.1.3 Geometry of Road Lighting System

Fig. 6.1 shows typical construction of Road lighting system which consist of Pole and Luminaire. The different term are depicts in the figure and in Table 6.1 the terms are explained.

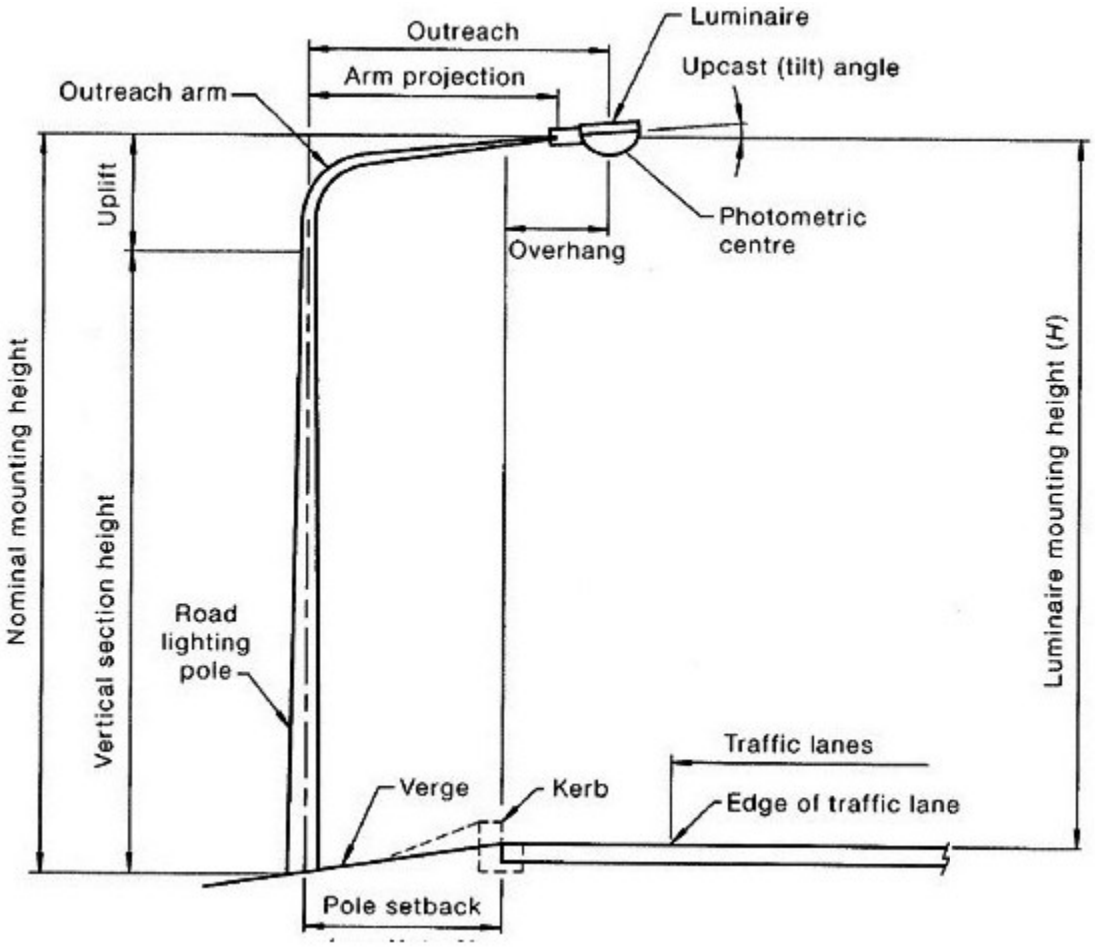


Figure 6.1: Geometry & Terminology used in a typical road lighting installation [42]

Table 6.1: Key Lighting Terminologies and their Application [42]

Term	Description	Application
Mounting Height	The vertical distance from the roadway surface to the photometric centre of the luminaire.	The most suitable standard height at which the luminaire's lighting performance can be most efficiently utilized within construction constraints.
Outreach	Outreach is measured horizontally from the centre line of the pole to the photometric centre of the luminaire.	The most suitable standard horizontal distance that places the luminaire at a lateral point across the road where the luminaire performance can be most efficiently utilized
Pole setback	The horizontal distance between the edge of the kerb (or edge of the traffic lane if no kerb) and the centre-line of the lighting pole, measured normal to the direction of traffic.	The dimension specified by the road controlling authority as being that required reduce the possibility of vehicle impact. It is relative to the road speeds, pole type and whether the road is curved or straight, proximity to intersections.
Upcast (tilt angle)	The angle between the axis of the fixing spigot entry is tilted above the horizontal when the luminaire is installed.	The angle at which the luminaire's lighting performance can be most efficiently utilized.
Carriageway width (W_k)	The portion (width) of the roadway that is devoted to the use of vehicles	The kerb-to-kerb width of that part of the carriageway which is used for Calculation or assessment of road lighting.
Overhang	Overhang is measured horizontally from the edge of the kerb to the photometric centre of the luminaire	This is a critical dimension used in design software applications in determining carriageway luminance and illuminance.
Spacing	The distance, measured along the centre line of the carriageway, between successive luminaires in an installation	The pole to pole distance of the installation to achieve average illuminance and uniformity
Span	That part of the highway lying between successive luminaires in an installation.	Required for calculation of number of poles required in a stretch

6.1.4 Lighting Arrangements

Luminaire arrangement is the pattern according to which luminaires are sited on plan. Four fundamental types of arrangement are recognized. [42] Fig. 6.2 and Fig. 6.3 shows different Lighting Arrangements.

6.1.4.1 Single Sided Arrangement

The single side arrangement, where all the luminaires are on one side of the carriageway, is recommended only when the width of the carriageway is equal to or less than the mounting height. The illumination on the road surface on the side remote from the luminaires is inevitably lower than that on the same side as the luminaires. [42]

6.1.4.2 Staggered Arrangement

The staggered arrangement, where the luminaires are situated on either side of the carriageway and in a zigzag formation, may be employed when the width of the carriageway is greater than the value recommended for single side lighting but not exceed 1.5 times the mounting height. It is superior to the single side arrangement in that it provides more nearly uniform illumination and better visibility of the two sides of the road. [42]

6.1.4.3 Opposite Arrangement

Opposite mounting in which the luminaires situated on either side of the carriageway opposite to one another is advisable when the width of the carriageway is more than 1.5 times the mounting height. [42]

6.1.4.4 Axial Mounting

Axial mounting, in which the luminaires are placed along the axis of the carriageway, is admissible for narrow roads the width of which does not exceed the mounting height. In some tree lined roads axial mounting may be the only acceptable device. It has in wide roads the undesirable effect of drawing the attention of the driver towards the centre of the carriageway and of reducing the illumination at its edges, which are just the points where obstacles may appear. [42]

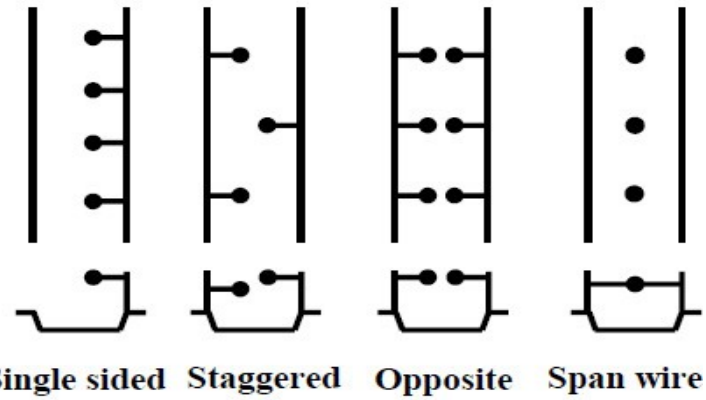


Figure 6.2: Lighting arrangement for 2-way Street

High speed ways and dual lanes lamps may be located on the separator and are termed central twin bracket arrangement. [42]

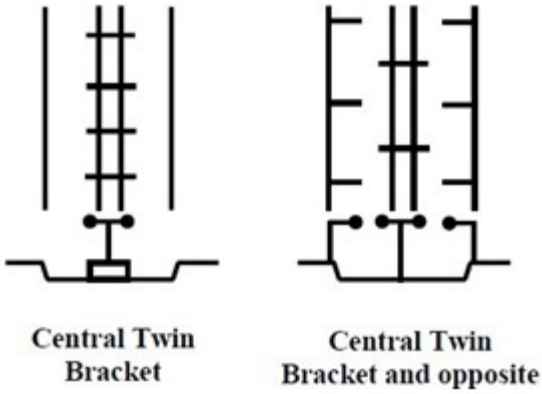


Figure 6.3: Lighting arrangement on the 2 Lane Roads

6.1.5 Fundamental Criteria of Road Lighting Installation

The quality of lighting should meet the requirements of' road users from their individual angle. The users being drivers and pedestrians, in practice, the requirements of the drivers are more stringent. However, it is the 'principles of vision' which are the guiding factors in public lighting. Hence, the function of a good road lighting installation is to provide good visual performance and visual comfort to the road users.

The most important quality criteria to be considered in road lighting are [42]:

- Luminance level
- Illuminance level
- lluminance uniformity
- Degree of glare limitation
- Visual guidance

6.1.5.1 Luminance

The most generally used approach to selecting quality criteria for lighting roads for motor traffic is based on the luminance concept. This is minimum value to be maintained throughout the life of the installation. It is dependent on the light distribution of the luminaires, the luminous flux of the lamps, the geometry of the installation and on the reflection properties of the road surface.

6.1.5.2 Illuminance

The illuminance level for road lighting in India is governed by IS 1944(Parts 1 and 2). These values must of course satisfy the basic principles of vision, criteria of quality etc and are classified as per the different types of roads. The lighting levels as specified are average values only.

6.1.5.3 Uniformity

A good overall uniformity ensures that all spots on the road are sufficiently visible. A good longitudinal uniformity ensures comfortable driving conditions without the ‘zebra’ effect.

6.1.5.4 Glare

This is caused due to the sudden presence of a very bright source in the visual field. Glare in public lighting is caused by luminaires. There are two types of glare namely, disability glare which impairs vision and discomfort glare which creates unpleasant viewing conditions.

Glare depends on the illumination produced by the luminaire on the eye of the observer. The light from the glare source scattered in the direction of the retina will cause a bright veil to be superimposed on the sharp image of the scene in front of the observer. This veil can be considered as having a certain luminance. [42]

$$L = k \sum_{i=1}^{n} \frac{E_{eye,i}}{\theta_i^2}$$

Where

$E_{eye,i}$ = Illuminance on the eye (in a plane perpendicular to the line of sight) caused by the i- th glare source (lux);

Θ_i = angle between viewing direction and direction of light incidence on the eye of the i-th glare source (degrees); and

k = age factor (usually taken as 10).

The equivalent veiling luminance and the adaptation state of the eye, which under road lighting conditions is determined by the average road luminance Lav, together play a role in determining the final loss of visual performance due to glare.

The amount of disability glare can be represented by the veiling luminance values and threshold increment.

The Threshold Increment (TI) is the percent increase in the luminance level required to make an object equally visible as in the absence of glare.

$$TI = 65 \frac{L_{veiling}}{(L_{av})^{0.8}}$$

The glare control mark (G) is a measure for discomfort glare in road lighting designs. It is calculated from certain luminaire and installation characteristics. The higher the value of G, the less will be the glare, resulting in a higher visual comfort for the road user. The glare control mark is given by the formula [42]:

$$G = SLI + 0.97 \log L_{av} + 4.41 \log h - 1.46 \log p$$

Where,

SLI = specific luminaire index;

Lav = average maintained road luminance;

h = luminaire height minus eye height; and

p = number of luminaires per kilometre.

The SLI is a luminaire characteristic and is given by [42]:

$$SLI = 13.84 - 3.31 \log I_{80} + 1.3 \log(I_{80}/I_{88})^{0.5} - 0.08 \log(I_{80}/I_{88}) + 1.29 \log F + C$$

Where,

I80 = luminous intensity at an elevation angle of 80 degrees in the C =0 plane of the luminaire;

I80/ I88 = ratio of the luminous intensity at an elevation angle of 80 degrees and 88 degrees in the C =0 plane, also called the **Run Back Ratio**;

F = flashed area of the luminaire; and

C = colour factor (dependent on the lamp type); for low pressure sodium vapour lamps, C = 0.4, for others = 0.

Typical values for G are shown in Table 6.2

Table 6.2: Typical values of G

Sl. No.	G	Assessment
1	<3	Bad
2	5	Moderate
3	>7	Good

The formula for G is valid for the following ranges of values:

50 < I80<7000 (cd);

1<I80/I88<50;

0.007< F < 0.4 (m2);

0.3 <La<7(cd/m2); 5<h<20(m); and 20<p< 100.

Number of luminaire rows = 1 or 2.

6.1.5.5 Surround Ratio

The function of the Surround Ratio (SR) is to ensure that sufficient light falls on the surrounds to provide a bright background for objects towards the edge of the carriageway to be revealed. It also helps the driver to anticipate the movement of pedestrians about to cross the road. [42] It is important in curved roads where the surround forms the greater part of the background against which objects are seen. The surround ratio is formally defined as the ratio of the average illumination on strips 5 m wide, or less if space does not permit, which are adjacent to the edge of both sides of the carriageway to the average illumination on the adjacent strips, 5 m wide or half the width of the carriageway, whichever is the smaller in the carriageway.

For dual carriageways, both carriageways together are treated as a single carriageway unless they are separated by more than about one-third the carriageway width and there are obstructions such as trees.

The surround ratio is usually determined by calculating the illuminance on a regular array of points on the strips and finding the average. In a situation where the surround ratio is applicable, a value of 0.5 is recommended.

6.1.5.6 Visual Guidance

This can be effectively created by the following principles [42]

- Positioning of poles;
- Using different lamp colours;
- Use of High Masts (>20m).

Curves of large radius of the order of 1000 m can be treated as straight. For curves of smaller radius, a study of the respective shows that it is mainly the luminaires which are placed at the outside of a bend which contribute to the brightness of the carriageway, and that in order to bring about the same degree of juxtaposition of the patches the spacing should be progressively reduced as the bend is more pronounced. For similar reasons the overhang should not be excessive.

In this case, single side arrangement is obviously indicated because it gives in addition effective beaconing of the curve. Staggered arrangement is to be avoided here as far as possible, because not only does the beaconing effect usually disappear, but the driver may even be deceived into thinking that there is a side road.

At curves on roads where the width exceeds 1.5 times the mounting height additional luminaires should be mounted on the inside of the curve. In those cases, there is less risk of misreading the pattern of lights.

Fig. 10.4 shows Position of Poles for visual guidance.

6.1.6 Road Lighting Luminaires

Luminaire characteristics are widely different for the different lamp types and for the different areas of application. The luminaires employed in road lighting are of three basic types: those that throw the main part of their light along the road, which is the case for most of the luminaires used for motorway lighting; those that have a more rotation symmetrically light distribution, as sometimes used for the lighting of nonlinear areas such as squares and some residential areas; those used for high-mast lighting, which may have a rotationally- symmetrical light distribution, but more often have an asymmetrical distribution that permits the lighting of complicated multi-level junctions. [42]

The light distribution itself and the efficiency with which it is created by its optical system are key quality aspects of a luminaire. However, the mechanical, electrical and thermal aspects of the luminaire are also important. These aspects determine both the lifetime of the luminaire itself and of the components it houses, like the lamp and gear. They are also important in view of safety and of ease of maintenance. Finally, since road lighting luminaires are part of the daytime scene of an area, also their aesthetical aspect has a role to play.

A luminaire is a device that controls the light distribution of the lamp contained within it and which includes all the items necessary for fixing and protecting the lamp (and sometimes the control gear as well) and for connecting them to the electrical supply circuit. In American English, the term fixture is usually used instead of luminaire, while in Anglo-Saxon countries the term fitting is also sometimes used. [42]

The principal characteristics of luminaires can he listed under the following headings:

- Photometrical
- Optical
- Mechanical
- Electrical
- Thermal
- Aesthetical

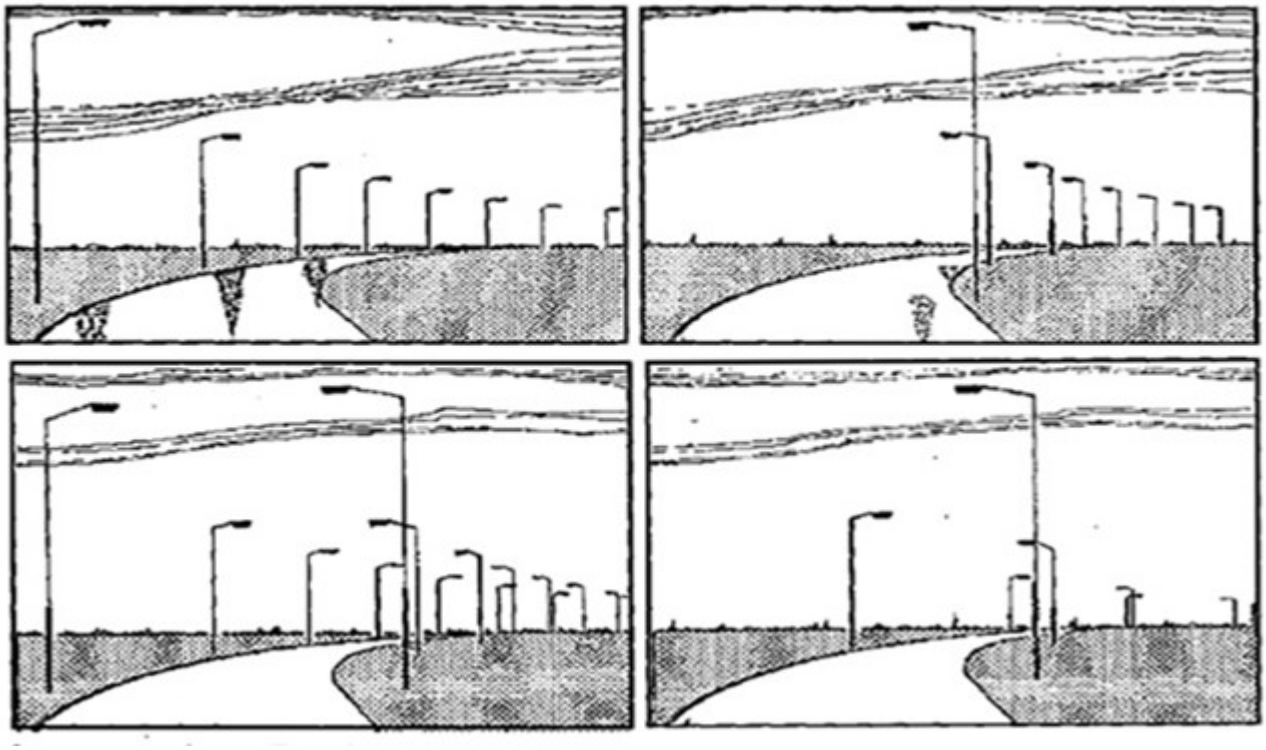


Figure 6.4: Positioning of Poles for Visual Guidance [42]

6.1.6.1 Photometrical Characteristics

A naked lamp radiates its light in all directions with more or less equal strength giving a uniform light distribution. It is the function of the luminaire to "shape" this light into directions where it is needed and to screen it from going in those directions where it could be disturbing. This should be achieved with a minimum loss of light. In lighting engineering terms: the light distribution of the luminaire should suit the application in question, while the luminaire should have a high light output ratio; the light output ratio being the quotient of lamp luminous flux and luminaire luminous flux. [42]

6.1.6.1.1 Light Distribution and Light Output Ratio

The light distribution of a luminaire defines how the luminous flux radiated by that luminaire is distributed in the various directions within the space around it. This is also called luminous intensity distribution. Since it is specified in terms of luminous intensities in all the directions in which the luminaire radiates its light.

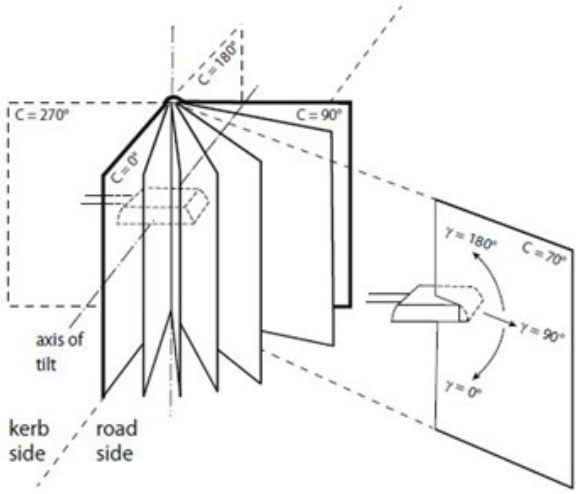


Figure 6.5: The C-γ system of coordinates used for specifying the light distribution of a Luminaire

To specify the complete light distribution of a luminaire in all directions, different standardized systems of coordinates are employed. The system normally used for road- lighting luminaires (as well as for indoor-lighting luminaires) is the so-called C- Gamma or short C-γ system. In the C-γ system of coordinates the axis of rotation of the C-planes is vertical and passes through the centre of the luminaire (Fig. 6.5). For road-lighting luminaires the C0°-C180° plane is the plane parallel to the longitudinal axis of the road. A direction in a particular C-plane is indicated by the angle γ, which ranges from 0° (down) to 180° (up).

The luminous intensities table, or I-Table, of a luminaire is the digital form of the light distribution of a luminaire and is the basic input for all lighting-calculation software. The intensity tables usually give relative intensity values viz. candela/l000 lamp lumen values so as to make the values solely dependent on the luminaire and not on the actual lumen of the lamp. Apart from the luminous intensity values, the photometric data file also needs to contain information on the dimensions of the light-emitting surface of the luminaire in order to enable glare calculations.

Different lighting-calculation software programs use different input formats for the photometric data file. The most often used formats are IES and EULUMDAT. The IES format is standardized by the Illuminating Engineering Society of North America (IES 2002) and approved by ANSI. It is also used outside the USA, including Europe. EULUMDAT is widely used in Europe, where it is the de-facto industry standard, although it is not defined and maintained by a recognized standardization body.

The optical devices that shape the light distribution of a luminaire absorb light. This is why the total lumen output of the luminaire is lower than the lumen output of the lamp (or lamps) contained within the luminaire. The light-output ratio (η) is the ratio of the total lumen output of the luminaire to the lumen output of the lamp(s):

$$\eta = \frac{\Phi_{\text{luminaire}}}{\Phi_{\text{lamp}}}$$

For the selection of suitable luminaires for a certain application clear insight into the photometric quality of a luminaire is needed. This is why luminaire manufacturers produce photometric data sheets containing at least the light-output ratio and polar intensity diagrams. The polar luminous intensity diagram provides a good indication of the suitability of the light distribution for a certain application.

In such diagram, the luminous intensities are presented using the C-γ system of coordinates in the form of curves in terms of cd/l000 lumen of the nominal lamp flux of the lamps employed. Each curve represents one C plane. Curves are given for only the more important planes. Figure 6.6 gives an example of a polar luminous intensity diagram for a road- lighting luminaire. That, in this example, the light distribution across the luminaire is asymmetrical is clearly evident from the curve through the plane across the road (C270°-C90° plane): more light is radiated towards the road rather than towards the kerb. How well the light is thrown in the direction parallel to the road can be seen from the curve through the C0°-C 180° plane. The same curve, at the higher elevation angles, also gives an insight into how good or how poorly glare is restricted by the luminaire.

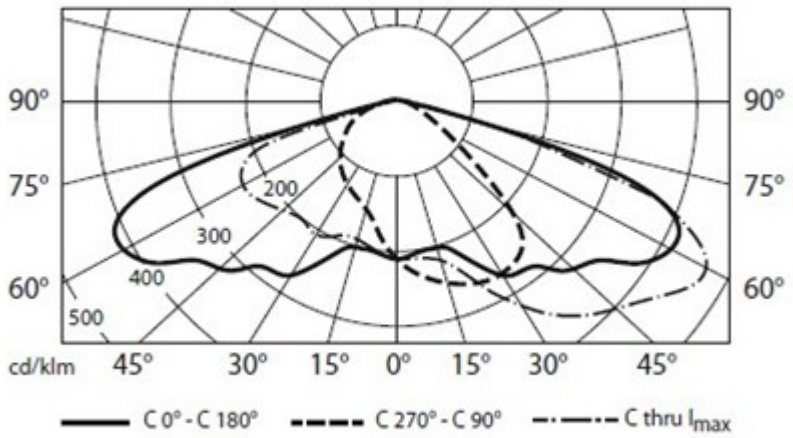


Figure 6.6: Polar Luminous Intensity Diagram of a Road Lighting Luminaire

6.1.6.1.2 Relative and Absolute Photometry

Many aspects of traditional photometry are not applicable for evaluating LED products. With conventional sources of the past, the science of photometry sought to completely decouple the characteristics of the lamp/ballast from the performance of the fixture. This enabled fixture and lamp performance to be evaluated separately, giving designers the information needed to select the best-performing combination of fixture and components to meet their needs. The methodology for this type of testing is known as relative photometry. In this method, a lamp is chosen to measure within the photometer at the lamp manufacturer's specified electrical conditions (e.g. 54W fluorescent driven by suitable ballast). A lumen value is measured and then calibrated to the lamp manufacturer's published lumen value. In this way, the actual variation of the tested lamp lumens is factored out of the photometric process. The same lamp and ballast are then placed within the luminaire and the distribution of the light is measured. In this way, the photometry is scaled to the rated value of lumens claimed by the lamp supplier. [5] In addition, the photometry can be used for other lamps that share similar characteristics (size, shape, distribution) by simply scaling the lamp lumens accordingly within lighting application analysis programs.

Decoupling lamp from luminaire in an LED product is not practical since the LED performance is so intricately tied to the thermal design of the luminaire. To overcome this issue, the IES (working in conjunction with DOE) developed IESNA LM-79-08 (Electrical and Photometric Measurement of Solid-State Lighting Products), which is a testing method to measure the performance of LED-based

luminaires. This method is termed absolute photometry, since the results are actual or "absolute" not "relative" or scaled to a source that was not actually tested. The limitation of absolute photometry is that it is applicable only for the exact luminaire / light source combination tested.

The consequence is that, unlike traditional photometry, efficiency in the world of LED lighting is a quantity that gives no meaningful information about the performance of the LED luminaire. For first-level comparisons, it is the luminaire lumens, a.k.a. "delivered lumens" that must be compared for LED luminaires - rather than fixture efficiency. In addition, the metric of luminaire (delivered) lumens is common to both absolute and relative photometry and therefore allows for a direct comparison of products measured with both methods.

As with traditional files, the generated photometric report for LED luminaires gives the measured lumens, distribution and Power Consumption of the tested luminaire. In some cases, additional information on the CCT and CRI of the luminaire is also provided, but not required. If needed, the generated electronic file is converted to standard IES file format for absolute photometry specified in IES LM-63-02 (Standard File Format for the Electronic Transfer of Photometric Data and Related Information). This file format is easily used in programs such as Visual to calculate the initial performance of the luminaire within a 25°C ambient environment. In ambient other than 25°C, an appropriate Luminaire Ambient Temperature (LAT) factor must be applied to account for the temperature response of the LED luminaire. This set of factors (LAT vs. temperature) is specific to each luminaire and is provided by the luminaire manufacturer. It is based on rigorous testing of the luminaire as well as information the luminaire manufacturer receives from their selected LED supplier.

Additional background on LM-79-08: A word of caution is warranted here. With the emergence of this standard, there may be a false sense of confidence that the photometric data reported is representative of a population of luminaires. With regard to the use of photometric data, LM-79-08 states "The data, however, should be used with the understanding that the photometric file describes the performance of a single luminaire and does not necessarily represent the average performance of a group of the same SSL luminaires."

As LED luminaires have become more integrated, optically and thermally, with the LED light source, it is now the responsibility of the luminaire manufacturer to ensure that their published performance data is indeed representative of the products they are manufacturing. In the past this was less of a concern as major manufacturers of conventional lamps maintained rigorous control of their product quality - and luminaire design had far less impact on lamp performance.

6.1.6.1.3 Luminaire Classification System

The luminaires employed in road lighting can be divided into three basic types: conventional road-lighting luminaires that throw the main part of their light along the road, rotationally-symmetrical luminaires, and floodlights with relatively narrow beams. While the CIE and the European Standard classify light distributions only according to their glare aspect, IESNA in North America classifies light distributions based on many more aspects. [42]

CIE (2010) classifies luminaires into six luminous-intensity classes G1-G6 according to the luminous intensities per 1000 lamp lumen for the angles of elevation 70, 80 and 90° and for the area above 90°. Table 6.3 shows the requirements for the three most stringent classes. The European Standard uses the same classes.

Table 6.3: CIE luminous intensity classes (CIE 2010)

	Imax (cd/1000 lm) at and above			
	70°	**80°**	**90°**	**95°**
G4	500	100	10	1
G5	350	100	10	1
G6	350	100	1	1

IES defines a luminaire classification system (LCS) based on the lumen distribution within solid-angle areas (IES 2007). It replaces the previously used full-cutoff, cutoff, semi-cutoff and non-cutoff system. The LCS system divides the light distribution of a luminaire into three zones.
As illustrated in Figure 6.7, the primary solid angles defined by the LCS are:

- The back-light quarter sphere, denoted by the letter B,
- The up-light hemisphere, denoted by the letter U
- The forward-light quarter sphere, denoted by the letter F, responsible for the lighting of the area to be lit. The higher elevation angles in this quarter sphere are also responsible for possible glare to road users outside the area, which is the reason why this zone is also denoted by the letter G.

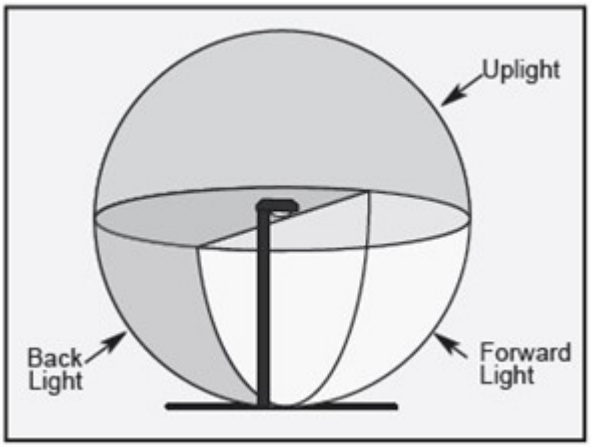


Figure 6.7: The three primary solid angles of the Luminaire Classification System (LCS)

The sum of percentages of lamp lumens within these three primary solid angles is equal to the photometric luminaire efficiency.

$$Photometric\ Luminaire\ Efficiency\ (\%) = 100 \times \frac{Forward\ Light\ (lumens) + Back\ Light\ (lumens) + Uplight\ (lumens)}{total\ bare\ lamp\ lumens}$$

$$Photometric\ Luminaire\ Efficiency\ (\%) = Forward\ Light\ (\%) + Back\ Light\ (\%) + Uplight\ (\%)$$

$$Trapped\ Light\ (\%) = 100\% - Photometric\ Luminaire\ Efficiency\ (\%)$$

Forward Light:

Forward light describes the lumen distribution in front of the luminaire. The forward light solid angle is defined between 0 and 90 degrees vertical, and 270 to 90 degrees horizontal in front of the luminaire. The forward light solid angle is further refined into four vertical secondary solid angles to evaluate the distribution of light in front of the luminaire. The forward light secondary solid angles (see Figure 6.9) are defined as follows:

- **Forward light low secondary solid angle (FL)** - Percent lamp lumens between 0 and 30 degrees vertical (or luminaire lumens within that solid angle) in front of the luminaire. This is the light emitted from directly below the luminaire to 0.6 mounting heights away from Luminaire.
- **Forward light mid secondary solid angle (FM**) - Percent lamp lumens between 30 and 60 degrees vertical (or luminaire lumens within that solid angle) in front of the luminaire. This is the light emitted from 0.6 to 1.7 mounting heights away from the luminaire.
- **Forward light high secondary solid angle (FH)** - Percent lamp lumens between 60 and 80 degrees vertical (or luminaire lumens within that solid angle) in front of the luminaire. This is the light emitted from 1.7 to 5.7 mounting heights away from the luminaire.
- **Forward light very high secondary solid angle (FVH)** - Percent lamp lumens between 80 and 90 degrees vertical (or luminaire lumens within that solid angle) in front of the luminaire. This is the light emitted beyond 5.7 mounting heights away from the luminaire.

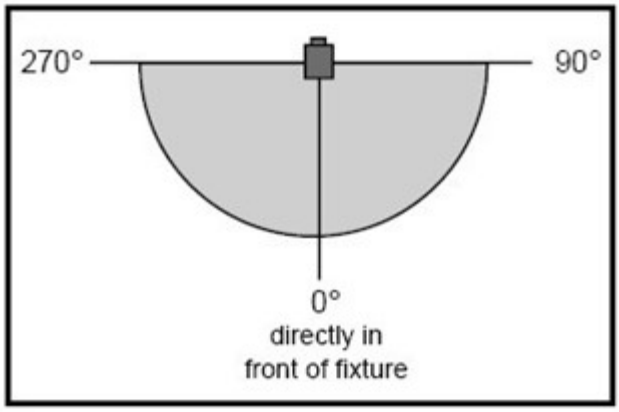


Figure 6.8: Plan view for forward solid angle

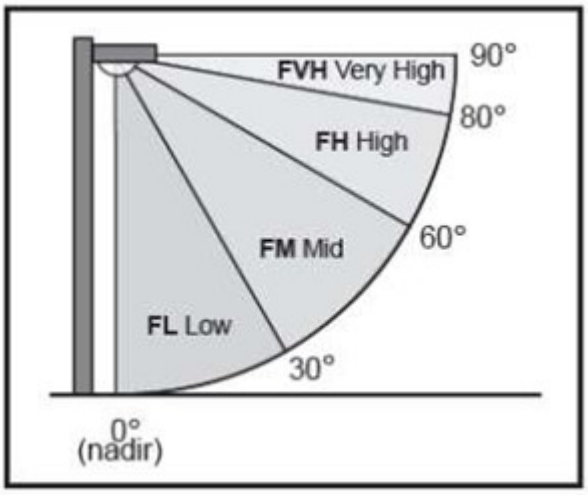


Figure 6.9: Section view for forward solid angle

Backlight, Up-light, and Glare (BUG) Ratings:

The following Backlight, Up-light, and Glare ratings may be used to evaluate luminaire optical performance related to light trespass, sky glow, and high angle brightness control. These ratings are based on a zonal lumen calculation for secondary solid angles defined in TM-15-07. The zonal lumen thresholds listed in the following three tables are based on data from photometric testing procedures approved by the Illuminating Engineering Society for outdoor luminaries (LM-31 or LM-35).

Table 6.4: Backlight Ratings (maximum zonal lumens)

	Secondary Solid Angle	B0	B1	B2	B3	B4	B5
Backlight / Trespass	BH	110	500	1000	2500	5000	>5000
	BM	220	1000	2500	5000	8500	>8500
	BL	110	500	1000	2500	5000	>5000

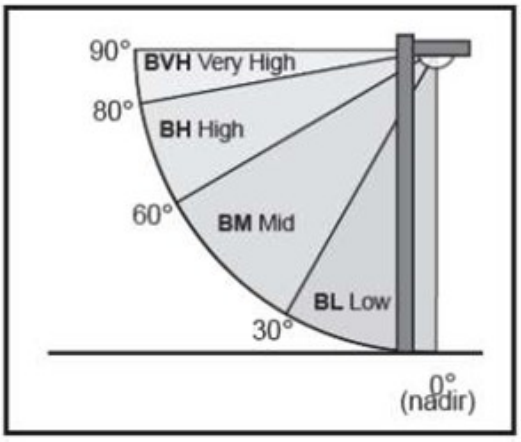


Figure 6.10: Section view for back light solid angle

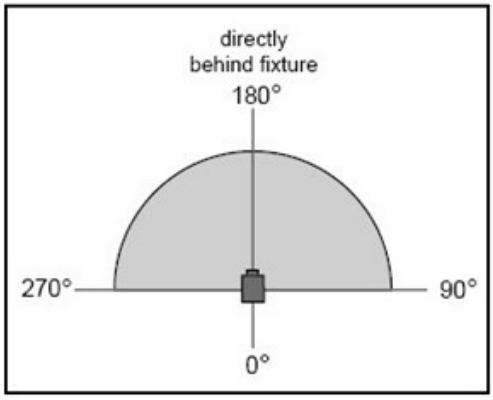


Figure 6.11: Plan view for back light solid angle

Table 6.5: Up light Ratings (maximum zonal lumens)

	Secondary Solid Angle	**U0**	**U1**	**U2**	**U3**	**U4**	**U5**
Up light / Sky glow	UH	0	10	100	500	1000	>1000
	UL	0	10	100	500	1000	>1000
	FVH	10	75	150			>150
	BVH	10	75	150			>150

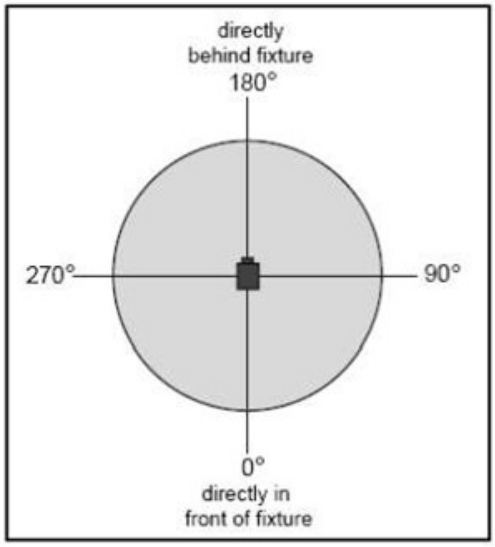


Figure 6.12: Plan view for uplight solid angle

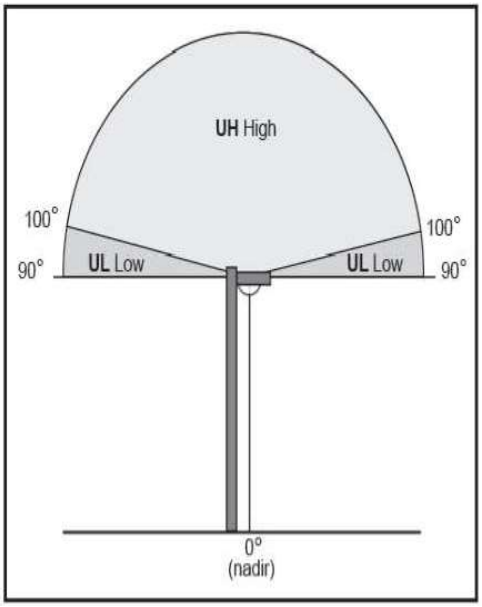


Figure 6.13: Section view for up-light solid angle

Table 6.6: Glare Rating for Asymmetrical Luminaire Types (Type I, Type II, Type III, Type IV)

	Secondary Solid Angle	G0	G1	G2	G3	G4	G5
Glare / Offensive Light	FVH	10	250	375	500	750	>750
	BVH	10	250	375	500	750	>750
	FH	660	1800	5000	7500	12000	>12000
	BH	110	500	1000	2500	5000	>5000

Table 6.7: Glare Rating for Quadrilateral Symmetrical Luminaire Types (Type V, Type V Square)

	Secondary Solid Angle	G0	G1	G2	G3	G4	G5
Glare / Offensive Light	FVH	10	250	375	500	750	>750
	BVH	10	250	375	500	750	>750
	FH	660	1800	5000	7500	12000	>12000
	BH	660	1800	5000	7500	12000	>12000

Some examples will serve to illustrate the practical meaning of the system. A luminaire with a BUG classification of, for example, 102 is strongly limited as regards its back light, emits hardly any upward light, and restricts glare reasonably well. A BUG classification of 254 denotes reasonable backward limitation of light, very bad upward limitation, and bad glare restriction. It should be noted that the expression 'forward' makes no distinction between the light radiated in the lengthwise and crosswise directions on the forward or road side. In this respect it would be interesting to combine the BUG classification system with a former CIE classification system that distinguishes the amount of light radiated forward into different classes of throw (light radiated in lengthwise direction) and spread (light radiated in crosswise direction) respectively (CIE 1976).

Previous IES classification system is based upon features of photometric performance similar to those used by the CIE, namely the luminaire's longitudinal and lateral light distributions and the degree of glare control present. The lateral classification describes the lateral light distribution with regards to the lighted area width (described as multiples of the mounting height - MH). The width of the half-maximum candela trace within the longitudinal distribution range (Very Short, Short, Medium, Long or Very Long) is used. The boundaries for each classification in terms of Longitudinal Roadway Lines (LRL, running along the roadway) are:

- Type I - Half-maximum candela trace falls between 1 MH LRL on the House side and 1 MH LRL on the Street side
- Type II - Half-maximum candela trace on the Street side is beyond the 1 MH LRL but not beyond the 1.75 MH LRL
- Type III - Half-maximum candela trace on the Street side is beyond the 1.75 MH LRL but not beyond the 2.75 MH LRL
- Type IV - Half-maximum candela trace on the Street side is beyond the 2.75 MH LRL
- Type V is a little special. It has circular symmetry being essentially the same at all lateral angles around the luminaire.

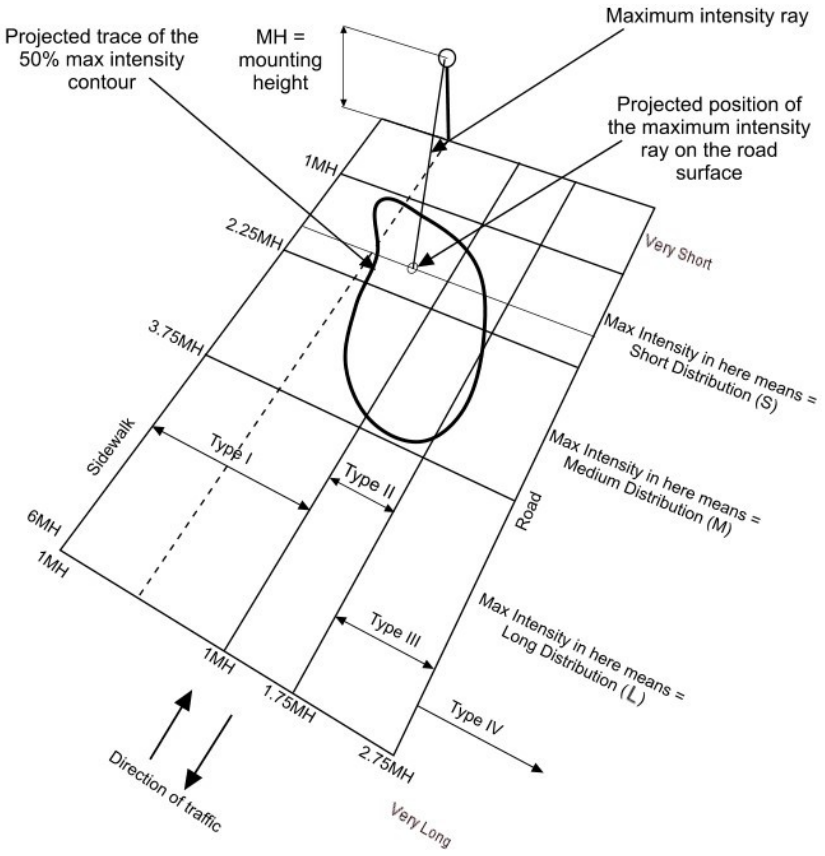


Figure 6.14: Sketch showing three degrees of longitudinal and four degrees of lateral light distribution defined by IES [57]

The extent of the glare-control facility is defined in terms of the luminous intensity at 80 and 90° above nadir, three degree of control being recognized, as described by the terms cut-off, semi-cut-off, and non-cut-off, Table 6.8.

Table 6.8: Definition of the degrees of glare control of luminaire light distribution - according to the IES of North America [57]

	Maximum permissible value of intensity emitted at an elevation angle of	
	80°	**90°**
Cut-off	100 cd/1000 lm	25 cd/1000 lm
Semi Cut-off	200 cd/1000 lm	50 cd/1000 lm
Non Cut-off	Any	any

6.1.6.2 Optical Characteristics

The desired light distribution of a luminaire is obtained through the application of one or more of the physical phenomena: reflection, refraction, and diffuse transmission. Many luminaires also make use of shielding in one form or another, principally to obtain the required degree of glare control and to limit light pollution. The shielding function may be performed by refractors, diffusers, mirror reflectors or, where very stringent glare control is required, by black surfaces.The way in which these various control techniques are employed in a given luminaire and the optical properties of the materials used also determine the light output ratio of the luminaire. [5]

6.1.6.2.1 Reflectors

Specular reflectors (also called high-gloss mirror reflectors) are often used when a precise form of light distribution is required. The reflector creates multiple images of the light source which, with a suitable reflector shape, overlap each other to form a uniform luminance pattern on the area to be lighted. The most widely-used material is sheet aluminium, which has the strength needed to produce a stable reflector. To obtain a highly-specular finish, the aluminium is polished: mechanically, chemically, electrolytically, or by a combination of these processes. Reflectance values are around 0.70. Alternatively, commercial-grade aluminium can be clad with a thin layer of super-purity aluminium or silver. With aluminium, reflectance values of up to 0.80 can be obtained, while with silver a reflectance of more than 0.90 is possible. Finally, there is vacuum metalizing, in which a specular layer of aluminium is deposited on a suitably-smooth substrate (metal, glass or plastics). The resulting reflectance, which is somewhere between 0.80 and 0.90, is dependent on both the substrate material and the quality of the metalizing process.

The best optical performance is obtained when using a curved reflector. Depending on the curvature, many different types of beams can be created. A curved reflector may be cylindrical, parabolic, elliptical, hyperbolic, or some other contour to suit a particular application. The cylindrical and parabolically-shaped reflectors are the ones often used. In some cases, these shapes can he combined (Fig. 6.15 a).

The most important optical property of a parabolic reflector is that a point source of light placed at its focus will produce a parallel beam of reflected rays (Fig. 6.15 b). If the light source is not at the focus but in front of behind it, the reflected rays are no longer parallel (Fig. 6.15 d). Thus, by choosing the position of the light source relative to the focal point, the desired beam shape (narrow to wide) can be created. [42]

Combinations of different reflector shapes in one luminaire are employed as well (Fig. 6.15 e). Since a lamp is never a real point source, deviations from the theoretical beam shape as obtained from a point

light source, will always occur (Fig. 6.15 f). The final shape of the light distribution depends on the size of the light source relative to the focal length of the reflector, the width of the open mouth of the reflector and the shape of the light source. The smaller the light source relative to the size of the reflector, the more accurately, can the beam be shaped but glare control then becomes more challenging.

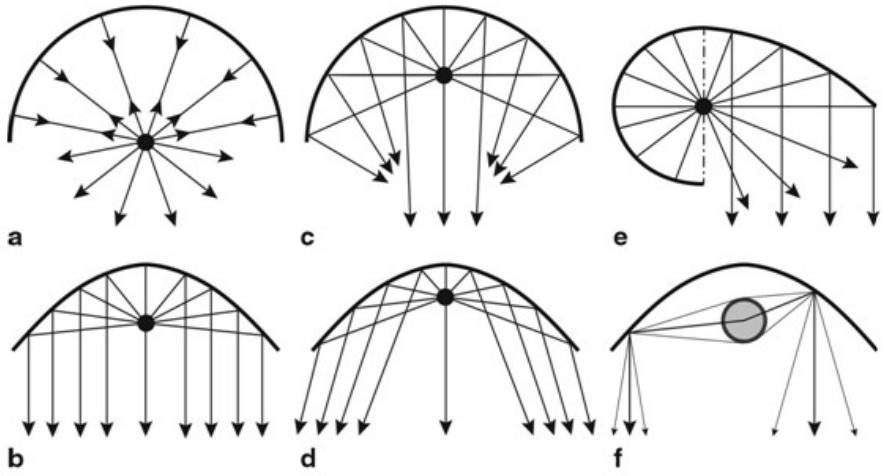


Figure 6.15: Reflector shapes: a cylindrical and b parabolic reflector with point light source at focal point; c and d point light source outside focal point; e: combination of cylindrical and parabolic reflector; f diverging rays because of a non-point source (not to scale)

6.1.6.2.2 Refractor and Lenses

Refracting devices are either lenses or prisms. They bend the light that passes through them. The angle through which the light is bent is dependent on both the shape of the refractor and its refractive index (Snell's law). Plastic prismatic controllers are used in road lighting, especially in residential area lighting applications. Refracting glass bowls were in the past sometimes used for high-pressure mercury and sodium road-lighting luminaires, but have now becomes obsolete. This is partly because they are heavy, but more so because lighting control in the upwards direction, and therefore control of light pollution, is not easily attainable. Today, in LED luminaires, advanced lens-type refractors, one for each individual LED point, are often employed. These make it possible to accurately shape the light distribution. Such a system makes it possible to modify the light distribution by switching or dimming different individual LEDs with different lenses in front of them. [5] This allows the designer to adapt the light distribution to suit the actual luminaire spacing and road width or to changing weather conditions and changes in the road-surface reflection properties.

Figure 6.16: Road lighting luminaires with lenses for individual LED

6.1.6.2.3 Diffusers

Translucent diffusers increase the apparent size of the light source. They scatter the light from the lamp in all directions without defining its light distribution. They serve mainly to reduce the brightness of the luminaire and thus the glare created by it. Diffusers are made of translucent plastics, commonly acrylic or polycarbonate. The material should be such that it scatters the light whilst producing the minimum amount of absorption. Diffusers are normally only employed where optical control is not critical, which is sometimes the case in the more decorative luminaires designed for use in pedestrian areas. Usually a top mirror or shield is incorporated into the design to restrict at least some of the upward light so as to help limit some light pollution.

6.1.6.3 Mechanical Characteristics

The mechanical function of the luminaire housing is threefold: it accommodates the various component parts of the luminaire, such as the optical system and the various components of the electrical system; it protects these against external influences; and it provides the means of mounting the luminaire in the installation.

6.1.6.3.1 Material

Aluminium alloys, in which other elements have been added to the pure aluminium to improve its mechanical and physical properties and its chemical protection, are used in the manufacture of cast, extruded and sheet-metal luminaires. Cast aluminium refers to the process in which molten aluminium alloy is poured (cast) in a mould. Extrusion is the process in which softened aluminium alloy is pressed through the openings of a die. Cast and extruded aluminium alloys are much used in housings for road, tunnel and floodlight luminaires. They can be employed in humid and damp atmospheres without having to add protective finishes.

Plastics may be used for complete luminaire housings, for transparent covers, and for many smaller component parts. All plastic housings can, of course, only be employed for light sources that have a relatively low operating temperature. In the case of LED luminaires it is important to take into account the fact that plastic is not a good heat conductor. Plastic covers are of methacrylate or polycarbonate. Methacrylate maintains its high light transmission properties over a long period, but its impact resistance is relatively low. The impact resistance of polycarbonates is very high and thus offers a high degree of protection against vandalism. It can be chemically treated to protect it from yellowing under the influence of ultraviolet radiation.

6.1.6.3.2 Strength

The luminaire and its mounting attachments should be of sturdy construction to ensure a good, steady positioning of the luminaire and its contents. Any weakness here could lead to changes in the luminaires light distribution and consequent changes in the planned lighting quality of the installation as a whole. The most critical part of a luminaire as far as its strength is concerned are the mounting brackets. The strength required here is covered by a safety factor: the mounting bracket(s) must be able to support at least five times the weight of the luminaire itself. With road-lighting and outdoor floodlighting luminaires the mounting brackets must also be strong enough to withstand the highest conceivable wind loading for the location. Here a good aerodynamic shape for the luminaire can be advantageous, as it also serves to reduce the strength required for the lighting mast. The term windage is used to refer to the resistance a luminaire presents to the wind. It is the projected area of the luminaire in the vertical plane. The smaller the windage, the lower is the resistance to the wind.

Where protection against vandalism is called for, the impact resistance of the luminaire itself is also important. Reference can be made in this respect to an IEC Standard (IEC 2002) that defines so-called IK codes. These vary from IK01 (low impact resistance: resistance to the impact of a 200 g object falling from a height of 7.5 cm), to IKI0 (vandal-proof: able to withstand the impact of a 5 kg object falling from a height of 40 cm.) These requirements are also expressed in impact joules from a pendulum or spring hammer as used in luminaire-testing laboratories. For example, for IK01 an impact of 0.14 Joules and for IKI0 an impact of 20 J. Table 6.9 depics IK code according to protection against impact resistance.

6.1.6.3.3 Dirt and Humidity Depreciation

The luminaire should protect the optical and electrical components contained within it against dirt and humidity. The degree of protection provided by the urinary is classified according to the International Protection code (IP code) as described in IEC (2013). The IP code consists of two numerals: IP.

The first numeral classifies the degree of protection against the ingress of solid foreign bodies (ranging from fingers and tools to fine dust) and protection against access to hazardous parts (Table 2.1). The second numeral classifies the degree of protection against the ingress of moisture (Table 2.2). The higher the IP values, the better the protection.

Dust and watertight (or waterproof) luminaire covers must always be used in conjunction with a sealing strip fitted in a strip channel, provided in the luminaire housing, for maximum effect. Due to the variation in temperature between the air inside and that outside the luminaire after switching on or off, pressure differences across the luminaire's cover-seal are bound to occur. The seal or gasket should prevent corrosive gases, moisture and dust from being sucked into the luminaire during cooling off. The effectiveness with which the front cover seals the luminaire against ingress of solids and liquids, and the durability of this sealing function, is determined by the type and quality of the sealing material employed.

Table 6.9 IK code according to protection against impact resistance

	Protected against	**Effective against**
IK 00	Not protected	_____
IK 01	Protected against 0.14 joules impact	Equivalent to impact of 0.25 kg mass dropped from 56 mm above impacted surface.
IK 02	Protected against 0.2 joules impact	Equivalent to impact of 0.25 kg mass dropped from 80 mm above impacted surface.
IK 03	Protected against 0.35 joules impact	Equivalent to impact of 0.25 kg mass dropped from 140 mm above impacted surface.
IK 04	Protected against 0.5 joules impact	Equivalent to impact of 0.25 kg mass dropped from 200 mm above impacted surface.
IK 05	Protected against 0.7 joules impact	Equivalent to impact of 0.25 kg mass dropped from 280 mm above impacted surface.
IK 06	Protected against 1 joules impact	Equivalent to impact of 0.25 kg mass dropped from 400 mm above impacted surface.
IK 07	Protected against 2 joules impact	Equivalent to impact of 0.5 kg mass dropped from 400 mm above impacted surface
IK 08	Protected against 5 joules impact	Equivalent to impact of 1.7 kg mass dropped from 300 mm above impacted surface.
IK 09	Protected against 10 joules impact	Equivalent to impact of 5 kg mass dropped from 200 mm above impacted surface.
IK 10	Protected against 20 joules impact	Equivalent to impact of 5 kg mass dropped from 400 mm above impacted surface

6.1.6.3.4 Installation and Maintenance

Many luminaires are of such a shape, size and weight as to make mounting them a difficult and time-consuming operation. Mounting, but also relamping and cleaning, must usually be carried out high above ground. This means that the ergonomic design of the luminaire should be such as to make these operations as easy and as safe as possible to perform. For example, for good serviceability covers should be hinged so that the electrician has his hands free to work on the lamp and gear. A luminaire of simple construction with clean lines will, by improving accessibility and facilitating cleaning, not only help to shorten relamping and cleaning times (thereby reducing maintenance costs),

it will also reduce the time a road or part of a road is out of commission whilst maintenance of the lighting installation is in progress.

6.1.6.4 Electrical Characteristics

The construction of a luminaire should he such as to render it safe electrically to all those involved in its handling. IEC (2009) classifies luminaires according to the degree of protection afforded against electrical shock (Table 6.10).

The sizes of the electrical conductors (wires and connecting blocks) used in the luminaire should be suitable for the actual electrical load. The cable insulation must be sufficient for the high ignition voltages, which may be far higher than the operating voltage and must withstand the often-high temperature in the luminaire during Operation. To relieve possible strain on the cables and their connections, a means of clamping the cables is required.

Table 6.10: Electrical safety classes [42]

Luminaire class	Electrical Protection
I	A luminaire having functional insulation, but not double insulation or reinforced insulation throughout, and without provision for earthing.
II	A luminaire having at least functional insulation throughout and provided with an earthing terminal or earthing contact, and, for luminaires designed for connection by means of a flexible cable or cord, provided with either an appliance inlet with earthing contact, or a non-detachable flexible cable or cord with earthing conductor and a plug with earthing contact.
III	A luminaire with double insulation and/or reinforced insulation throughout and without provision for earthing.
IV	A luminaire designed for connection to extra-low-voltage circuits, and which has no circuits, either internal or external, which operate at a voltage other than extra-low safety voltage.

6.1.6.5 Thermal Characteristics

A considerable amount of the electrical energy supplied to the lamp is converted into heat. The ballast adds to this heating effect within the luminaire. To protect the ballast from overheating, it is sometimes (especially with high-power lamps) screened off from the heat radiation of the lamp by having it placed in a separate compartment of the luminaire. Very- high-powered lamps, as used in some floodlights, should be placed outside the luminaire in a special ballast box. [42]

For a given lamp/ballast combination, the working temperature reached by the luminaire is dependent upon three factors:

- The volume of the luminaire. The greater the volume, the lower will be the temperature rise inside the luminaire.
- The ease with which the heat generated within the luminaire can be conducted through it to the surrounding air. One way of promoting air flow through the housing is to make use of heat-

conducting materials in its construction. Most metals are good in this respect, while plastics, on the other hand, are thermal insulators and cannot therefore be employed as housing materials where high- power lamps are involved.

- The cooling effect of the surrounding air. Good heat dissipation calls for large surface areas to be in contact with the surrounding air. Luminaires for high-power lamps, such as some floodlights, and some LED luminaires, that are very sensitive to high temperatures, are therefore provided with cooling fins.

Luminaires are designed to meet the conditions under which they are most likely to be used. The maximum ambient temperature, Ta, at which a luminaire can be operated safely, is indicated on the type label on the product. If no temperature indication is given, the product is intended for use at a maximum ambient temperature of 25 °C. The use of luminaires above their specified maximum ambient temperature may reduce safety margins and will generally lead to a reduction of the lifetime of the various luminaire components. With LED luminaires, not only will the lifetime be reduced but also the lumen output and the luminous efficacy.

6.2 Basics of Illumination in Industrial Area

6.2.1 Introduction

Due to industrialization, industries are growing at a rapid pace but survey, research and standardization of industrial lighting are very few when compared to interior lighting. Industrial lighting is very different from inferior lighting. In interior lighting daylight plays a much bigger role which saves a major portion of Power Consumption. But in case industrial lighting, utilization of daylight is very difficult as most of the activities are performed in closed area with involvement of large sized equipment and machines. Thus choice of luminaires, commissioning and installation plays a big role in achieving energy efficient solution in case of industry lighting. Despite changes in industry lighting standards and guidelines most of the industries still prefer to use conventional lighting system owing to high capital cost.

6.2.2 General Features in Industrial Area

Industrial lighting encompasses seeing tasks, operating condition and economic considerations. For a good industrial lighting involves careful consideration of various parameters. Physical Hazards exists in manufacturing processes and therefore lighting contributes to the safety factor in mitigating accidents. Designer should take into account the operating condition of the site, application and visual tasks for which illumination required. Energy efficient lighting is one of the biggest challenges for industrial lighting, in order to achieve it followings steps need to be taken:

Step 1: Determine the quality of illumination required for different industrial activities.

Step 2: Determine the amount of illumination required for different industrial activities.

Step 3: Color rendering required for different task.

Step 4: Selection of suitable light sources and luminaries that satisfies all the design parameters and specifications along with mechanical performances.

Step 5: Installation of lighting fixtures for proper maintenance and safety.

Step 6: Review the energy, economic and operation characteristics of the lighting system.

6.2.3 Criteria for Industrial Lighting Practice [46]

A good lighting system should take into account:

- Adequate quantity of illumination
- Good quality of illumination
- Quantity of Illumination

The utilization goal for a lighting system is to provide for optimal performance for a given task. The starting point will be the determination of the relationship illumination and performance, but the final recommendation has to take into consideration other factors like avoidance of fatigue, physiological and psychological effects, economics etc.

A general lighting system should be designed to provide a uniform distribution of light over the entire working area, where work areas are close to the wall like work benches, first row of luminaries should be located near to the wall or additional lighting should be provided near the working space to compensate the loss due to wall reflectance.

The desirable amount of light required for an space depends on the seeing task, the importance of speed and accuracy of the task. Illumination recommendations for different industrial activities are given in Table 7.3.

6.2.3.1 Quality of Illumination

Quality of illumination means uniform distribution of light over the entire work space which contributes to visual performances, visual comfort, ease of seeing safety and aesthetics for the specific visual task involved. Glare, direction, uniformity, color, luminance and luminance ratios all have a significant effect of visibility and ability to detect objects easily. Area where tasks are sever and performed over a long period of time require much higher quality of illumination than casual tasks or relatively short duration.

6.2.3.2 Maintenance Factor [46]

Maintenance factor is a factor which takes into account the reduction of luminous flux with time of any luminaire.This factor comprises mostly of the

- Lamp Lumen Depreciation (LLD)
- Luminaire Dirt Depreciation(LDD)
- Room Surface Dirt Depreciation (RSDD)

The details of these factors are described in article 2.5 of Chapter 2.

As the Lumen depreciation of LED is much less than conventional fixtures, so the MF factor in case of LED is taken 0.80. In case of industrial area, the maintenance factor is largely dependent on application area and type of lamp-luminaire is used.

6.2.3.3 Glare [46]

To reduce glare in industrial area, following steps are to be taken

- Decrease the luminance of light sources or luminaries or both
- Reduce the area of high luminance causing glare condition

- Increase the angle between glare source and line of vision
- Increase the luminance of the area surrounding the glare and against which it is seen.

6.2.3.4 Luminance and Luminance Ratios [46]

The ability to see details depends on the contrast between the details and the background. The greater the contrast i.e., the difference in luminance the more readily the seeing task is performed.
To achieve the recommended luminance relationship, it is important to select the reflectance of all the room surfaces and the equipment as well as control the luminance distribution.
Table 6.11 shows the percentage of reflectance of following surfaces: [43]

Table 6.11: Reflectance Percentage in Industrial Area

Surface	Reflectance Percentage
Ceiling	80-90
Wall	40-60
Desk, Bench tops, Machine and equipments	25-45
Floor	Not less than 20

But in case of practical scenarios for designing proposes, Ceiling reflectance is considered as 50%[], Wall reflectance 30% and floor reflectance 10% is considered as in most industry the maintenance cycle is very less. So the ceiling-wall-floor surfaces remains dirty most of the time. That's why the most minimum reflectance values are considered.

6.2.3.5 Distribution, Shadow and Stroboscopic Effect [43]

In uniform distribution of light with a maximum and minimum illumination at any point should not be 1/6th above or below the average level in the area. Harsh shadows should be avoided though in some cases it is preferred in order to accentuate the depth and form the objects. Care should be taken that no stroboscopic effect takes place as this might cause serious accidents to occur.

6.2.3.6 Colour of Light

For general seeing task in industrial areas, there appears to be no effect upon visual acuity by variations in color of light. However, color discrimination and color matching is a part of the work, the light sources selected should have the desired color rendering index.

6.2.3.7 Veiling Reflections

Where the task materials are specular or semi-specular, veiling reflections can reduce, or in some cases increase, task visibility. Source/task/eye geometries should be carefully considered in the design process to ensure high visibility. Vision and Perception, for additional information on veiling reflections.To decrease task visibility; care should be taken to minimize veiling reflectance where seeing task details are specular.

6.2.3.8 Brightness Consideration [43]

The apparent brightness of the various surfaces will depend on eye adaption level. When a room interior is seen through an open door outside with bright daylight, it will appear gloomy. But on entering the room, after the eye has adopted, things will appear brighter. When a room is lit by daylight the eye has a fairly high adaptation level due to the bright sky seen through the window

opening. Therefore, the parts of the room remote from the windows will appear gloomy even if the illumination in these parts visual task. It is, therefore, necessary to brighten up these parts if a proper balance of brightness is to be restored which will create a comfortable visual environment. This second consideration is at least as important as the flrst while determining the amount of light to be supplied by the supplementary lighting system. This requirement in some cases may result in having higher levels of illumination than required for the particular visual task involved.

During the night time since the entire area is illuminated to a level recommended for the satisfactory performance of the task carried out in the work area concerned, no additional problem of balance of brightness is involved, provided the general requirement of avoidance- of high brightness contrast by having suitably finished. Surfaces in the room are satisfied.

6.2.4 Lighting Related to structure of Industrial premises

6.2.4.1 Lighting of factory spaces with skylights [43]

Where daylighting is given due consideration in the design of a building, the shape of the building is primarily determined by this requirement. The working area is also planned on the basis of daylighting. While planning the artificial lighting, the layout of the luminaires has to be related to the layout of the working area to obtain the most comfortable working conditions. The lighting can be integrated with the natural shape and structure of the building while still meeting the requirements of the lighting effect on the working place to achieve a better result. Close coordination between the architect and lighting engineer can result in a lighting installation which is in tune with the architectural form of the building.

6.2.4.2 Lighting of factory spaces with closed ceilings [43]

In this type of construction there is very little dependence on daylighting. The artificial lighting has to be designed purely on the needs of the nature of work, layout of machinery, etc. Where a false ceiling is provided, the luminaires maybe recessed in the false ceiling for better aesthetics.

It is generally desired from the user point of view that the luminaires should, as far as possible, be fixed to the existing members in the roof structure like the bottom members of the trusses or longitudinal tie members. The luminaires have to be oriented according to the layout of the machinery to obtain the most satisfactory seeing conditions.

A layout decided on such a consideration may not coincide with the existing structural elements and additional members may have to be provided specifically for fixing the luminaires. An interesting development which takes care of this problem economically is the trunking system. The trunking, which is essentially metal channels with cover plates at the bottom, of standard lengths joined together, is run across the hall with suspensions at necessary intervals. Incidentally, this minimizes the number of suspension points compared to individually mounted luminaires each with two suspension pipes. The wiring is run through the trunking itself and the luminaires are attached to the trunking at the required locations.

6.2.4.3 High-bay lighting [43]

Generally high roofing is provided in the heavy engineering industry, where overhead travelling cranes are provided and/or fumes and smoke have to be evacuated. The artificial lighting has

to be located at a greater height in the roof structure to allow unobstructed movement of cranes, etc. While for low and medium mounting height fluorescent lamp lighting is an immediate choice, for highbay lighting it is advantageous to use a smaller number of high lumen output sources like the high Power Consumption high pressure gas discharge lamps.

6.2.5 Factors for Special consideration [43]

6.2.5.1 Lighting and Space Conditioning [43]

Sometimes lighting, heating, cooling, and atmospheric control are combined in an integrated system. The lighting system may provide a significant amount of the heat energy during winter months. When cooling is required, much of the lighting heat can be removed by the ventilation system.

6.2.5.2 High Humidity or Corrosive atmosphere and Hazardous Location lighting [43]

Enclosed and gasketed luminaires are used in nonhazardous areas where atmospheres contain nonflammable dusts and vapors. Enclosures protect the interior of the luminaire from conditions prevailing in the area. Steam processing, plating areas, wash and shower rooms, and other areas of unusually high humidity require enclosed and gasketed luminaires. Severe corrosive conditions necessitate knowledge of the atmospheric content to permit selection of proper material for the luminaires. Enclosed and gasketed luminaires are also required in food preparation areas of manufacturing plants, in dairy and ice cream plants, and food processing plants to permit the hosing-down of the areas for cleaning and sanitary reasons.

Hazardous locations are areas where atmospheres contain flammable dusts, vapors, or gases in explosive concentrations. They are grouped on the basis of their hazardous characteristics, and all electrical equipment must be approved for use in specific classes and groups. Luminaires are available specifically designed to operate in these areas, which are classified as Class I, Class II and Class III locations which is detailed available in IS5572.

6.2.5.3 Abnormal Temperature Condition [43]

Low ambient temperatures exist in unheated heavy industrial plants, frozen food plants, and cold storage warehouses. Equipment has to be selected to operate under these cold conditions, and particular attention should be given to lamp starting and light output characteristics if fluorescent equipment is considered. With HID equipment, temperature variations have practically no effect on light output, but the proper starting conditions must be provided. With incandescent lamp equipment, neither starting nor operation is a problem at low temperatures.

Abnormally high temperatures are common at truss height in foundries, steel mills, and forge shops. Caution should be exercised in selecting lighting equipment for mounting in these locations. It is particularly important to consider the temperature limitations of fluorescent and HID ballasts. Ballasts should be remotely located at a lower and cooler level or located within a cooled enclosure, or special high-temperature equipment should be used. Reduced fluorescent lamp output at high operating temperatures should be recognized. Incandescent lamps operated under high-temperature conditions, as in an oven, may experience a reduction in life. The luminaire chosen should be designed to withstand the ambient temperature conditions of its surroundings at the intended mounting height.

6.2.6 Light Sources in Industrial Lighting [43]

For industrial lighting the sources of light generally available in the country at present are tubular fluorescent lamps, high pressure mercury vapour (HPMV) lamps, high pressure sodium vapour (HPSV) lamps, metal halide lamps and LED. The selection of anyone of these or a combination of these depends on:

- Type of application
- Atmospheric conditions of industrial interiors and exteriors
- Structural features
- Initial outlay
- Running cost
- Ease of maintenance

Apart from these, the following factors such as luminous efficacy, lamp luminance, lamp life, lumen depreciation, colour temperature, colour rendering properties and ease of optical control, play a very vital role in the choice of light sources. All these aspects should be carefully considered while designing an industrial lighting scheme.

It may also be added here as a broad guide line that for low and medium height ceilings in industry, tubular fluorescent lamps are used for general uniform lighting whereas for highbays it is desired from lighting technique, economic and maintenance considerations to use HPMV or HPSV lamps or a combination of HPMV, HPSV, and metal halide lamps. Application of tungsten filament lamps is Iimited according to modern lighting practice, to local lighting and in certain cases also for colour appreciation and in case of infrequent use for short durations.

In spite of very low initial outlay due to Poor efficacy, short life and eventual frequent replacement, tungsten filament lamps are not employed for the general lighting of industries. Tubular fluorescent lamps, HP lamps, HPSV lamps and metal halide lamps for general lighting have to be selected after considering the above noted aspects.

6.2.7 Luminaires for Industrial Lighting [43]

The manner in which the light from the lamps is controlled by the luminaire governs to a large extent the important effects of glare, shadows, distribution and diffusion. Luminaires are classified in accordance with the way in which they control the· light. Most industrial applications call for either the direct or semi-direct types. Luminaires with upward components of light are preferred for most areas because an illuminated ceiling or upper structure reduces luminance ratios between luminaires and the background. The upwardlight reduces the 'dungeon' effect of totally direct lighting and creates a more comfortable and more cheerful environment.

Good environmental luminance relationships can also often be achieved with totally direct lighting if their illuminance and room surface reflectance are high.

In selecting industrial luminaires, it will be noted that other factors leading to more comfortable installations include:

- Light coloured finishes on the outside of luminaires reducing luminance ratios between the outside of the luminaire and the inner-reflecting surface and light source;
- Higher mounting heights to raise luminaires out of the normal field of view;

- Better shielding of the light source by deeper reflectors, cross baffles or louvres. This is particularly important with high Power Consumption incandescent filament or high intensity discharge sources and the higher output fluorescent lamps;

Selecting light control material, such as specular or non specular aluminum or prismatic conflgurated glass or plastic that can limit the luminaire luminance in the shielded zone.

Top openings in luminaires generally minimize dirt collection on the reflector and lamp by allowing an air draft path to move dirt particles upward and through the luminaire to the outer air. Therefore, ventilated types of luminaires have proven their ability to minimize maintenance of fluorescent, high intensity discharge, and incandescent filament types of luminaires. Gasketed dust tight luminaires are also effective in preventing dirt collection on reflector surfaces. Special attention is required to be paid to the selection of luminaires for industrial interiors with highly corrosive atmosphere or fire and explosion hazards.

Luminaires made of corrosion resistant material specially designed for corrosive atmospheres are to be selected for chemical factories, fertilizer plants and other similar industries where corrosive fumes are present in the atmosphere. For industrial areas containing inflammable dust and gases, the choice of luminaire will be guided by the relevant Indian Standard.

6.3 Basics of Illumination in Metro Railway

6.3.1 General Features of Metro Railway Lighting

Metro Railway is a type of high-capacity public transport generally found in urban areas. Unlike buses or trams, rapid transit systems are electric railways that operate on an exclusive right-of-way, which cannot be accessed by pedestrians or other vehicles of any sort, and which is often grade separated in tunnels or on elevated railways.

Modern services on rapid transit systems are provided on designated lines between stations typically using electric multiple units on rail tracks, although some systems use guided rubber tires, magnetic levitation, or monorail. The stations typically have high platforms, without steps inside the trains, requiring custom-made trains in order to minimize gaps between train and platform. They are typically integrated with other public transport and often operated by the same public transport authorities. However, some rapid transit systems have at-grade intersections between a rapid transit line and a road or between two rapid transit lines. It is unchallenged in its ability to transport large numbers of people quickly over short distances with little to no use of land.

The Illumination system should be functional, yet complementary to those other aesthetic features in the space which provide an atmosphere of relative comfort, pleasantness and cleanliness of surroundings and a sense of personal safety and security. Lighting for passenger stations should be bright and cheerful. The lighting system should provide adequate lighting levels rated for continuous operation, contrast ratios and other visibility attributes necessary to stimulate productivity, facilitate the use of facilities by patrons or the successful completion of tasks in a timely yet safe manner, and maintain appropriate surveillance levels under all ambient light conditions.

6.3.2 Metro Railway System [43]

The metro system may be divided into the following three categories:

- Underground Metro Railway: Trains run in a network of tunnel under the city. This format of the metro is popular where land cost are high and also there no space is available still metro railway requires for fast transportation.
- Elevated/ Surface Metro Railway: Trains run on dedicated corridors, at street level or elevated above street level.
- Mixed Metro Railway: Train run on a network cornprising underground tunnel along with elevated and surface corridor.

6.3.3 Metro Railway Application Area [43]

Metro Railway Application area are broadly divided in two categories i.e. Public areas and Non-Public Area

6.3.3.1 Public Area

Public areas are described as the areas that are used by passengers. The Public areas in Metro Railway system are:

- Public Parking Areas and Approach Roads;
- Entrance or Exit areas and Public Assemby;
- Circulation Areas
- Platform
- Platform edges
- Train display area
- Concourse area
- Building facades and signage
- Landing
- Restrooms and Toilets

6.3.3.2 Non-Public Area

Non-Public areas are those areas that are restricted for passenger uses and only used by metro railway staffs for operation of metro railway services. The non public areas in Metro railway system are:

- Railway Yard
- Workshop and car Shed
- Inspection Bays
- Tunnels
- Railway Offices
- Signaling Room
- Station Control Room
- Store Rooms
- Battery Rooms

6.3.4 General Requirement of Metro Railway Lighting [43]

The lighting system should be installed throughout all station areas, tunnels, ancillary buildings, station forecourts, parking areas; auto, taxi and bus drop off points, relocated and new access roads. The lighting should take into account efficiency, symmetry, application, glare, glare to CCTV or signage, computer screen environments, maintainability and long life. The lighting design should achieve a bright look, avoid any dark patches and afford easy safe access to all the areas. The lighting should be sufficient to avoid any unsafe situation under any normal or abnormal conditions. The type and quantity of lighting equipment and their luminous intensity should relate to the space being illuminated and take into account the effect of the architectural space, concept and colour scheme.

Emergency lighting systems should be installed to ensure that all the escape routes including tunnels, from the various areas can be safely and effectively identified in an emergency situation. All station and passageways should have emergency lighting powered from the essential power switchboard. The lighting system requirements associated' with the electrical systems and equipment should comply with the relevant latest standards and codes of practice.

6.3.5 Different Areas in Metro Railway and Lighting Requirement [43]

6.3.5.1 Public Areas

1. Approach Roads:

Lighting of approach roads should be designed to have:

Average maintained illumination of 20 Lux; and

Uniformity (E_{min}/E_{avg}) = 0.40.

Luminaires used should have good aesthetics, be durable, provide efficient and glare free lighting and should be easy to maintain.

2. Private and Public Parking Areas

The lighting design of private and public parking lots should consider the following:

- General lighting with high-masts with use of high pressure sodium vapour/metal halide lamps. Mounting height and number will depend on area to be illuminated;
- Avoidance of spill light and objectionable glare with proper choice of luminaires, like asymmetric luminaires
- Use of high efficacy lamps to reduce number of light points and Power Consumption;
- Lamp with low reignition time; and
- Greeneries and parking lots with isles demarcated.

For semi-enclosed parking lots a typical mounting height is 4 to 6 m. The luminaire is mounted on trusses. Luminaires selected should be suitable for surface mounting and lamps used fluorescent and metal halide.

For parking areas with sheds the luminaires used should be:

- Dust and moisture proof (IP65);
- Impact resistance proof (IK Rating)
- Light weight and sturdy with polycarbonate or die-cast aluminium housing and with cover.

3. Platform Areas

Platforms can be considered as semi-outdoor areas with a typical height of 2.7 to 4 m. For platform areas, luminaires selected should meet the considerations mentioned under design requirements.

Luminaires recommended for use in platform areas are:

- Mirror optics luminaires with acrylic or glass cover;
- General purpose luminaires with polycarbonate cover; and
- Symmetric-Asymmetric luminaires for platform edge lighting

4. Concourse

Concourse areas generally have a height of 2.4 to 5 m. The concourse area can be divided into two parts; paid concourse and unpaid concourse. The lighting treatment for both these areas is generally the same. The light level requirement is high, in the range of 300 lux .This area has very high footfalls. Linear fluorescent lamps with good colour rendering, lamp life and efficacy should be used in these areas. Luminaires selected should be suitable for recessed mounting with mirror optics. They should also have good efficiency to achieve optimum spacing as well as good aesthetics so that it is visually pleasing to the passengers. The luminaires used should have at least twin lamps so that in the event ofa lamp failure, that particular area is not left in total darkness.

5. Restrooms

Restrooms are generally areas with false ceilings. Lighting should be done using downlighters to minimize Power Consumption. CFL lamps are generally chosen for their compact size, ease of installation, high efficacy along with long life and good colour rendering.

6. Facades and Signages

Advertising forms a major form of revenue for metro authorities. Major companies find it as an extremely attractive medium to communicate to a huge cross section of people availing metro services daily. Proper lighting effects applied to facades and signages increase the commercial and prestige value of the metro as well as create interest in the mind of the passengers. For facade and signage lighting, LED solutions should be used to get a vibrant and dynamic effect. Station names can be displayed prominently through LED signages. For facade lighting LED fixtures can be integrated into the architecture itself to enhance the night time view without spoiling the day time view. Using the striking and unique features of LEDs, lighting effects can be created. The long life and low Power Consumption of LEDs also makes them an ideal product for these applications.

6.3.5.2 Non Public Areas

1. Yard Lighting

Lighting of yards should be designed to have:

Average maintained illuminance of 15-20 Lux; and

Uniformity (Emin/Eavg) = 0.33.

Lighting should consider:

- General lighting with high-masts with use of high pressure sodium vapour or metal halide lamps.

- Mounting Height and number will depend on area to be illuminated;
- Use of asymmetric luminaires to avoid glare and maximum energy efficiency; and
- Lamp with low reignition time.

2. Workshop/Car Shed

Workshops and car-sheds should be designed to have:
Average maintained illuminance of 300 lux; and
Uniformity (Emin/Eavg) = 0.40.

3. Inspection Bays

Inspection Bays should be designed to have:
Average maintained illumination of 500 lux; and
Uniformity (Emin/Eavg) = 0.40

4. Signaling/ Control Room

In control and equipment rooms, as well as substations, particular attention shall be given to the illumination of vertical surfaces such as screens, control panels, switches, and meters. Supplementary lighting may be used to achieve proper visibility and minimize shadows and reflection in glass faces. In battery rooms, industrial batten with or without reflectors may be used.

5. Tunnel/Trackway

Lighting systems should be installed in all tunnels. Lighting interference or distraction with the signal lamps should be taken into consideration. Lighting fixtures should contain instant start lamps. All tunnel lighting systems should be on emergency supply in running tunnels. Care should be taken that luminaires placed in the tunnel do not infringe on train clearance. The luminaires should have proper impact resistance protection. Trackways should be provided with sufficient light to define a path for evacuation under emergency condition.

6.3.6 Criteria for selecting lighting equipment [43]

Selection of lighting equipment will depend on the following factors:

- Ceiling type;
- Mounting height and Mounting possibility;
- Application areas (for selection of IP classification);
- Criticality of restricting glare;
- Importance of colour rendering index (mainly for selection of lamps); and
- Use of lamps with proper colour temperature.

6.3.7 Lamps used in Metro Railway [43]

For indoor areas linear and compact fluorescent lamps should be used. Preference should be given to environment friendly lamps with low mercury content (Less than 3 mg). For semi- outdoor and outdoor applications preference should be given to high intensity discharge lamps.

6.3.7.1 Linear Tubular Fluorescent Lamps

These lamps are available in different Power Consumptions, diameters, lengths, efficacies, colour temperatures, CRI, and life in burning hours. Recent developments in linear lamps have resulted in further reduction of lamp diameter and increase of lamp life. The increase of lamp life is highly advantageous for the metro where the daily usage of lamps is high, and re- lamping is disruptive causing inconvenience to passengers. Taking these points into consideration, it is preferable to use lamps with longer life in burning hours, in the range of 24000 to 42000 burning hours and above. The lamp life further increases when used with standard electronic ballasts. The use of lamps with longer life causes a reduction of maintenance cost per point, which leads to a high amount of saving,' as the number of fluorescent lamps used is quite high in a metro installation, typically 1 000 and above. Fluorescent lamps with a diameter of 16 mm (T5) also offer significant advantages. These lamps have higher efficacies than standard 26 mm diameter (T8) lamps, bringing down the energy costs significantly.

The availability of different Power Consumptions from 14W to 80W and lumen output from 1350 lumens to 7000 lumens increases the utility of FTL lamps in metro applications. The smaller diameter of these lamps also permits the use of luminaires with sleeker dimensions, resulting in better aesthetics. Shatter-proof lamps with protective coating can also be used where open luminaires are used, for increased safety.

For metro applications it is recommended by National Lighting Code-2010 that the lamp selected should meet the following criteria:

Lamp Efficacy: >90 Lumen/Watt;

Colour Rendering Index: > 80;

Colour Temperature: 4000 to 6500 K; and

Life: with HF at least 16 000 burning hours.

6.3.7.2 Compact Fluorescent Lamp

These lamps have been developed to provide a very energy effective lighting solution. CFLs are a compact light source and like linear fluorescent lamps they are available in different sizes, Power Consumptions, efficacies, colour temperatures, CRI and life in burning hours. CFLs are ideal for use in, orientation, decoration, security, task lighting and areas with relatively low lighting requirements. Their compact' size makes them very popular for use in downlighters. The development of high Power Consumption CFLs up to 120 W and high lumen output now permits its use in medium and highbay indoor lighting. The high Power Consumption lamps are very useful in lighting double height areas such as escalator areas, staircase landings, etc.. While selecting CFLs for metro application, the following parameters should be met:

- Instant Start;
- Colour Rendering Index: > 80; and
- Colour Temperature: 4000 to 6500 K.

6.3.7.3 High Pressure Sodium Vapour Lamps

High pressure sodium lamps should be used where efficacy and long life are more important than colour rendering. Sodium lamps have the highest lamp efficacies among all high intensity discharge lamps. High pressure sodium lamps give a golden white light which gives a warm

appearance and better visual acuity. These lamps have a universal burning position and low sensitivity to voltage fluctuations, which make them a very reliable choice for outdoor applications. The sodium lamps selected should meet the following criteria:
Lamp Efficacy: > 130 lrn/W;
Colour Rendering Index: > 23;
Colour Temperature: 2000 K;
Life: > 10000 burning hours; and
Restriking Time: <30 s.

6.3.7.4 Metal Halide Lamps

Metal halide lamps should be used where lamps with high efficacy as well as good CRI are required. Metal halide lamps have the highest efficacies and lamp life after sodium type lamps. Metal halide lamps give attractive white light, thus increasing visibility and creating a pleasant ambiance. The metal halide lamps selected should meet the following specifications:
Colour Rendering Index: > 65 for 250 W and 400 W; for lower Power Consumption 70 W and 150 W, it should be > 80.
In the family of metal halide lamps, there is a type with a ceramic discharge tube. These are compact in size and are available in low Power Consumptions. These can be used indoors in areas with high ceilings and outdoors in decorative applications and for floodlighting in pedestrian precincts. The compact ceramic discharge metal halide lamps selected for metro applications should meet the following criteria:
Lamp Efficacy: > 95 lm/W;
Colour Rendering Index: > 80; and
Life: 6 000 to 15 000 burning hours.

6.3.8 Luminaire [43]

Luminaires should have a downward light output ratio of the order of 70 percent and should not cause glare to the passengers and the train drivers. Luminaires should be weather proof so as to-avoid failure due to water seepage in tunnels. Collection of dust on the optical/reflecting surface impairing the light output should be prevented. It should be possible to clean it with ease and the reflecting surface should not get defaced for at least 10 years. The luminaires when mounted outside the station areas must have suitable protection against dust, moisture and rain (IP52/54 is preferred). The luminaire shall not emit toxic gases in case of fire. All the components including the internal wiring of the luminaires should be manufactured of material which are of the low smoke and zero halogen type. Luminaires should be the instant start type and without any restriking time for the underground areas and tunnels.
Luminaires selected should have the following features:

- Luminaires should be designed for good performance under the following ambient temperatures:
- Indoor luminaires at 45°C; and
- Outdoor luminaires atJ5°C.
- Luminaires should be able to operate at ± 6% voltage fluctuation without appreciable lighting level variation;

- Luminaires should conform to IS 10322(part 1);
- Photometry testing should be carried out as per IS 13383(Part 1 to Part 3); and
- Luminaires for fluorescent lamps should preferably be with electronic ballasts.

6.3.9 Ballast and Control Gear [43]

Ballasts are required to drive the lamp. There are two kinds of ballasts available: electromagnetic or EM ballasts and electronic or high frequency ballasts. Regardless of which type is chosen, the ballasts should be of high efficiency. The traditional electromagnetic ballast remains popular, but electronic ballasts offer significant advantages over traditional ballasts; they last longer, tolerate high voltage fluctuations, operate flicker- free and start quicker. Additionally, they save costs by using less power and extending the lives oflamps. The electronic ballast gives project designers far greater flexibility, to dim lamps, for instance. They also enhance safety by protecting against surges in voltage and operating at noticeably lower temperatures. Electronic ballasts also save electricity costs by generating less heat and reducing the load on air conditioning units. Electronic high frequency ballasts are also much lighter than conventional electromagnetic ballasts making them ideal for metro applications which are very prone to vibrations because of the continuous passage of trains.

For low pressure lamps such as fluorescent lamps used in metro applications, Only high frequency electronic ballasts should be chosen because of their merits discussed above.

For high pressure gas discharge lamps, high frequency electronic ballasts up to medium Power Consumptions have been developed and they provide the same benefits as ballasts for low pressure lamps. Electronic ballasts selected for metro applications should have extremely low ballast losses, long life, capability of withstanding wide voltage fluctuations of ±20 percent, and cause no electromagnetic interference with other equipment. The ballasts should be designed so that it should function continuously without any noise or hum.

While selecting ballasts for metro applications the following parameters should be met:

- All luminaires for fluorescent lamps shall preferably be with electronic ballasts;
- It is desirable to have high power factor ballasts for linear fluorescent lampsand CFLs;
- Ballast efficiency defined as a ratio of lamp Power Consumption to total input power should not be less than 0.95;
- Ballasts should maintain consistent light output for all fluorescent lamps over a voltage range of 192to 288 V;
- Input harmonic content should be < 10 percent. Individual supply current harmonics should conformto IS 14700(Part*3/Sec 2).*

6.3.10 LED Luminaire [45]

According to Delhi Metro Rail Corporation, the lumen maintenance of the LED fittings shall not be less than 70% after 5000 burning hour. The luminaire should pass IEC 60598-1, 2, 3, IEC 62031 and IEC/PAS 62612 or latest edition depending upon the type of luminaire. The luminaire should also comply IS 15885, 16101, 16102, 16103, 16104, 16105, 16106, 1610 (Part 1 and 2) as per application.

The fixture shall be suitable to work under maximum ambient temperature of 45ºC and the luminaire shall be designed to work in coastal, humid, salt laden and corrosive atmosphere. If heat sink is not used then housing should be made of 0.5 mm thick CRCA sheet or 2 mm thick extruded aluminium

or 2mm thick pressure die-cast aluminium, conforming to relevant standards, polyester powder coated of at least 40 microns and high UV and corrosion resistant. Heat-sink used should be extruded aluminium or pressure die-cast aluminium having high conductivity.

Luminaire should be covered with suitable Glass or diffuser with High Transitivity. Outdoor luminaire shall be with clear toughened glass or clear polycarbonate cover. Lighting fixtures and accessories shall be designed for continuous trouble free operation under diverse atmospheric conditions without deterioration of materials. There should be minimum IP65 protection for outdoor luminaire and IP20 protection for indoor luminaire. The fixture should have surge protection of 2KV to protect the device from under-voltage situation. The fixture should conform to IS-10322. The mixture should be suspended or recessed type depending upon the application area.

If reflector is used then there should be high quality aluminium reflector and shall have efficiency more than 85% to achieve a wide light distribution. The anodic film shall have a minimum thickness of 2.5 microns.

The LED chip efficacy shall be greater than 120 Lumen/Watt. The efficacy of the LED chip at 85ºC junction temperature shall be more than 85%. For lower Power Consumption luminaires (<45W), luminaire system luminous efficacy should be greater than 60 Lumen/Watt and for higher Power Consumption luminaires (>45W) luminaire system luminous efficacy should be greater than 80 Lumen/Watt. Adequate heat sink with proper thermal management shall be provided when high power LED chips are used. For low and mid power LED chip, the body of the luminaire acts as a heat sink. Minimum view angle of the LED luminaire shall not be less than 120º. Power factor of complete fitting shall be more than 0.9. LED chip shall be surface mounted type duly soldered to PCB by Reflow system or COB type. The solder used shall be ROHS compatible for environment friendliness.

Input frequency range shall be 50Hz ± 3. LED luminaire sall have CRI>80 for indoor application and CRI>70 for outdoor application with 3000K -6500K CCT value depending upon application. The LED driver shall be constant current type and operating voltage range or the driver should be 160 V to 270 V at 50Hz. The driver should have under voltage, over voltage, short circuit and earth fault protection. The driver shall have minimum efficiency of 85%. The Total Harmonic Distortion (THD) shall be less than 25% for luminaire Power Consumption less than 50W and shall be less than 15% for luminaire Power Consumption greater than 50W. The current waveform should meet EN 61000-3-2. The equipment should comply with IEC 61547 for EMC immunity requirement.

6.3.11 Ingress Protection [45]

Ingress protection is to be governed as per IEC 60529. As per DMRC there are three levels of IP for standardized application:

IP65: External areas, high mast towers etc. Ingress protection assures dust tight with no ingress of dust, complete protection against dust and there shall be no harmful effect when water is projected by a nozzle (6.3 mm) against enclosure from any direction.

IP54: Platform and entry and exit point etc. Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment. Water splashing against the enclosure from any direction shall have no harmful effect.

IP20: ASS/ESR and any other area; Ingress protection is for objects of size more than 12.5 mm with no protection for water.

6.3.12 Light loss factor [45]

The light loss factor shall be 0.9 for an air conditioned area, 0.7 for non-air conditioned area and 0.6 for outdoor area. LED luminaires technology is evolving and light loss factor shall be reviewed as per recommendations of the manufacturer.

6.3.13 Working Level [45]

The working level shall be zero meters whenever referred for passenger area ir floor level. It shall be 0.8 meter when referred to desk or staff working level.

6.3.14 Reflectance Factor [45]

The reflectance factor of the floor is taken as 10% and that of ceiling and walls shall be 50% and 30% from front and back house respectively. But generally now a day, it is taken as 70% for ceiling, 50% for Walls and 20% for floor as most of the ceiling and walls are clean white and floor is marbel finished.

6.3.15 Uniformity of distribution of Illumination [45]

The layout of the luminaires shall be decided to have the best level of uniformity index. It is not considered to lay down any standard of uniformity index, but shall be finalized considering the need for the purpose os security, safety and aesthetic. The locations for the installation of the luminaires shall be finalized after the layout of the equipment, working table or layout for the staff is tentatively finalized and in such a manner to take the advantage of providing Emax at locations important for the utility.

6.3.16 Glare [45]

The lighting design should minimize glare by the correct choice of location, number, type, and luminance of luminaires and shielding of lamps. Luminaires in control rooms shall be positioned so that no reflected glare from dials or monitor screens interferes with the operator's vision.

6.3.17 Mounting arrangement and type of Luminaires [45]

Reflector luminaires are used for illumination of platform and concourse public area. Batten luminaires shall be used in escape stairs and corridors within ASS/ESR areas and store rooms. Recessed modular luminaires shall be used in all operation and control romms for glare control. Recessed modular luminaires with louver will be used in passenger subways and staff areas where false ceiling system are installed but glare control is not required. Luminaires in riser ducts abd staircases will generally be wall mounted under structural soffit. Where wall mounted luminaires are used, the mounting level is 2.5 meter to underside of the fitting above the finished floor level. Luminares in ASS/ESR are suspended on conducts to approximately 3meters above finished floorlevel and on 2.5 meter at wall. The light fittings are to be so selected and mounted that it is easy to attend and replace the lamp, cleaning of reflector etc.

6.3.18 Emergency Illumination [45]

For security and safety of passengers and staff it is essential that in the event of a power failure there should not be total darkness. So it is recommended that in critical areas a certain number of luminaires be placed on emergency supply. This emergency line should be on uninterrupted power supply (UPS). The luminaires connected to emergency supply should be so chosen that they provide at least 30 percent of the general illuminance level in that area. This will ensure that till the DG set takes over or the power comes back, there will be sufficient illumination to ensure the safety and security of the passengers and staff. Emergency lighting should be provided in all public areas, on escalators and stairways, escape routes including those in the tunnels, control rooms, main offices, and plant rooms.

6.4 Basics of Illumination in Office

6.4.1 Lighting Layout [43]

According to National Lighting Code-2010, two types of layout are recommended

Modular Layout in which sufficiently large amount of surface mounted or recessed mounted luminaires are used according to field arrangement. Generally 2ft x 2ft grids are formed in the ceiling and upon that luminaires are arranged.

Fig. 6.17 Modular Office Layout

Trunk of lights in which continous lines of trunks of luminaires are formed. The luminaires used are mainly recessed or suspended or surface mounted.

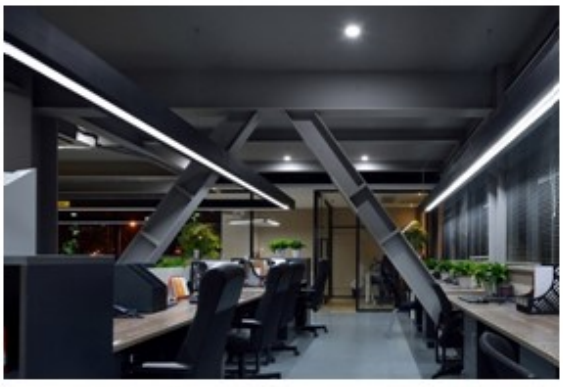


Fig. 6.18 Trunk of Light

6.4.2 Light Sources [43]

According to IESNA, Fluorescent lamps are most suitable to create working environment inside office. Hence T8, T5, CFL downlighters are being used. As per energy usage concern, now a day LED luminaires with IP20 protection and proper colour temperature are used in office spaces.

6.4.3 Illumination Level [43]

According to IS-3646, the recommended maintained illuminance on the working plane is 300-500-700 Lux. Usually the mis value is taken. The minimum and maximum values are taken where occupance age, accurary etc are considered.

According to IESNA 10th Edition Handbook, for age group of 25-65, 500 Lux level is considered. In practical scenarios, when the light level crosses 400 Lux, it creates eye strain and glare. That's why in most cases comparing with classroom lighting, the illumination level is maintained at 300 Lux as the maintenance cycle in office is frequent.

For critical application like conference room, 500 Lux is maintained.

6.4.4 Switching [43]

Switching is important in offices as it can reduce electricity consumption through ON-OFF control. For this purpose, individual or group switching is carried out.

6.4.5 Dimming [43]

For non-partioned or open planned office, multilevel dimming is preffered over switching control.

6.4.6 Daylight Integration [43]

Using the daylight in office can reduce the electricity consumption during daytime. But in India, daylight carries lots of heat which increases the load of HVAC system. Moreover daylight causes glare.

6.4.7 Colour [43]

According to CIE, for office spaces CRI>80 is required. To achieve this, lamps having colour temperature more than 4000K are used.

6.4.8 Glare [43]

In office, most of the glare comes from Visual Display Terminals (VDT) such as computers. This glare can be minimized by setting proper shielding angle. In this way, no direct reflection of the lamps on the VDT screen appears. Matte finished furniture is preferred for the same purpose.

6.4.9 Vertical Illuminance [43]

Proper Vertical illuminance is to be maintained for good appearance of 3D objects. If vertical illuminance is not sufficient, wall washer luminaires are used.

6.4.10 Reflectivity [43]

As per National Lighting Code-2010, in order to obtain desired luminous distribution following values of reflectivity are required

Ceiling: 60%-90%

Wall: 30%-80%

Working Plane: 20%-60%

Floor: 10%-50%

In practical design purposed, in modern office spaces, the minimum reflectance factors are taken as 70-50-20 % for Ceiling, Wall and Floor respectively.

6.4.11 LG7 Guideline [47]

One major cause of discussion about the new LG7 was the issues of illuminance on the walls and ceiling. LG7 included the recommendation that designers consider the amount of light falling on the ceilings and walls to ensure that the room appeared light and gave the occupiers a good visual environment to work in. These recommendations were not new, having appeared in the Code for Interior Lighting since the seventies. Perhaps designers had forgotten about them or had let their attention drift to much towards just providing the recommended illumination levels on the working plane.

The diagram shown in Fig.6.19 has appeared in the last four Codes in one form or another. It shows recommendations for room surface reflectance and illuminance levels. The 2001 amendment to LG3 specifically reminded designers that to avoid the room appearing dark they needed to achieve around 30% of the average working plane illuminance on the ceiling and 50% on the walls. In other words if the average working plane illuminance was intended to be 400 Lux the average wall illuminance should be 200 Lux and the average ceiling illuminance should be 120 Lux.

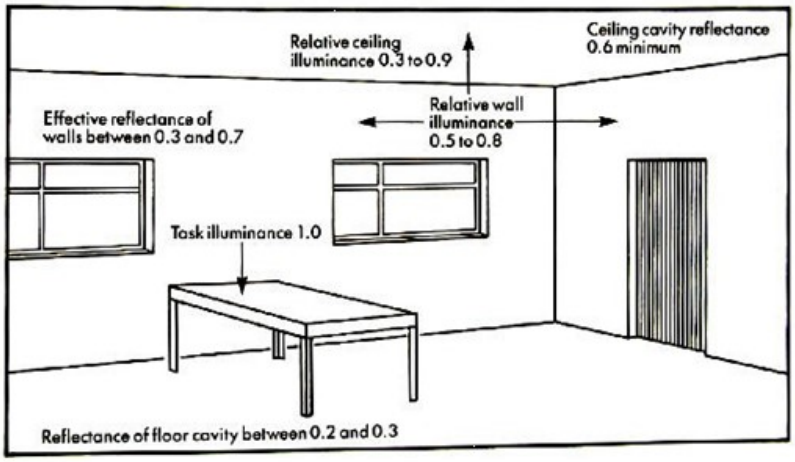


Fig. 6.19 Interior Reflectance and Illumination

Following the issuing of the 2001 amendment the Society had a lot of feedback from designers and manufacturers about practical problems in achieving the ceiling illuminance levels in spaces with low ceiling heights. The Society reviewed these comments and has modified its recommendations for the new LG7 to include variations for ceilings below 2.4m.

Where the ceiling height is below 2.4m and the client/developer cannot be persuaded to increase the height, and then the designer can provide less that the preferred 30% on the ceiling. The level should

not however fall below 20% or the ceiling will look dark by comparison with the rest of the office space which may make it appear oppressive to the occupants.

6.4.12 Human Centric Lighting

Light has deeply connection with circadian rhythm of human being. Upon applying cool white light (5700-6500K), cortisol hormone level becomes high and melatonin (Sleep hormone) level decreases which in turn boosts human alertness. After sunset, generally level of melatonin increases and cortisol level decreases for which sleep comes at night which in turn maintains circadian cycle. But after sunset if cool white light is applied, then cortisol level becomes high, so sleep comes at very late night which disrupt the circadian cycle.

In office spaces, now a day to maintain circadian rhythm, human centric light is used where light colour remains cool-white in daytime and after sunset it switches to warm white light. In daytime under cool white light, cortisol level boosts up which in turn increases alertness. Studies have found that in warm white light melatonin is not suppressed, which in turn maintains the circadian rhythm.

Now a day, many light companies are investing in making the human centric light. Due to the demand of increasing IT industries and offices, Human centric light demands are also going higher.

Chapter 7
Various Lighting Codes and Standards under Design Consideration

7.1 Introduction

A **standard** consists of technical definitions and guidelines that function as instructions for designers/manufacturers and operators/users of equipment/system designer. These provides guidelines but not enforceable by law.

A **code** is a standard that has been adopted by one or more governmental bodies and is enforceable by law.

The designs illustrated in this thesis work are in conformation with the various codes and standards followed in India. The various codes and standards have been discussed below.

7.2 Codes and Standards for Road lighting

The codes and standards that have been followed to do the Road lighting designs in document are listed below:

1. National Lighting Code (is.sp.72.2010)
2. IS:1944(Parts I and II) – 1970 : Code Of Practice For Lighting of Public Thoroughfares

7.2.1 National Lighting Code [43]

The national lighting code is published by the Bureau of Indian Standards, has been formulated for the purpose of setting out in a convenient form the requirements for responsible social, commercial and engineering conduct as designers, manufacturers and suppliers of lighting. Lighting technology plays a significant role in achieving basic social safety and environmental objectives.

The intent of this code is to encourage good lighting practices and systems which would minimize light pollution, glare, light trespass and conserve energy while maintaining safety, security, utility and productivity.

The lighting industry is highly fragmented and has relatively low technical barriers to entry. Despite its fundamental importance to many basic safety operations it is subject to comparatively low levels of regulation. Consequently, end users and consumers do not always have access to accurate and reliable information on what represents a safe, reliable and efficient lighting system. This code aims to build up a trust between the industry and its customers through integration of commerce and technology.

The NATIONAL LIGHTING CODE (NLC) covers the following:

a) Guidance on illuminating engineering practices to be followed by various types of occupancies;
b) Guidance on good engineering practices to be followed in the design, selection, installation and maintenance of lighting systems for indoor and outdoor areas;
c) Matters related to the science of illumination such as physics of light, electric light sources, luminaires and photometry
d) Coordination aspects to be considered while designing the lighting systems such as daylighting; and
e) Aspects relating to energy management and energy conservation in lighting installations including guidelines for design and good practices to be adopted for effective and efficient use of light sources.

The National Lighting Code is a single document in which, like a network, the information contained in various Indian Standards is compiled into a pattern of continuity and cogency with the interdependent requirements of Sections carefully analysed and fitted in. This makes the whole code a cogent continuous volume.

This code contains good practices and regulations which can be immediately adopted or enacted for use by various departments and public bodies. It lays down a set of minimum provisions necessary to protect the interest of the public with regard to lighting levels and quantity, and safety parameters. For the choice of lighting products and method of lighting design for the lighting professional, detailed guidelines have been provided in this code, still leaving enough scope for the integrity of the users, designers, architects and consultants.

This National Lighting Code is applicable to the lighting systems in large varieties of interior and exterior installations including special areas like hospitals, utilities, sports complexes, metro railway, etc, under the control of qualified persons. This NLC is divided into 13 parts some of which are having sections making a total of 29 parts.

The NLC as written is based on the present stage of knowledge on the various aspects of lighting systems. In this NLC many of the problems have been answered fully and some partially. Therefore, a continuous programme will go on, by which additional knowledge that is gained through technological evolutions, users' views over a period of time pinpointing areas of classification, and coverage and results of research in the field would be incorporated into the code from time to time to make it a living document. It is therefore proposed to bring out changes to the code periodically. In the meantime, all or some parts of the code may be adopted with or without changes by delegated legislative authorities in their regulations, administrative orders or similar documents.

7.2.1.1 Lighting recommendations for different road types- IS classification

The classification of road types and its recommended illuminance and other parameters are taken from IS 1944, Part I and II.

7.2.1.2 Lighting recommendations for junctions

Table 7.1 shows lighting recommendations for Junctions as per National Lighting Code- 2010.

Table 7.1: Lighting Recommendations for Junctions

Sl. No.	Junction Type	E_{av} (Lux)	E_{min}/E_{av}
i)	Key Junctions & Complex Flyover interchanges	50	0.4
ii)	Main City Junctions without any interchanges	20	0.4
iii)	Other smaller junctions	15	0.4
iv)	Pedestrian Crossings	50*	-
v)	Bus Bays	5	-

* This value is vertical illuminance on pedestrians at 1.2 m.

7.2.1.3 Lighting Measurement Methods

The lighting measurement method written in NLC is adopted from CIE. The ClE (1976a) recommends that where the luminaire spacing does not exceed 50 m, there should be 10 evenly spaced transverse rows of calculation points over its length, while for luminaire spacing greater than 50 m, the number of transverse rows should be such that the distance between two successive rows does not exceed 5m. The calculation grid as proposed by ClE; (1976a) is shown in Fig. 7.1.

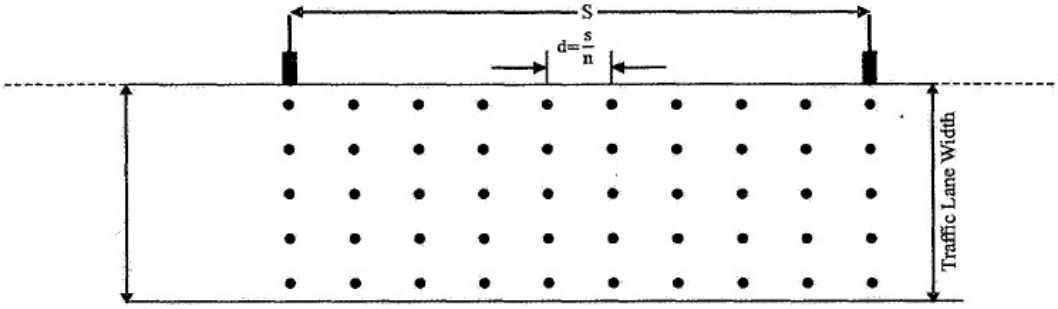


Fig. 7.1: Calculation grid

S = Spacing; d = longitudinal spacing between calculation points; n = no. Of transverse rows. For, S ≤ 50 m, n = 10; S > 50 m, n = smallest integer giving d ≤ 5 m.

Finally, the CIE also recommends that there should be 5 points across each traffic lane, with 1 point positioned on the centre line of each lane. It is stated that where the uniformity is good, $U_0 \geq 0.4$, subsequent calculations may be based on 3 points instead of 5.

$$Average\ illuminance\ E_{av} = \frac{P1 + P3 + P7 + P9}{16} + \frac{P2 + P4 + P6 + P8}{8} + \frac{P5}{4}$$

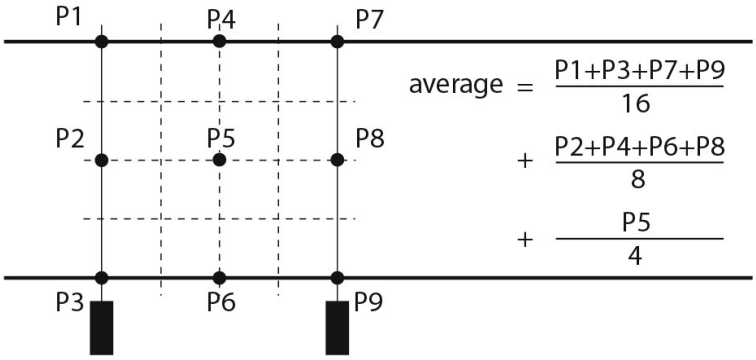


Figure 7.2: Nine-point measuring grid suitable for obtaining a rough indication of the lighting level; with weighting formula for calculation of the average value

For practical on-site measurements, the 9-point method is most acceptable. Fig. 7.2 illustrates the layout of a 9-point measuring grid of the kind sometimes used when checking new road lighting installations. The formula above the figure gives the weighting procedure that should be followed when calculating the average lighting level. Where extreme accuracy is required, the CIE recommends using as many measuring points as specified earlier.

7.2.2 IS: 1944(Parts I and II) – 1970: Code of Practice for Lighting of Public Thoroughfares [48]

This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 3 March 1970, after the draft finalized by the Illuminating Engineering Sectional Committee had been approved by the Electrotechnical Division Council.

This standard was first published in 1961. The number of motor vehicles plying on the streets in the towns and cities of India has increased considerably in these intervening years. Further, more efficient light sources are now available for use in street-lighting installations and levels of illumination which were considered too high then can be achieved economically. It was felt by the Sectional Committee

that the values of illumination prescribed earlier are low in practice and need to be increased. Hence this revision has been undertaken.

In this revision apart from traffic routes, the lighting of residential streets, bridges and flyovers, town and city centers, etc, are being dealt with. The code lays down the principles governing the lighting of public thoroughfares and makes recommendations on the quantity and quality of lighting to be provided. The details of design entirely depend on local circumstances.

This standard is divided into Parts I and II. Part 1 includes the new classification and a statement of general principles for non-specialist users; Part II gives recommendations for the lighting of traffic routes (Groups Al, A2 and B).

7.2.2.1 Basis of Lighting Requirements [48]

The level and type of lighting adopted for a street is based mainly on its traffic importance, both vehicular and pedestrian. However, the system of lighting to be provided should take into account all the relevant factors, such as the presence of factories, or places of public resort, the character of the street (whether a shopping area or a ring road in non-built-up area j, aesthetic considerations, the properties of the carriageway surface, the existence of humps, bends or long straight stretches and overhanging trees.

7.2.2.2 Classification of Lighting [48]

The classification is one of lighting and not of roads, but is linked with traffic density. It is left to the local engineer to decide upon the category of the lighting for the given road. Lighting for streets is classified into the following groups:

- ***Group A***- For main roads. This is sub-divided into two categories:
    - ***Group A1*** – For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of the drivers.
    - ***Group A2*** – For other main roads with considerable mixed traffic like main city streets, arterial roads and thoroughfares.
- ***Group B*** – For secondary roads which do not require lighting up to Group A standard. This is also divided into two categories:
    - ***Group B1*** – For secondary roads with considerable traffic, such as principal local traffic routes, shopping streets, etc.
    - ***Group B2*** – For secondary roads with light traffic.
- ***Group C*** – Lighting for residential and unclassified roads not included in the previous groups.
- ***Group D*** – Lighting for bridges and flyovers.
- ***Group E*** – Lighting for town and city centres.
- ***Group F*** – Lighting for roads with special requirements, such as roads near airfields, railways and docks.

7.2.3.3 Recommended Values of Illumination

Taking into account considerations of principles of vision, criteria of quality, and characteristics of sources and luminaires, set out in the code, Table 7.2 gives for each classification of installation the desirable level of illumination, the degree of uniformity, and the luminaires which are recommended or permitted.

Table 7.2: Classification of lighting installation and levels of illumination

Classification of Lighting Installation	**Type of Road**	**Average Illuminance on Road Surface E_{avg}**	**Uniformity Ratio E_{min}/E_{av}**	**Tranverse Uniformity E_{min}/E_{max}**	**Type of Luminaire Preferred**	**Type of Luminaire Permitted**
Group A1	Important traffic routes carrying fast traffic	30	0.4	0.33	cut-off	semi-cut-off
Group A2	Other main roads carrying mixed traffic like main city streets, arterial roads, throughway roads etc.	15	0.4	0.33	cut-off	semi-cut-off
Group B1	Secondary roads with considerable traffic like principal local traffic routes and shopping streets etc.	8	0.3	0.2	cut-off or semi-cut-off	non-cut-off
Group B2	Secondary roads with light traffic	4	0.3	0.2	cut-off or semi-cut-off	non-cut-off

7.3 Codes and Standards for Industrial Lighting

7.3.1 IS 6665: Codes of Practice for Industrial Lighting (1972) [46]

IS 6665 code has been drawn up in order to deal with the Speecia1 aspects of industrial lighting and shall be read in conjunction with IS 3646. This Indian Standard was adopted by the Indian Standards Institution on 8 August 1972, after the draft finalized by the Illuminating Engineering Sectional Committee had been approved by the Electro-technical Division Council.

7.3.1.1 Basis of Lighting Requirement

Industrial lighting encompasses seeing tasks, operating conditions and economic conditions. Visual tasks may be classified either small or very large; dark or light; opaque, transparent or translucent; specular or diffuse surfaces; flat or contoured shapes. With each of the various task conditions, lighting should be suitable for adequate visibility in developing raw materials into finished products. Physical hazards exist in manufacturing processes and, therefore, lighting should contribute to the utmost as a safety factor in preventing accidents. The speed of operations may be such as to allow only minimum time for visual perception and, therefore, lighting should be a compensating factor to increase the speed of vision.

Light should serve not only as a production tool and an aid to safety but should also contribute to the overall environment conditions of the work space. The lighting system should be a part of a planned environment contributing to the comfort and well-being of the users.

The design of a lighting system and selection of equipment is influenced by many economic factors. The choice, however, should not only be based on the project and the running costs of the lighting but also on the relationship of total lighting cost to costs arising out of other plant producing facilities and labour.

7.3.1.2 Recommended Values of Illumination

The illumination level used in Case Study on Thermal Power Plant and Case Study on Oil Refinery are based on IS 6665. From that code the standard values are listed in Table 7.3

Table 7.3: Recommended illuminance for different areas in a Thermal Power Plant an Oil Refinery

Name of Room/ Area	Range of Illumination (Lux)
Office Room	300-500-700
Battery Room	50-100-150
Motor Control Center	100-150-200
Wagon Tippler Control Room	200-300-500
Transformer Room	100-150-200
Pump House	100-150-200
Drive House	100-150-200
Remote Input Output Area	200-300-500
Switchgear Room	100-150-200
Cable Cellar Room	100-150-200
Corridor	100-150-200
Transfer Points	50-100-150
Crusher House	50-100-150
Junction Tower	50-100-150
Bunker Area	50-100-150
Conveyor	50-100-150

7.4 Codes and Standards for Metro Railway Station Lighting [45]

For Metro Railway Station lighting, there is no Indian Standard available till now. Most of the design descriptions are based on Part 6 Section 7 of National Lighting Code where illumination level are described according to areas which is described in Chapter 6.

Delhi Metro Rail Corporation Electrical and Design Wing has published a document named "Specifications for supply, installation, testing and commissioning of Indoor Lighting System" on 28th June, 2016. This document is used as a guideline of metro railway design.

7.4.1 DMRC Guideline

According to DMRC Electrical and Design Wing, the illuminance level at different areas is as described in Table 7.4

Table 7.4: Recommended illuminance for different areas in a Metro Railway [45]

Application	Average Designed Illuminance (Lux)
Passenger Area	
Circulating Area	30 (Localised 50-100 as per design utility)
Entrance/ Exit/ Passage/ Mezzanine/ Corridors/ Consourse	200 (Localized 250 as per design)
Customer Care/ Ticketing	200 (Localized 250)
Platform	200 (Localized 250 at PF Edges)
Trainway, Walkways and walking surfaces for emergency circulation	10
Escalators, Lifts, stairs and landing	250
Toilets	150
Operation Rooms	
Tunnel	20
Metro Stabling Lines	20
Depots/ Inspection Bays/ Repair Sections	200 (Localized upto 500)
Station Control Room/ OCC	250 (Localised 500)
Stabling Shed of Rakes	100
Underground Track Area and Cable Galleries	20
Stores Room	200
Equipment Room	
ECS/ TVF/ Signalling and Telecommunication/ UPS/ Battery/ Pump /Chiller /Auxiliary Substation / TSS /DG Room /LT Panel etc (All Plant Room)	200 (Localized 250)
Service Corridors	200

7.4.2 Energy Conservation Guideline in Metro Railway Station [45]

According DMRC Electrical Standards and Design Wing, the energy conservation principles and directives shall be followed in right earnest selection of lamps, dimmer, sensors and auto switch.
For transporation and offices, the ECBC 2016 defined value of LPD is 10.8 W/m^2. According to DMRC, they shall work to better the LPD norms as given in above table by at least 30% i.e. not more than 7.5.
During very recent installation of DMRC on an underground station, elevated station and depot, Standard LPD value of 7 W/m^2 is achieved.

7.5 Codes and Standard for Commercial Office Lighting

To design Commercial Office building, IS 3646 (Part 1 and 2) and ECBC-2017 guideline is followed.

7.5.1 IS-3646 (Part 1): Codes of Practice for Interior Illumination

In IS-3646 Part 1, the range of illuminance required in a interior space is given. It was published in 1992. According to IS-3646 Part 1, Lux level requirement in commercial area is given in Table 7.5.

Table 7.5: Illuminance Requirement in Commercial Area

Area	Required Illuminance Level (Lux)
Offices	
General offices	300-500-750
Deep plan general offices	500-750-l 000
Computer work stations	300-500-750
Conference rooms, executive Offices	300-500-750
Computer and data preparation rooms	300-500-750
Filing rooms	200-300-500
Drawing Offices	
General	300-500-700
Drawing boards	500-750-1000
Computer aided design and drafting	-
Print rooms	200-300-500
Banks and Building Societies	
Counter or office area	300-500-750
Public area	200-300-500

7.5.2 IS-3646 (Part 2): Scheduled for values of Illumination and Glare Index

According to IS-3646 Part 2, the Glare index i.e. Unified Glare Rating should be under 19 for commercial offices.

Table 7.6: UGR values corresponding to Discomfort Glare Criterion

UGR	Discomfort Glare Criterion
10	Imperceptible
13	Just perceptible
16	Perceptible
19	Just Acceptable
22	Unacceptable
25	Just Uncomfortable
28	Uncomfortable

7.5.3 Energy Conservation Building Guideline in Commercial Office Area

For energy efficient lighting designs in hospital there are some limiting values of light Power Density (LPD) to provide minimum and optimum energy requirements in an interior space area or in a building area as mentioned by Energy Conservation Building Code (ECBC). The Energy Conservation Building Code (ECBC) has been developed by the International Institute for Energy Conservation (IIEC) under contract with the United States Agency for International Development (USAID) as a part

of the Energy Conservation and Commercialization (ECO) Project and ECBC was launched in 2007 on a voluntary basis by the Bureau of Energy Efficiency (BEE).

Unlike ECBC 2016, ECBC 2017 has divided building rating into three divisions i.e. ECBC Building, ECBC+ Building and Super ECBC building depending upon least energy usage by satisfying all the criteria.

Accoding to ECBC 2017, By Building Area method, the Lighting Power Density for Commercial Office spaces to satisfy ECBC Building Rating is 9.50 W/m^2, to satisfy ECBC+ Building rating it is 7.60 W/m^2 and to satisfy SuperECBC Building, it is 5.0 W/m^2.

By Space Function Method, according to ECBC 2017, Lighting Power Density for Commercial Office Spaces is listed in Table 7.7, 7.8, 7.9.

Table 7.7: Interior Lighting Power for ECBC Buildings – Space Function Method [49]

Category	**LPD (W/m^2)**
Common Space Types	
Restroom	7.70
Storage	6.80
Conference/ Meeting	11.5
Parking Bays (Covered/ Basement)	2.20
Electrical/ Mechanical	7.10
Corridor/Transition	7.10
Lobby	9.10
Parking Driveways (Covered/ Basement)	3.00
Workshop	17.1
Stairways	5.50
Business	
Enclosed	10.0
Banking Activity Area	12.6
Open Plan	10.0
Service/Repair	6.80

Table 7.8: Interior Lighting Power for ECBC+ Buildings – Space Function Method [49]

Category	**LPD (W/m^2)**
Common Space Types	
Restroom	6.10
Storage	5.40
Conference/ Meeting	9.20
Parking Bays (Covered/ Basement)	1.75
Electrical/ Mechanical	5.70
Corridor/Transition	3.60
Lobby	7.30
Parking Driveways (Covered/ Basement)	2.50
Workshop	13.70
Stairways	4.40
Business	
Enclosed	8.60
Banking Activity Area	9.30
Open Plan	8.60
Service/Repair	5.50

Table 7.9: Interior Lighting Power for SuperECBC Buildings – Space Function Method [49]

Category	**LPD (W/m^2)**
Common Space Types	
Restroom	3.80
Storage	3.40
Conference/ Meeting	5.70
Parking Bays (Covered/ Basement)	1.10
Electrical/ Mechanical	3.50
Corridor/Transition	2.30
Lobby	4.60
Parking Driveways (Covered/ Basement)	1.50
Workshop	8.60
Stairways	2.70
Business	
Enclosed	5.40
Banking Activity Area	5.80
Open Plan	5.40
Service/Repair	3.40

Chapter 8
Case Studies

8.1 Introduction

The main objective of this chapter to show the simulation of results of Road, Industrial Area, Commercial Office and Hospital by using conventional luminaires and LED luminaires. The design illuminance follows the relevant guideline which is described in Chapter 8. The softwares used in these simulations are AGI32, DIALux 4.13 and DIALux EVO 8.0. All the case studies are shown here are practically existed.

8.2 Case Study on Road Lighting

The road used in this study is a State Highway where warm white light is mandatory due to dirt accumulation beside the road. White light gives max colour rendering in which dust particles can be objectified which in turn causes road accident. [50] The state highway is divided into points for the calculation purposes. The distance of different points of the road is shown in Table 8.1 along with the lighting arrangement. The Road survey map is shown in Fig. 8.1 and in Fig. 8.2 shows the distance of the road stretch in pie chart.

Table 8.1: Different Section of the road used in this case study

Sl. No.	Road Stretch	Distance (m)	Type of Road	Width of Road (m)	Median width (m)	Luminaire Arrangement
1	A to B	475	A1; Dual Carriage	11	1	Twin- Central
2	B to C	1131	A1; Dual Carriage	11	1	Twin- Central
3	C to D	363	A1; Dual Carriage	11	1	Twin- Central
4	D to E	652	A1; Dual Carriage	11	1	Twin- Central
5	E to F	160.5	A1; Dual Carriage	11	1	Twin- Central
6	G to H	242	A1; Dual Carriage	11	1	Twin- Central
7	H to I	450	A1; Dual Carriage	11	1	Twin- Central
8	I to J	725	A1; Single Carriage	15	NA	Stggered

After going through a survey by measuring the distances of the areas, the road lighting simulation was done by AGI32 software. In DIALux 4.13 software, the illuminance values are calculated between a span i.e. between two adjacent lumnaires which in practical cases creates difference with actual results. So to get 30 Lux averages [48] throughout the area **"Typical Construction of Road"** is simulated through AGI32 as AGI32 calculates throughout the constructed road area.

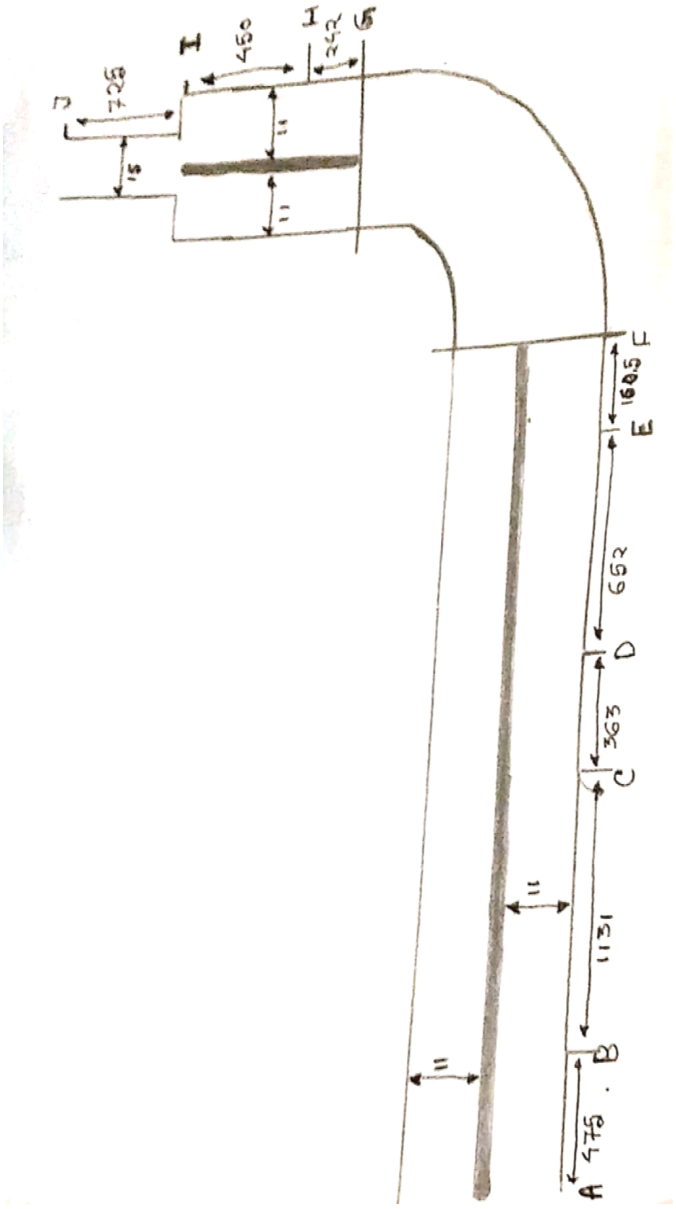


Fig. 8.1: Road Diagram

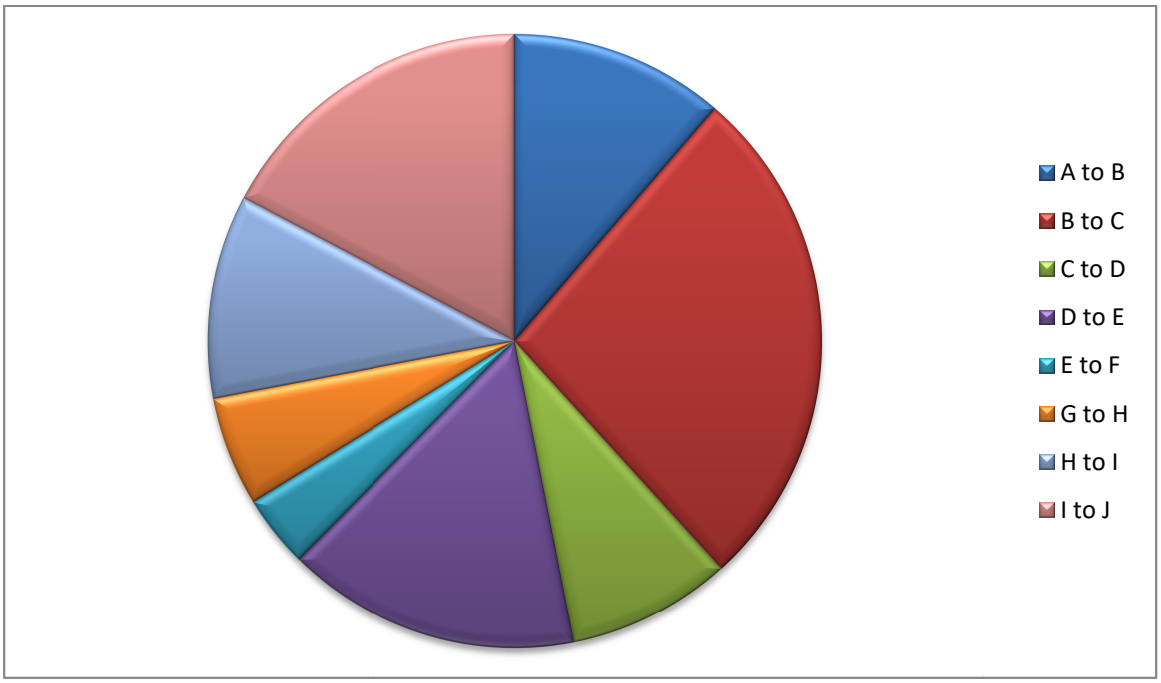


Fig 8.2: Pie chart of Road Stretch Distance

8.2.1 Simulation by using Conventional Fixtures

At first, an AGI32 simulation was done by using conventional luminaires. The light loss factor is taken 0.7 as in case of conventional fixtures the lumen depreciation is rapid. [53]
The simulation reports are shown in Annexure III.

8.2.2 Simulation by using LED Luminaire

As the road in this case study is a state highway so warm white light is used instead of white light as in highways, there is so much possibility of accumulation of fog and in white light the chance of accident increases when the environment is dusty. That's why in dusty area for not detecting dust particles properly, warm white or yellow light is used. [50]
The overall light loss is taken as 0.8 as in cases on LED luminaires, the lumen depreciation is very less comparing with conventional luminaires. [53]

Result and Cost Analysis of this case study is shown in Chapter 10.

8.3 Case Studies on Industrial Lighting

As Industrial Lighting is a very vast topic and it covers many industrial areas, here only focus has given on Thermal Power Plant and Oil Refinery Sector. This section deals with the Lighting simulation result on "Thermal Power Plant" and "Oil Refinery" using DIALux 4.13 lighting software and thereafter analyze it on different parameters of energy efficiency.

8.3.1 Case Study on Thermal Power Plant

Since a Thermal Power Plant comprises different areas and each area is dedicated for a specific purpose, the following study attempts to give an overview of general lighting system that is found in most Thermal Power Plant .The entire project has been divided into 2 parts:

a) General Area

b) Coal Handling Plant

8.3.1.1 Design Input

The design input is described in Table 8.6.

Table 8.6: Thermal Power Plant Design Input

Sl. No.	Area	Dimension (LXWXH) m	%Reflecion Factor (Ceilling-Wall-Floor)	WP Height (m)	Required Lux level	Uniformity
1	Office Room	5X4X2.7	70-50-20	0.76	300	>0.4
2	Battery Room	8X6X5.5	50-30-10	0.76	100	>0.4
3	Motor Control Centre	6X7X5.5	50-30-10	0.76	200	>0.4
4	Transformer Room	39.5X8X5.5	50-30-10	0.76	100	>0.4
5	Pump House	30X10X5.5	50-30-10	0.76	100	>0.4
6	Drive House	9.25X9X7	50-30-10	0.76	100	>0.4
7	Corridor	21X2X4.5	50-30-10	0.76	150	>0.4
8	Switch Gear Room	44.50X8X4.5	50-30-10	0.76	200	>0.4
9	Cable Cellar Room	23.89X13.71X2.5	50-30-10	0.76	200	>0.4
10	RIO Room	6X4.5X3.5	70-50-10	0.76	300	>0.4
11	Wagon Tripler Control Room	7.47X3.50X3.5	70-50-10	0.76	300	>0.4
12	Transfer Point	16X11X4.5	50-30-10	0.76	100	>0.4
13	Junction Tower	19X14X4.5	50-30-10	0.76	150	>0.4
14	Bunker Area	42X12.75X10	50-30-10	0.76	100	>0.4
15	Crusher House	32X25X8	50-30-10	0.76	100	>0.4
16	Belt Conveyor	268.7X10X3	50-30-10	0.76	70	NA
17	Pipe Conveyor	70X4X3.2	50-30-10	0.76	70	NA

.

8.3.1.2 Area-wise Description

❖ **Office Room**

Offices are designed to house working people engaged in thought and in a number forms of communication(visual, telephone, manual etc.).Office lighting should enable workers to perform these tasks efficiently.

Design Requirement: (as specified by Client)
Target Illuminance (E_{avg}): 300 lux
Target Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area this is to carry out office works like using desktop, files, laptop etc. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Battery Room**

Light fixtures should be fixed to the wall or suspended at more than from the ceiling but not vertically above the battery units. Light Fittings should be of closed type are recommended. However, watertight Fittings with flameproof construction are recommended because of corrosive and inflammable gas environment.

Design Requirement: (specified in Table 8.3)
Target Illuminance (E_{avg}): 100 lux
Target Overall Uniformity (U_o): ≥ 0.4

Fig. 8.5: Typical Battery Room

Design Aim:

To achieve uniform illumination of the mentioned area this is used to carry out inspection and monitoring of battery. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Motor Control Centre**

A motor control center is an assembly of one or more enclosed sections having a common power bus motor control units. A motor control center can include variable frequency derive, PLCs, and metering.

Fig. 8.6: Typical Motor control centre

Design Requirement (as specified by Client)

Target Illuminance (E_{avg}): 200 lux

Target Overall Uniformity (U_o): ≥0.4

Design Aim:

To achieve uniform illumination of the mentioned area used for monitoring data which are used for efficient working of motors, the designed illuminance should be very near to the desired value as per client requirement.

❖ **Transformer Room**

Transformers are used either to raise or lower voltage and currents in an electrical circuit. Transformer room should be adequately illuminated as transformer needs extensive maintenance.

Fig. 8.7: Typical Transformer Room

Design Requirement (as specified by Client)

Target Illuminance (E_{avg}) : 100 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area which is to carry out activities like monitoring and maintenance of the transformers, the designed illuminance should be very near to the desired value as per client requirement.

❖ **Pump House**

Filtered water pumps and desalinated water pumps are kept in Pump House. Since thermal power plant run via Rankine Cycle these pumps helps in cooling the steam. Circulation of water is very important since it affects the availability and operational efficiency of a thermal power plant.

Fig. 8.8: Typical Pump House

Design Requirement (as specified by Client))

Target Illuminance (E_{avg}) : 100 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area for monitoring and controlling of the pumps, the designed illuminance should be very near to the desired value as per client requirement. Luminaire should be chosen effectively to give techno-commercial solution.

❖ **Drive House**

Drives House is responsible for control of motors which are responsible for conveyor belt system, crushing mechanisms and wagon tippler system.

Fig. 8.9: Typical Drive House

Design Requirement (as specified by Client)

Target Illuminance (E_{avg}): 100 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area used for monitoring and controlling of drives. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Corridor**

Corridor is the pathway between different departments or walk spaces in any room.

Fig. 8.10: Typical Corridor

Design Requirement (specified in Table 8.3)

Target Illuminance (E_{avg}): 150 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area so that personnel have enough visibility to walk through the area. The designed illuminance should be very near to the desired value as per client requirement

❖ **Switch Gear Room**

Switch gear is the combinations of electrical disconnect switches, fuses or circuit breaker used to control, protect and isolate electrical equipment. It also includes all devices associated with control, metering and regulation of electrical power system.

Fig. 8.11: Typical Switchgear Room

Design Requirement (as specified by Client)

Target Illuminance (E_{avg}): 200 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area to used for controlling ,metering and regulation of electrical power system. The designed illuminance should be very near to the desired value as per clients' requirement.

❖ **Cable Cellar Room**

It is a room under Switch Gear Room. All important cables of switchgear are passed through this room. It is a very important section of Thermal Power Plant so proper selection of luminaire is important.

Fig. 8.12: Typical Cable Cellar Room

Design Requirement (as specified by Client)

Target Illuminance (E_{avg}): 200 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area which is mainly to carry out inspection of cable which are part of switchgear system, the designed illuminance should be very near to the desired value as per client requirement.

❖ **Remote Input Output (RIO) Room**

Remote input output room is a microprocessor controlled electronic devices equipped room that interfaces objects in the physical world to a distributed control system by transmitting data to a master system and by using messages from master system to control connected objects.

Fig. 8.13: Typical Remote Input Output Room

Design Requirement (specified in Table 8.3)

Target Illuminance (E_{avg}) : 300 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

Achieving uniform illumination of the mentioned area is mainly to carry out recording data and monitoring and control of different devices. As this room requires manual operation uniformity is important. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Wagon Tripler Control Room**

A control room will be provided adjacent to wagon tippler for operation and control of wagon tippler. The complete view of the unloading system will be available from control system.

Fig. 8.14: Typical Wagon Tripler Control Room

Design Requirement (as specified by Client)

Target Illuminance (E_{avg}): 350 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area mainly to carry out effective operation of wagon tippler, the designed illuminance should be very near to the desired value as per client requirement.

❖ **Transfer Point**

At transfer points materials are transferred from tail pulley of one conveyor belt to head pulley of another conveyor belt with the help of a flip gate.

Design Requirement (specified in Table 8.3)

Target Illuminance (E_{avg}): 100 lux

Target Overall Uniformity (U_o): ≥ 0.4

Fig. 8.15: Typical Transfer Point

Design Aim:

To achieve uniform illumination of the mentioned area which isused to transfer coal from one pulley to another. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Junction Tower**

Junction Towers are used where conveyors has any angular deviations.

Fig. 8.16: Typical Junction Tower

Design Requirement (as specified by Client)
Target Illuminance (E_{avg}) : 150 lux
Target Overall Uniformity (U_o): 0.4

Design Aim:

To achieve uniform illumination of the mentioned area this is used to carry out inspection of the conveyor parts. The designed illuminance should be very near to the desired value as per clien's requirement.

❖ **Bunker Area**

Bunkers are for storing coal for a longer time in order to supply coal on a continuous basis to feeder. Bunkers are designed in such a way that they can hold coal for 24 hours of use.

Design Requirement (specified in Table 8.3)
Target Illuminance (E_{avg}): 100 lux
Taregt Overall Uniformity (U_o): ≥ 0.4

Fig. 8.17: Typical Bunker Area

Design Aim:

To achieve uniform illumination of the mentioned area this is used for storing of coal in the bunkers. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Crusher House**

At crusher house coals are crushed up to a certain size and this crushing size depends on the requirement. After crushing, coal is sent to bunkers.

Fig. 8.18: Crusher House

Design Requirement (specified in Table 8.3)
Target Illuminance (E_{avg}): 100 lux
Target Overall Uniformity (U_o): 0.4

Design Aim:

To achieve uniform illumination of the mentioned area to carry out maintenance of the equipment's which crushes the coal. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Belt Conveyor**

A conveyor belt is a conveyor structure is dragged from tail pulley where material is loaded into the conveyor to the head pulley or drive pulley where the material is discharged. At every conveyor there is carrying and return belt.

Fig. 8.19: Belt Conveyor

Design Requirement (as specified by Client)
Target Illuminance (E_{avg}): 70 lux

Design Aim:

To achieve uniform illumination of the mentioned area that is for the maintence and effective operation of conveyor belts. The designed illuminance should be very near to the desired value as per client requirement.

❖ **Pipe Conveyor**

A pipe conveyor a belt is wrapped into the tubular shape and this allows the conveyor to negotiate vertical and horizontal curves.

Design Requirement (as specified by Client)
Target Illuminance (E_{avg}): 70 lux

Design Aim:

To achieve uniform illumination of the mentioned area for the maintence and effective operation of conveyor pipes. The designed illuminance should be very near. The designed illuminance should be very near to the desired value as per client's requirement.

Fig. 8.20: Typical Pipe Conveyor

8.3.1.3 Simulation by using Conventional fixtures

When using conventional fixtures, the maintenance factor is taken 0.7 as the lumen depreciation of conventional fixture is higher. [53]

8.3.1.3.2 DIALux 4.13 Simulation Results

The DIALux 4.13 simulation reports are shown in Annexure V.

8.3.1.4 Simulation by using LED fixtures

The manner in which the light distribution is controlled by the luminaire, governs to a large extent the effects of glare, shadows, distribution and diffusion. Most industrial application requires either direct or semi direct type lighting systems. Most industries tend to use conventional fittings owing to initial coast of LEDs. But these conventional lighting system consumes a lot of energy and responsible for industrial pollution too. Thus industries are moving towards a cleaner, safer and pollution free lighting system, that is LED. Though LEDs are expensive but their initial cost can be recovered by calculating their payback period and return of investment.
For simulation, the light loss factor is taken as 0.8. [53]

8.3.1.4.2 DIALux 4.13 Simulation Results

The DIALux 4.13 simulation reports are shown in Annexure VI
The light loss factor is taken as 0.8 as in case of LED lumen depreciation is less. [53]
Result and Cost Analysis of this Case Study is shown in Chapter 10.

8.3.2 Case Study on Oil Refinery

An Oil Refinery covers a vast area comprising various activities like Pumping, Oil Storage & Handling, Pipeline to name a few. Our scope was to survey the different areas and rooms under Pipeline Division of the Concerned Oil Refinery. During Survey Work, we had to note down different parameters required for designing a lighting system like dimensions of the room, type of luminary, no. of luminaire and if possible Power Consumption of the luminary and illuminance level of the rooms. Based on the field work we had to propose a energy efficient lighting solution, that must be LED Lighting system.

8.3.2.1 Design Input

The design input is detailed in Table 8.41.

Table 8.41: Oil Refinery Design Input

Sl. No.	Area	Dimension (LXWXH) m	%Reflecion Factor (Ceilling-Wall-Floor)	WP Height (m)	Required Lux level	Uniformity
1	Office Room	3.9X3.6X3	70-50-20	0.76	300	>0.4
2	Electrical Workshop	9.30X7X4	50-30-10	0.76	100	>0.4
3	Radio Room	6.60X3.60X4	50-30-10	0.76	100	>0.4
4	PMCC HT & LT Room	12.77X5.50X4	50-30-10	0.76	150	>0.4
5	Isolator Room	11.50X5.50X4	50-30-10	0.76	70	>0.4
6	Variable Frequency Room	10.50X5.58X4	50-30-10	0.76	100	>0.4
7	Capacitor Room	3.25X5.04X4	50-30-10	0.76	100	>0.4
8	PLC Room	6.90X5.38X4	50-30-10	0.76	100	>0.4
9	HB Pump Shed	25.20X12.90X4	50-30-10	0.76	150	>0.4

8.3.2.2 Area wise description

❖ **Office Room**

Offices are designed to house working people engaged in thought and in a number forms of communication (visual, telephone, manual etc.).Office lighting should enable workers to perform these tasks efficiently.

Design Requirement (as specified by client)

Target Illuminance (E_{avg}): 300 lux

Target Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area which is used to carry out office works like using desktop, files, laptop etc. The designed illuminance should be very near to the desired value as per client's requirement.

❖ **Electrical Workshop**

Electrical Workshop is a place where employees get the knowledge on the operation of various process involved in production, tools involved and properties of different materials involved in the industry.

Fig. 8.64: Typical Electrical Workshop

Design Requirement (as specified by client)

Target Illuminance (E_{avg}): 100 lux

Target Overall Uniformity (Uo): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area this is used for fabrication task. The designed illuminance should be very near to the desired value as per client's requirement.

❖ **Radio Room**

Radio room is used to communicate with employees who are deployed at different departments for various activities. It includes operating and stand by equipments like transmitter and receiver.

Fig. 8.65: Typical Radio Room

Design Requirement (as specified by client)

Target Illuminance (E_{avg}): 100 lux

Target Overall Uniformity (Uo): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area is operate different devices used for communication. The designed illuminance should be very near to the desired value as per client's requirement.

❖ **PMCC HT & LT Panel**

It is a part of the switchgear room. It comprises equipment like circuit breaker, switches and fuses.

Fig. 8.66: Typical PMCC HT & LT Panel

Design Requirement (as specified by client)
Target Illuminance (Eavg) : 150 lux
Target Overall Uniformity (Uo): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area is used to check the readings of HT and HT panel. Since accurate readings need to recorded uniformity is very important. The designed illuminance should be very near to the desired value as per client's requirement.

❖ **Isolator Room**

Isolator room comprises isolator which separates the circuit from power line and discharged the trapped charge in the circuit. Since isolator are off load devices and need to be operated manually.

Fig. 8.67: Typical Isolator Room

Design Requirement (as specified by client)
Target Illuminance (Eavg) : 70 lux
Target Overall Uniformity (Uo): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area which is used to operate the isolator. Since it requires manual operation uniformity is important. The designed illuminance should be very near to the desired value as per client's requirement.

❖ **Variable Frequency Drive Room (VFD)**

VFD room is used to monitor the controlling speed, start and stop the AC Motors. A VFD system involves AC motor, controller and operator interface. Pumps in oil industry are driven by fixed /variable speed electric motors. Keeping an electrically driven pump online is critical to achieving maximum profitability.

Design Requirement (as specified by client)

Maintained Average Illuminance (E_{avg}): 100 lux

Overall Uniformity (U_o): ≥ 0.4

Fig. 8.68: Typical VFD Room

Design Aim:

To achieve uniform illumination of the mentioned area which is mainly used for operation and control of drives, the designed illuminance should be very near to the desired value as per client's requirement.

❖ **Capacitor Room**

A capacitor bank is a group of several capacitor of same rating that is connected either in series or in parallel with each other to store electrical energy.

Fig. 8.69: Typical Capacitor Room

Design Requirement (as specified by client)

Maintained Average Illuminance (E_{avg}): 100 lux

Overall Uniformity (U_o): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area which is used keep capacitors banks. The designed illuminance should be very near to the desired value as per client requirement.

❖ **PLC Room**

PLC is a computing system is used to control electromechanical processes. It is a type of industrial control system that is used to monitor and control facilities and infrastructures in industries.

Fig. 8.70: Typical PLC Room

Design Requirement (as specified by client)

Target Illuminance (E_{avg}): 100 lux

Target Overall Uniformity (Uo): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area this is used to monitor the control system of any industrial technology. The designed illuminance should be very near to the desired value as per client requirement.

❖ **HB Pump shed**

Pumps are widely used in oil industry. By converting the mechanical energy, pumps are used to accelerate and transport the fluid from one location to another, with size being proportional to volume being moved.

Fig. 8.71: Typical HB Pump Shed

Design Requirement (as specified by client)

Target Illuminance (Eavg) : 100 lux

Target Overall Uniformity (Uo): ≥ 0.4

Design Aim:

To achieve uniform illumination of the mentioned area which is used for operation and controlling the pumps. The designed illuminance should be very near to the desired value as per client requirement.

8.3.2.3 Simulation by using Conventional Fixtures

When using conventional fixtures, the maintenance factor is taken 0.7 as the lumen depreciation of conventional fixture is higher. The DIALux 4.13 simulation reports are shown in Annexure VII.

8.3.2.4 Simulation by using LED Fixtures

The light loss factor is taken as 0.8 as in case of LED lumen depreciation is less. The DIALux 4.13 simulation reports are shown in Annexure VIII. The results are section-wised summarized below.

Result and Cost Analysis of this Case Study is shown in Chapter 10.

8.4 Case Study on Metro Railway Station

For this case study, Station Platform level and Concourse level are taken into account. First a simulation has done by using conventional luminaires and then another simutaion is done by using LED luminaires by maintaining the proper illuminance level as per standard.

8.4.1 Platform and Staircase Area

8.4.1.1 Autocad Drawing

Fig. 8.92: Plan View of PlatformLevel

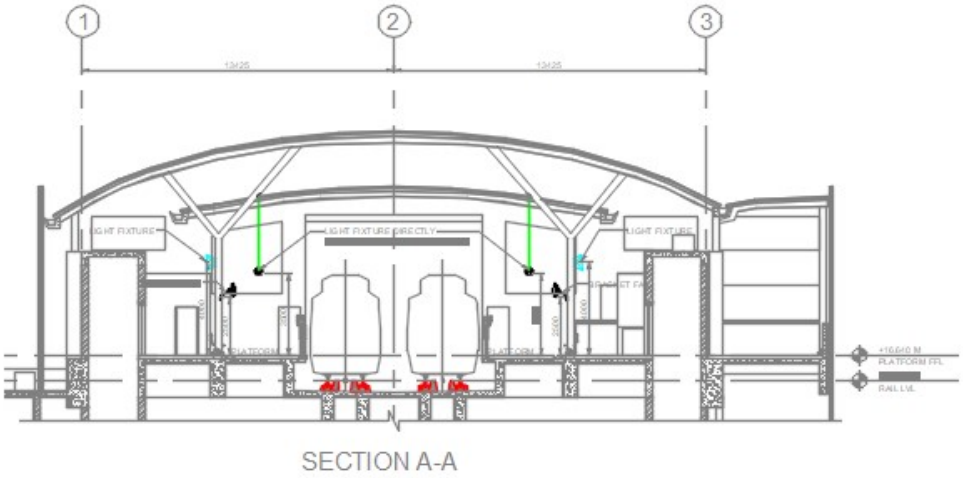


Fig. 8.93: Elevation of Platform Level

8.4.1.2 Simulation by using Conventional Luminaires

Simulating with conventional luminaires, the light loss factor is taken as 0.70. The simulation reports are shown in Annexure IX.

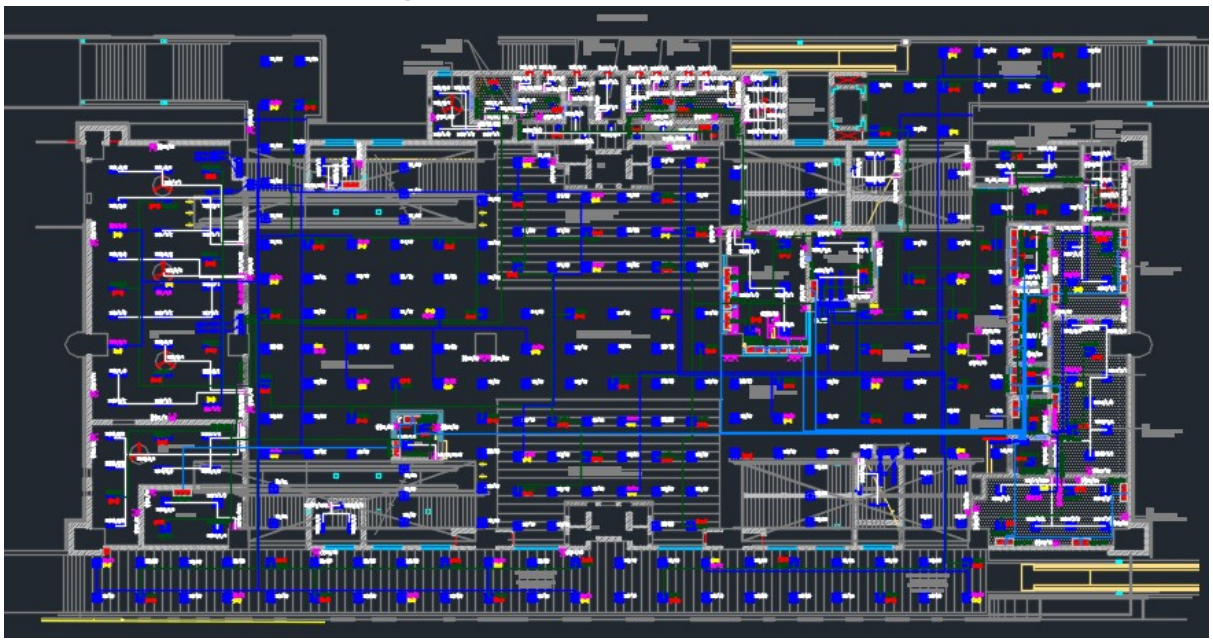
8.4.1.3 Simulation by using LED Luminaires

Simulating with LED luminaires, the light loss factor is taken as 0.80 or 0.85 depending upon area.The simulation reports are shown in Annexure X.

8.4.2 Consourse Area

The concourse area can be divided into two parts; paid concourse and unpaid concourse. The lighting treatment for both these areas is generally the same.

8.4.2.1 Autocad Drawing



8.4.2.2 Simulation by using Conventional Luminaires

Simulating with conventional luminaires, the light loss factor is taken as 0.7. The simulation reports are shown in Annexure IX.

8.4.2.3 Simulation by using LED Luminaires

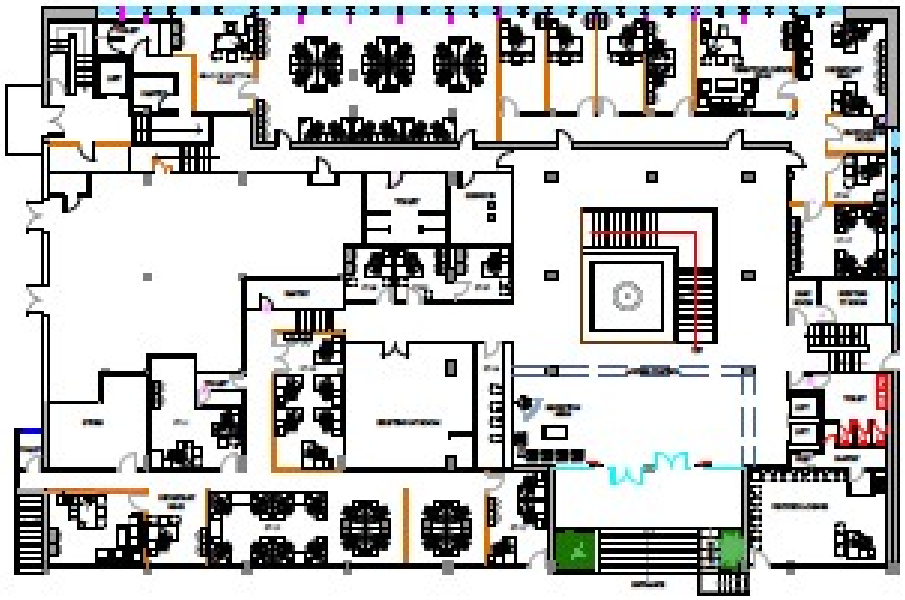
Simulating with conventional luminaires, the light loss factor is taken as 0.8. The simulation reports are shown in Annexure X.

Result and Cost Analysis of this Case Study is shown in Chapter 10.

8.5 Case Study on Office Lighting

For this case study, an office area generally a part of IT office is taken into consideration. Firstly a design is done by using conventionl luminaires and then the same design simulation is done by using Led luminaires.

8.5.1 Autocad Design



8.5.2 Simulation by using Conventional Fixtures

While designing with conventional luminaires, the light loss factor is taken as 0.7 as in case of conventional fixtures, lumen depreciation is rapid.

The design simuation reports are shown in Annexure XI.

8.5.3 Simulation by using LED Luminaires

While designing with conventional luminaires, the light loss factor is taken as 0.8 as in cases of LED Luminaires, lumen depreciation is less. [53]

The DIALux evo simulation results are summarized below. The design reports are attached in annexure XII.

Result and cost analysis of this Case Study is shown in Chapter 10.

Chapter 9
Result and Cost Analysis

9.1 Introduction

In this chapter we will discuss about the results that are shown in Chapter 9. By comparing the simulations by using conventional luminaires and LED luminaires, a payback period calculation is shown.

9.2 Result Analysis and Cost Analysis of Case Study on Road Lighting

9.2.1 Result Analysis of Case Study on Road Lighting

The Illuminance, Uniformity, Transverse uniformity and Power consumption in the road stretch are the main focused comparison criteria.

- ***Road Stretch A to B***

The total distance between two points is 725 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

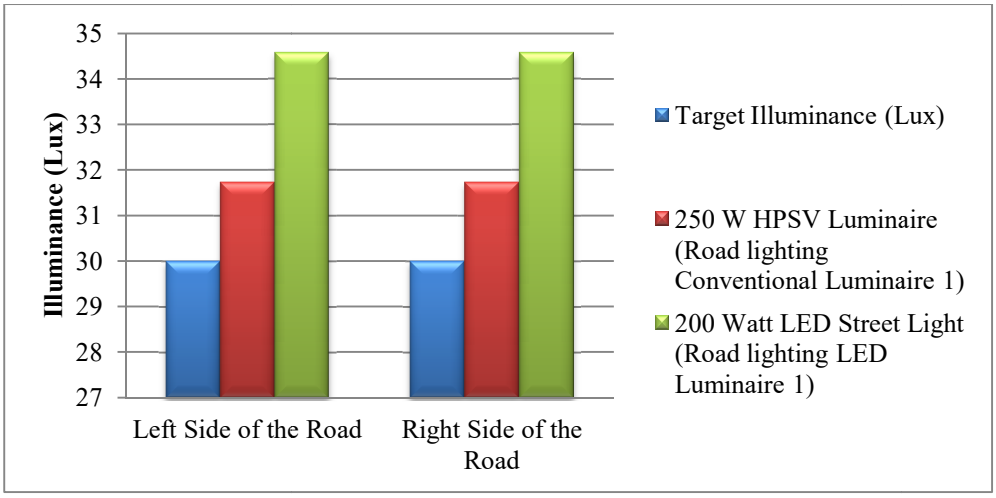


Fig. 9.1: Illuminance comparison of the Road Stretch A to B

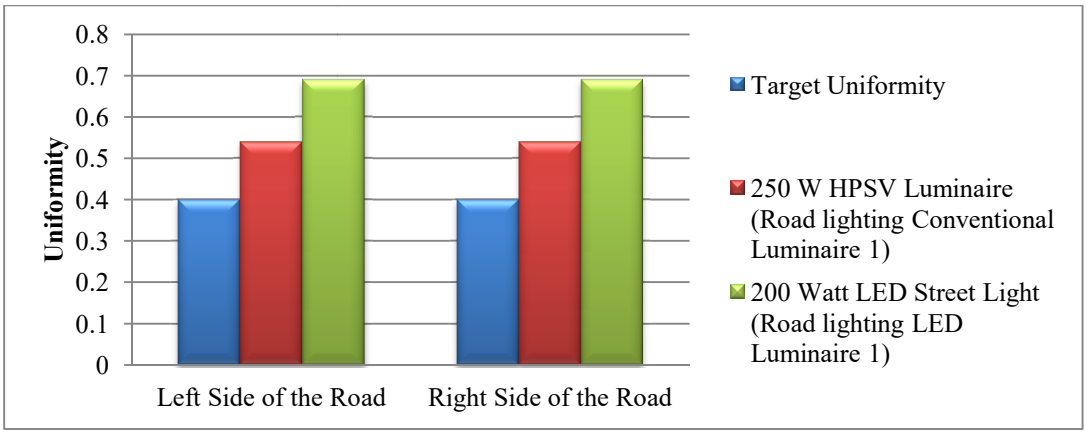


Fig. 9.2: Uniformity comparison of Road Stretch A to B

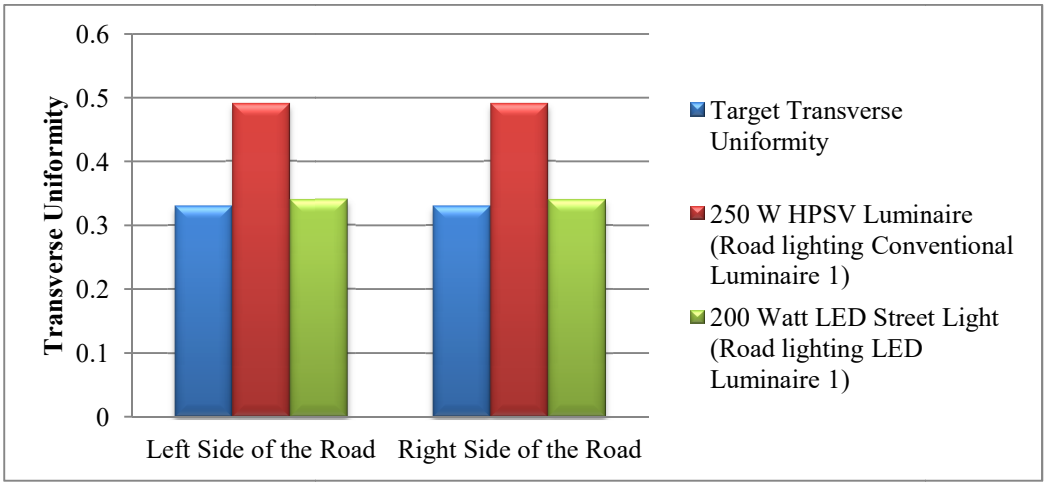


Fig. 9.3: Transverse Uniformity comparison of Road Stretch A to B

In Fig. 9.1 the average illuminance comparison is shown where average illuminance achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target illuminance is achieved in both cases.In Fig. 9.2, uniformity comparison is shown where uniformity achieved by using LED Luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.In Fig. 9.3, transverse uniformity comparison is shown where transverse uniformity achieved by using conventional luminaires at the both side of the road is higher than the LED luminaires. Also target uniformity achieved in both cases.

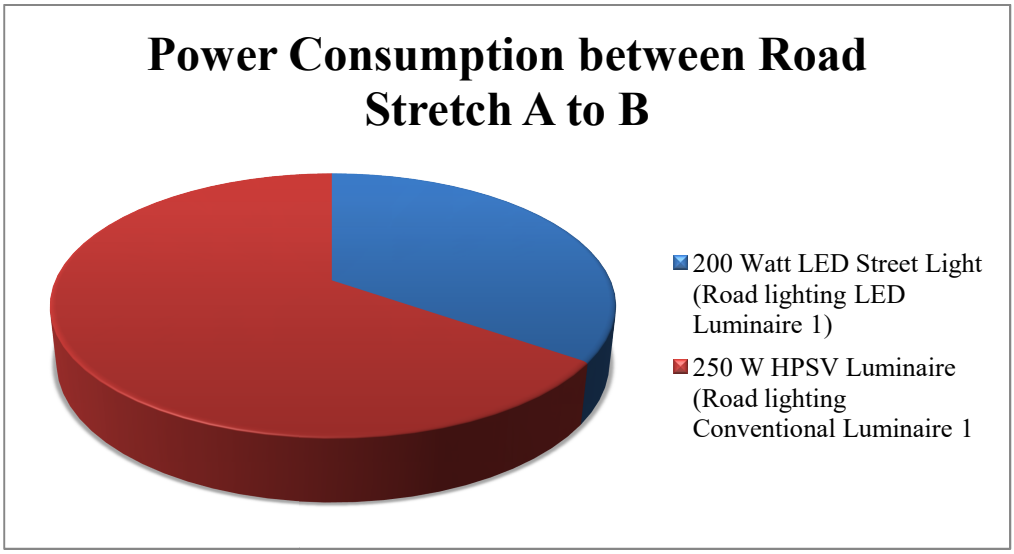


Fig. 9.4: Power Consumption comparison of Road Stretch A to B

In Fig. 9.4, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is 1.88 times of using LED luminaires.

- ***Road Stretch B to C***

The total distance between two points is 1131 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

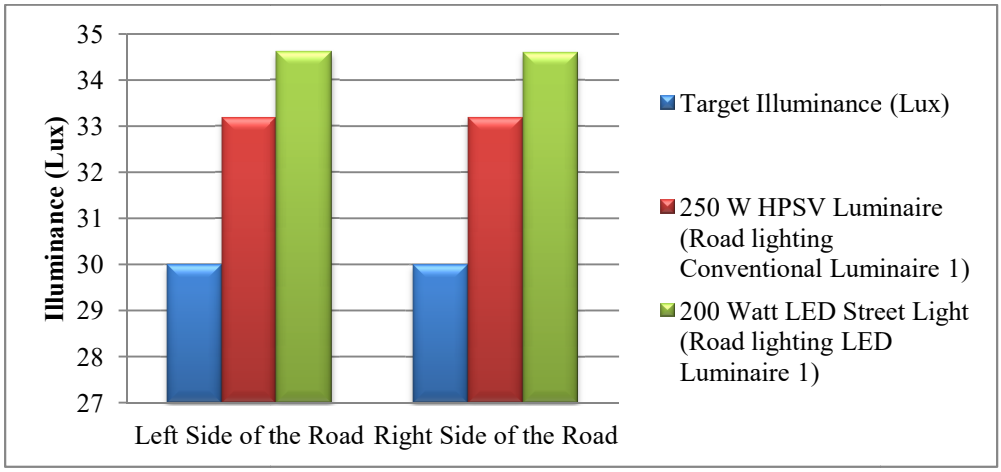


Fig. 9.5: Illuminance comparison of Road Stretch B to C

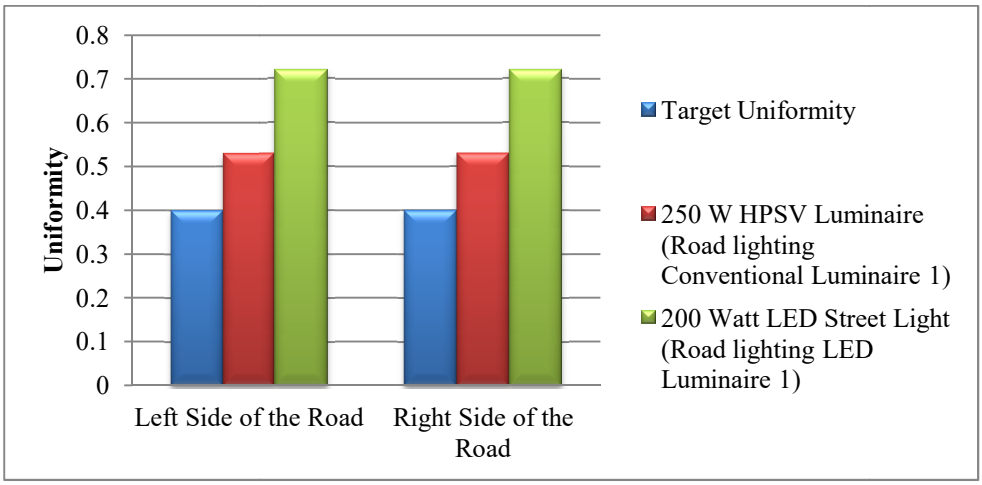


Fig. 9.6: Uniformity comparison of Road Stretch B to C

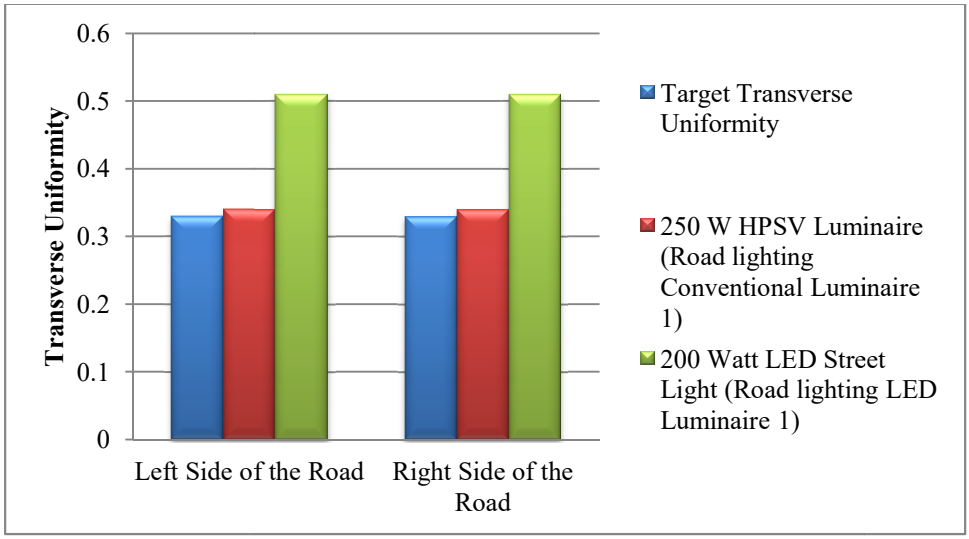


Fig. 9.7: Transverse Uniformity comparison of Road Stretch B to C

In Fig. 9.5 the average illuminance comparison is shown where average illuminance achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.6, uniformity comparison is shown where uniformity

achieved by using LED Luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.In Fig. 9.7, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.

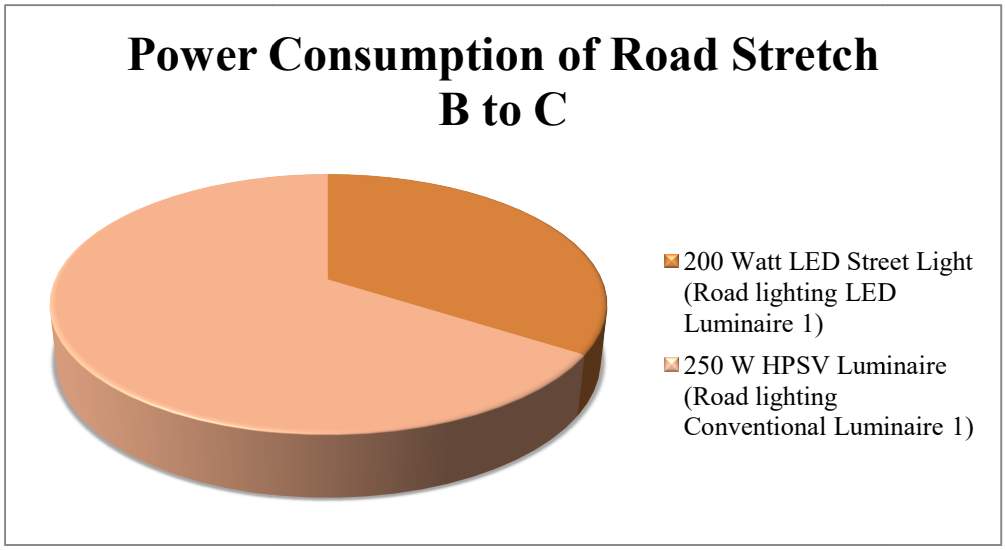


Fig. 9.8: Power Consumption comparison of B to C

In Fig. 9.8, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is approx 1.93 of using LED luminaires.

➢ ***Road Stretch C to D***

The total distance between two points is 363 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

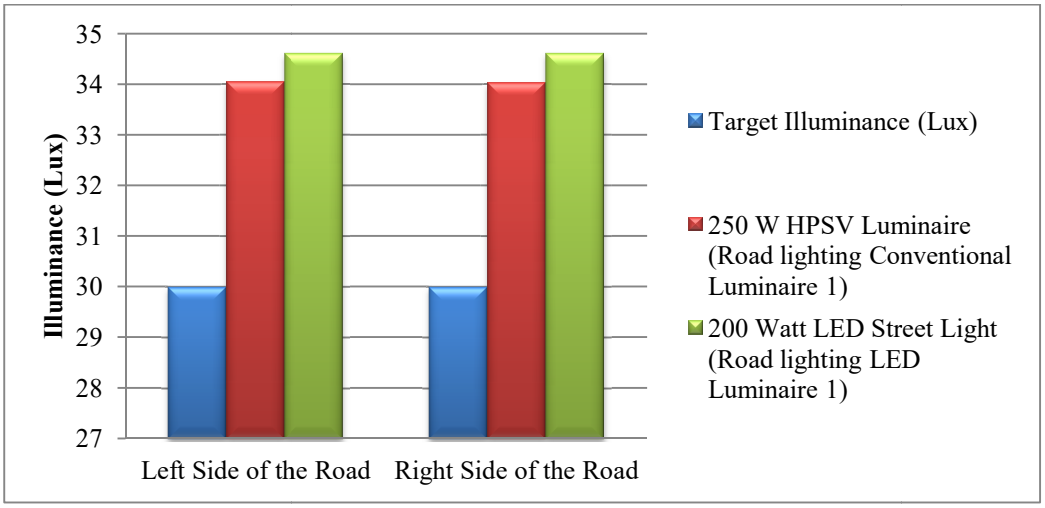


Fig. 9.9: Illuminance comparison of Road Stretch C to D

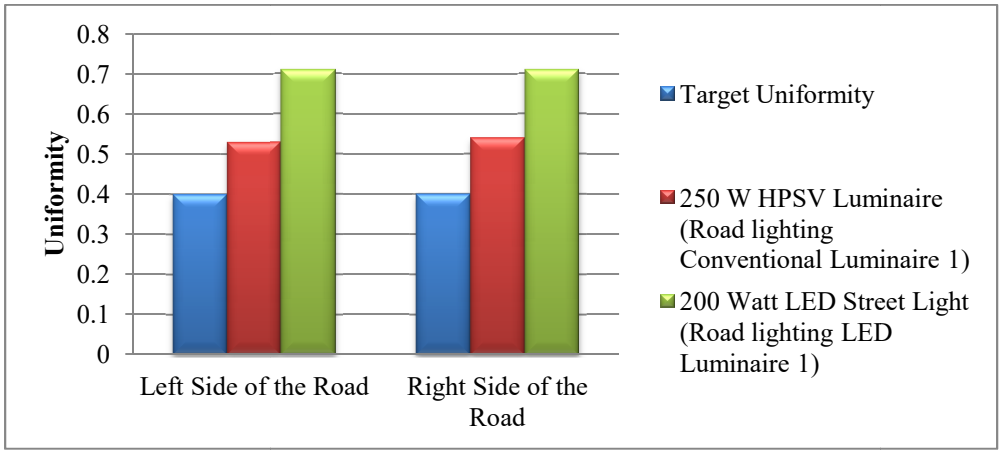


Fig. 9.10: Uniformity comparison of Road Stretch C to D

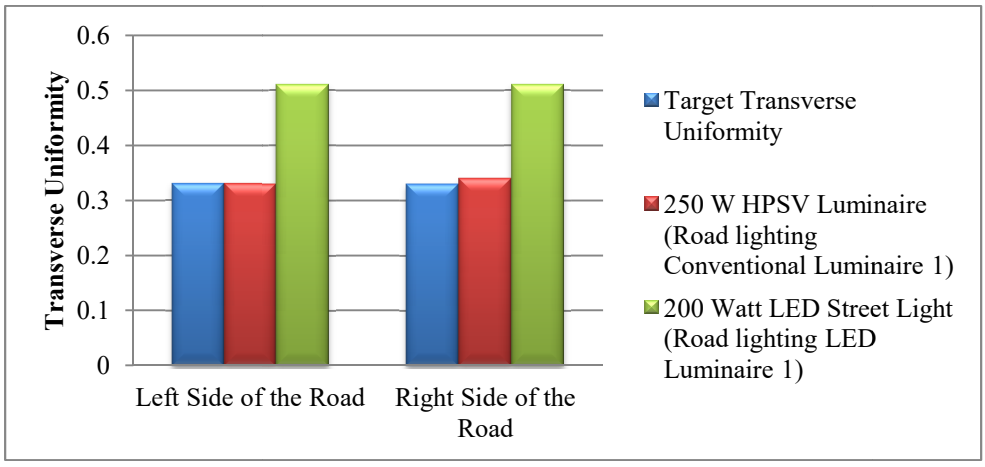


Fig. 9.11: Transverse Uniformity comparison of Road Stretch C to D

In Fig. 9.9 the average illuminance comparison is shown where average illuminance achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.10, uniformity comparison is shown where uniformity achieved by using LED Luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases. In Fig. 9.11, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.

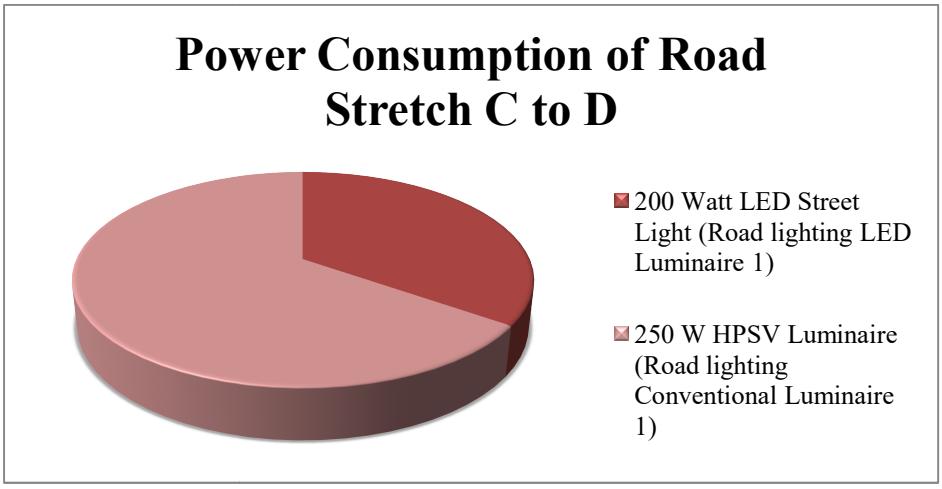


Fig. 9.12: Power Consumption comparison of Road Stretch C to D

In Fig. 9.12, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is approx 1.88 times of using LED luminaires.

- ***Road Stretch D to E***

The total distance between two points is 652 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

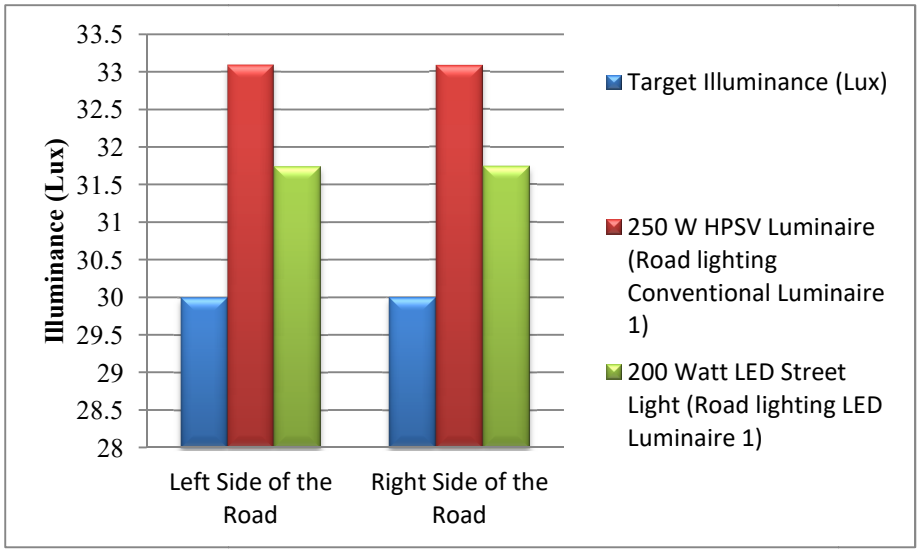


Fig. 9.13: Illuminance comparison of Road Stretch D to E

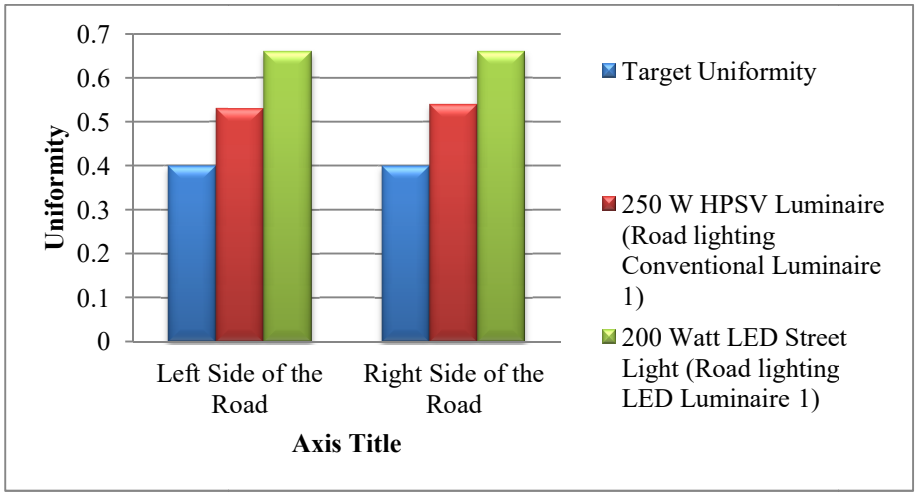


Fig. 9.14: Uniformity comparison of Road Stretch D to E

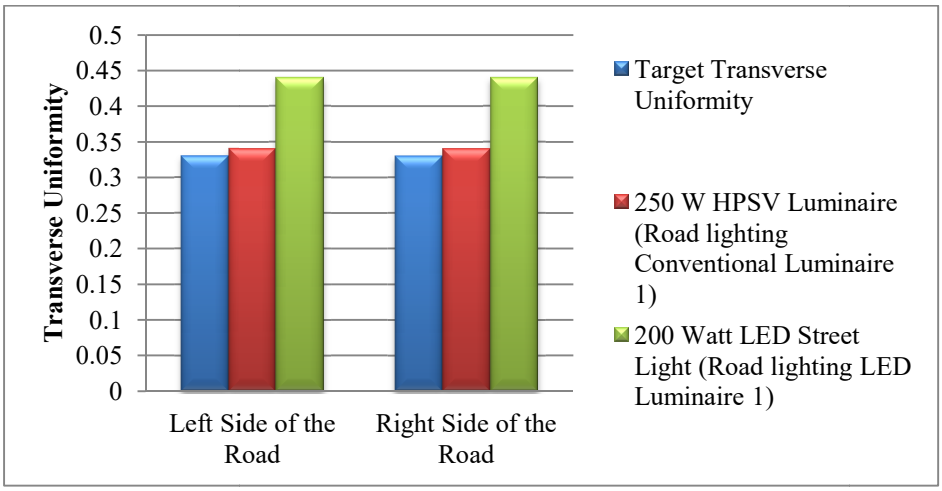


Fig. 9.15: Transverse Uniformity comparison of Road Stretch D to E

In Fig. 9.13 the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires at the both side of the road is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.14, uniformity comparison is shown where uniformity achieved by using LED Luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases. In Fig. 9.15, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.

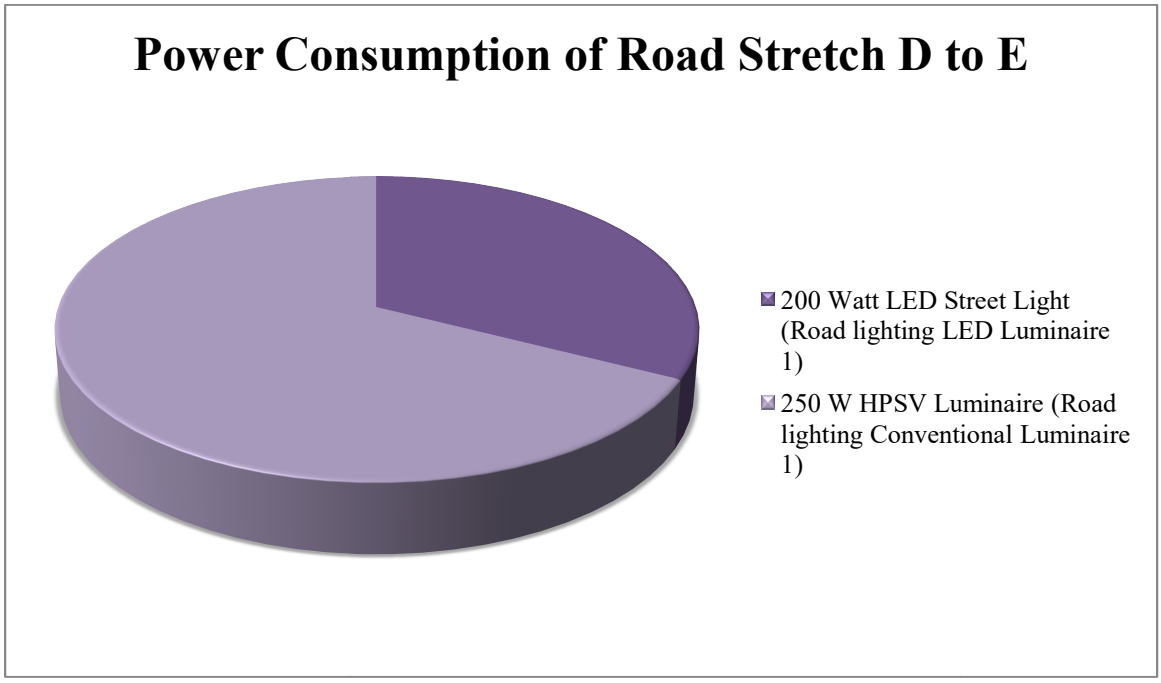


Fig. 9.16: Power Consumption comparison of Road Stretch D to E

In Fig. 9.16, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is approx 2.08 times of using LED luminaires.

- ***Road Stretch E to F***

The total distance between two points is 160.5 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

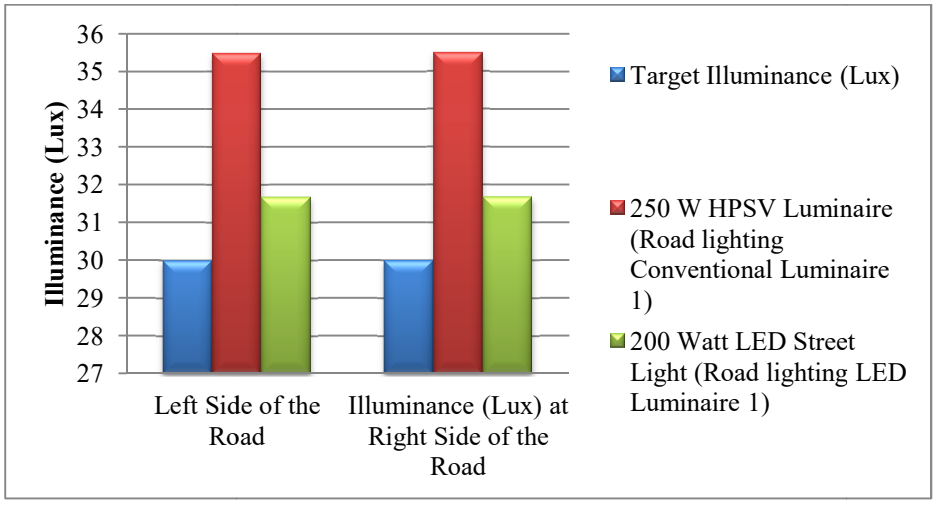


Fig. 9.17: Illuminance comparison of Road Stretch E to F

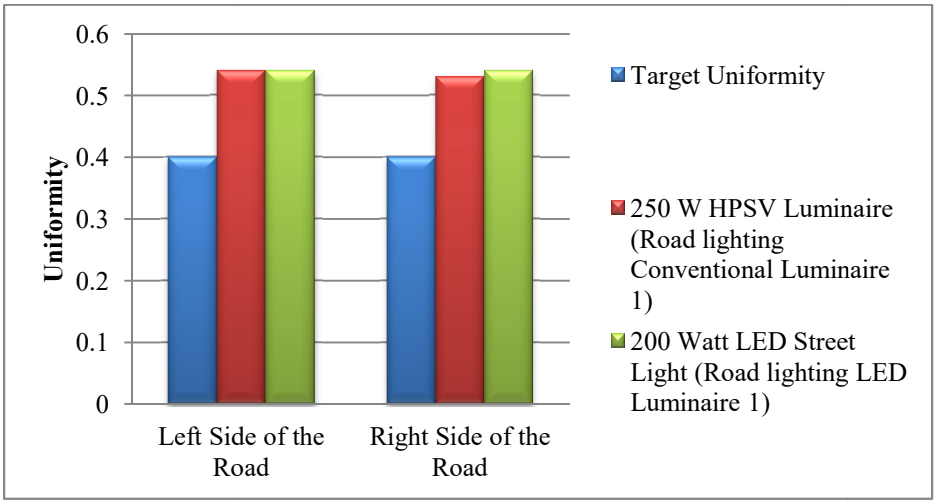


Fig. 9.18: Uniformity comparison of Road Stretch E to F

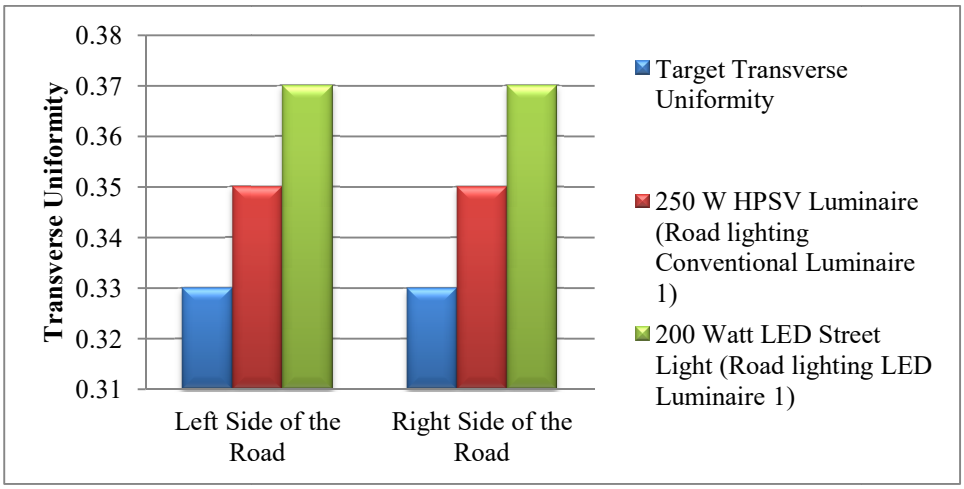


Fig. 9.19: Transverse Uniformity comparison of Road Stretch E to F

In Fig. 9.17 the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires at the both side of the road is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.18, uniformity comparison is shown where uniformity achieved by using LED Luminaires at the right side of the road is higher than the conventional luminaires. In left side of the road, in both cases, uniformity is same. Also target uniformity achieved in both cases. In Fig. 9.19, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.

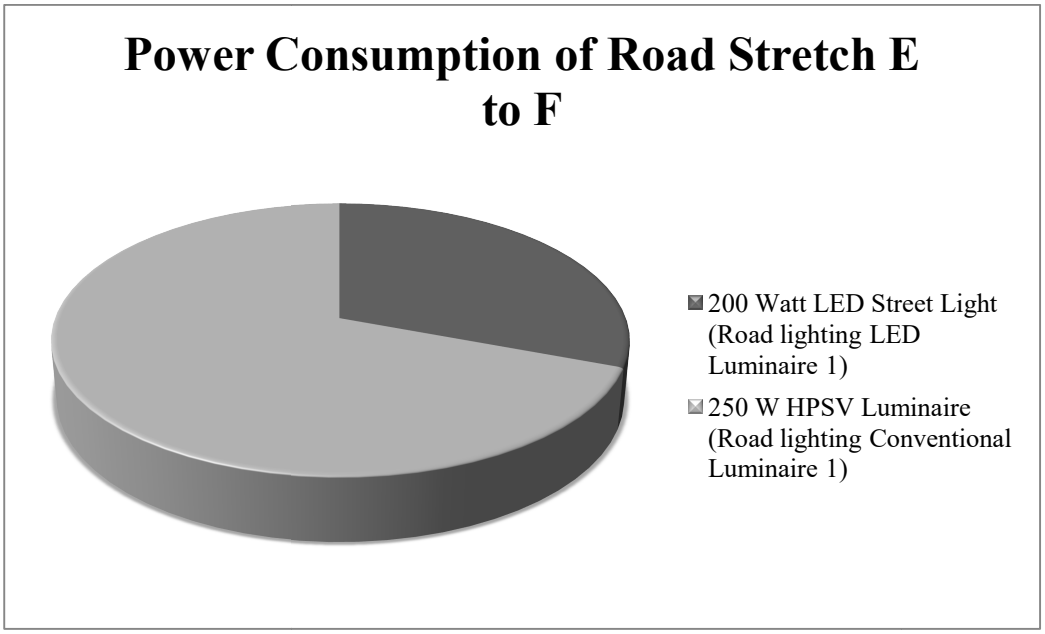


Fig. 9.20: Power Consumption comparison of Road Stretch E to F

In Fig. 9.20, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is 2.26 times of using LED luminaires.

- ***Road Stretch G to H***

The total distance between two points is 242 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

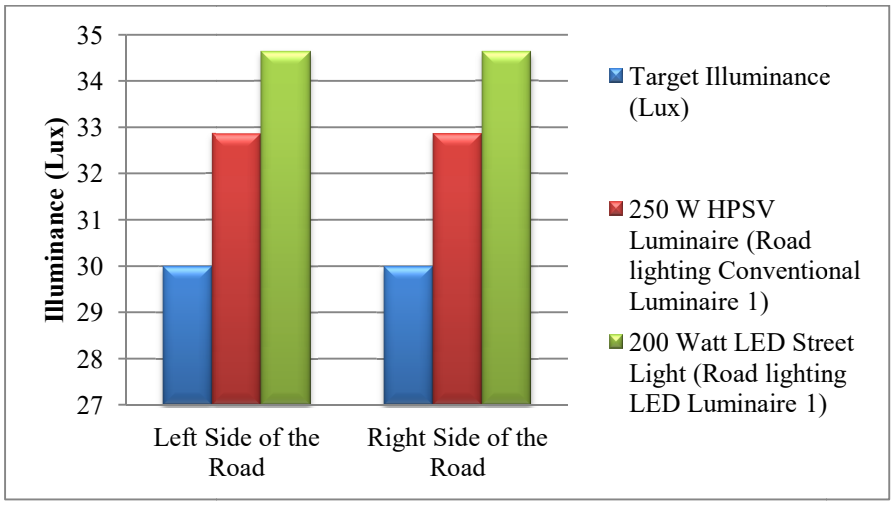


Fig. 9.21: Illuminance comparison of Road Stretch G to H

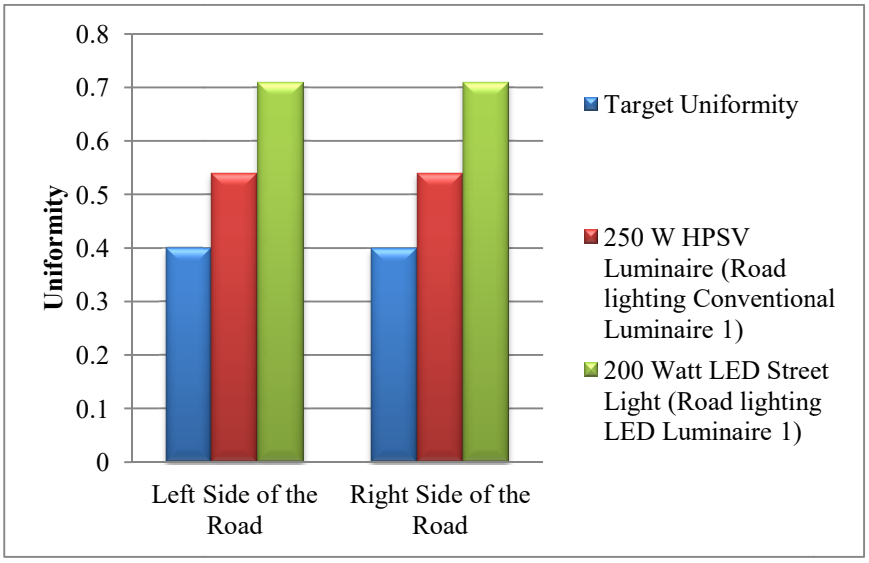


Fig. 9.22: Uniformity comparison of Road Stretch G to H

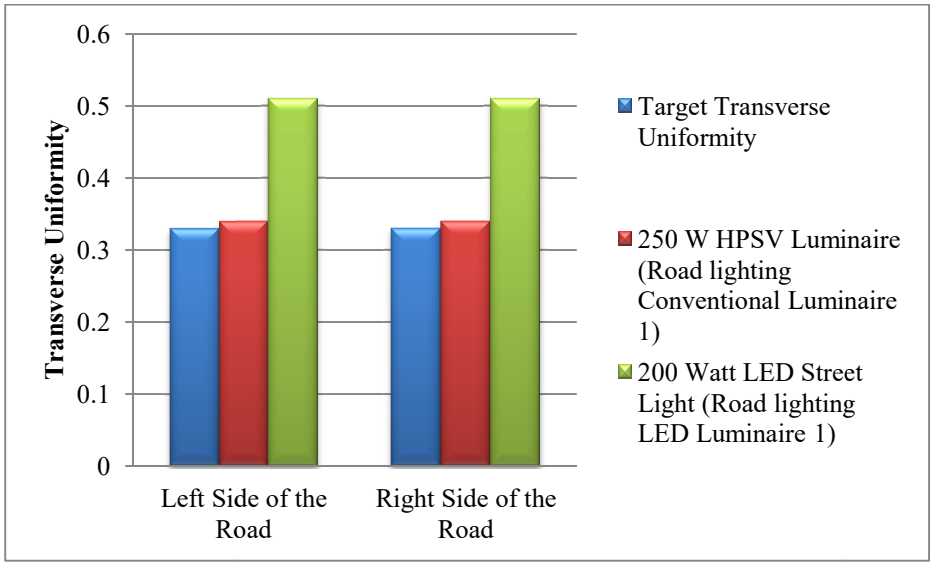


Fig. 9.23: Transverse Uniformity comparison of Road Stretch G to H

In Fig. 9.21 the average illuminance comparison is shown where average illuminance achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.22, uniformity comparison is shown where uniformity achieved by using LED Luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases. In Fig. 9.23, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.

In Fig. 9.24, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is approx 1.94 times of using LED luminaires.

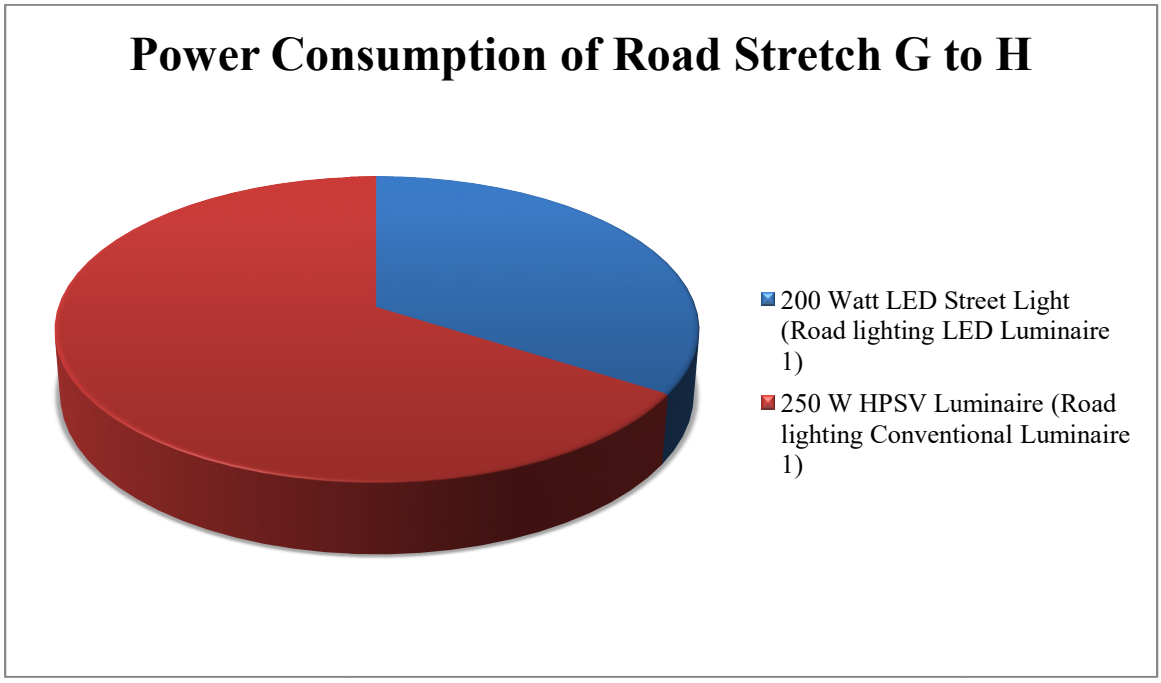


Fig. 9.24: Power Consumption comparison of Road Stretch G to H

➢ ***Road Stretch H to I***

The total distance between two points is 450 m and road width on either side is 11 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

In Fig. 9.25 the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires at the both side of the road is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.26, uniformity comparison is shown where uniformity achieved by using LED Luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases. In Fig. 9.27, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires at the both side of the road is higher than the conventional luminaires. Also target uniformity achieved in both cases.

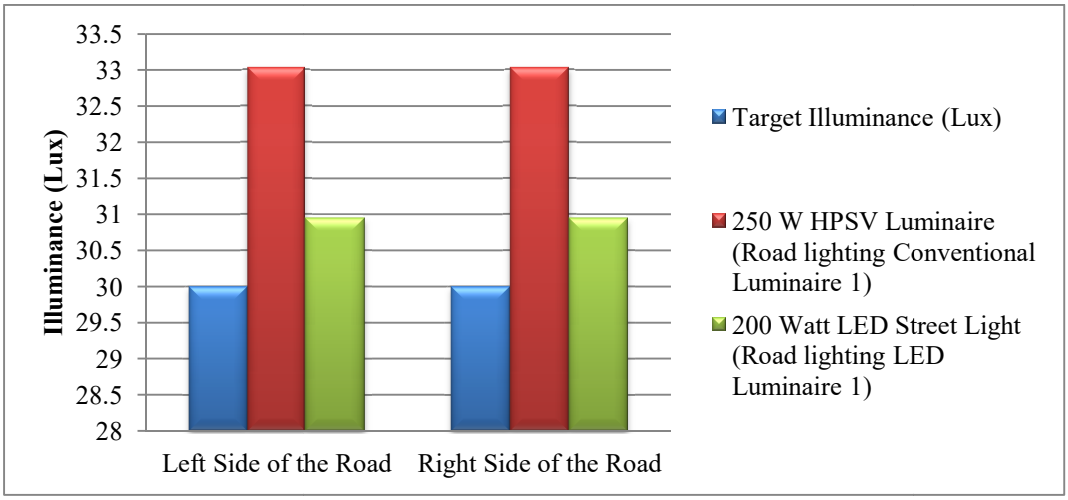


Fig. 9.25: Illuminance comparison of Road Stretch H to I

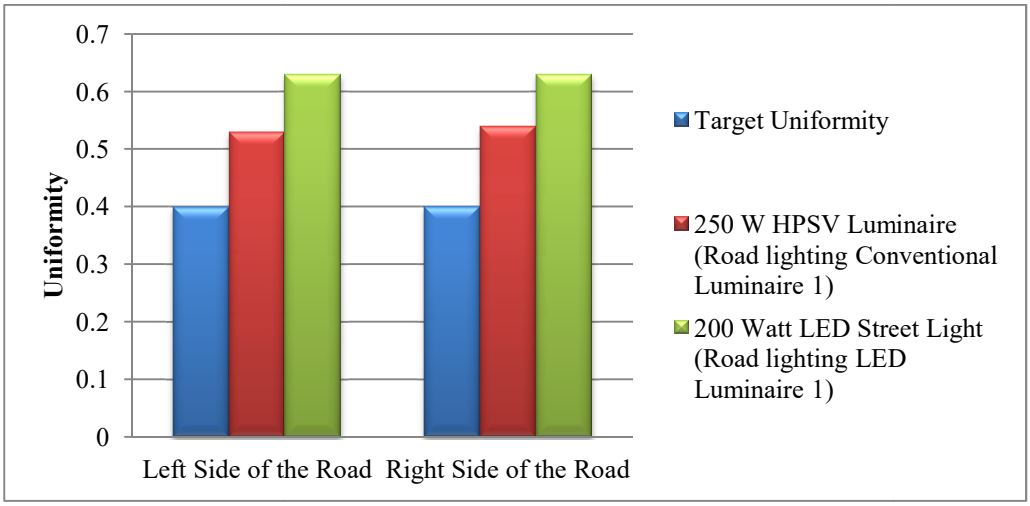


Fig. 9.26: Uniformity comparison of Road Stretch H to I

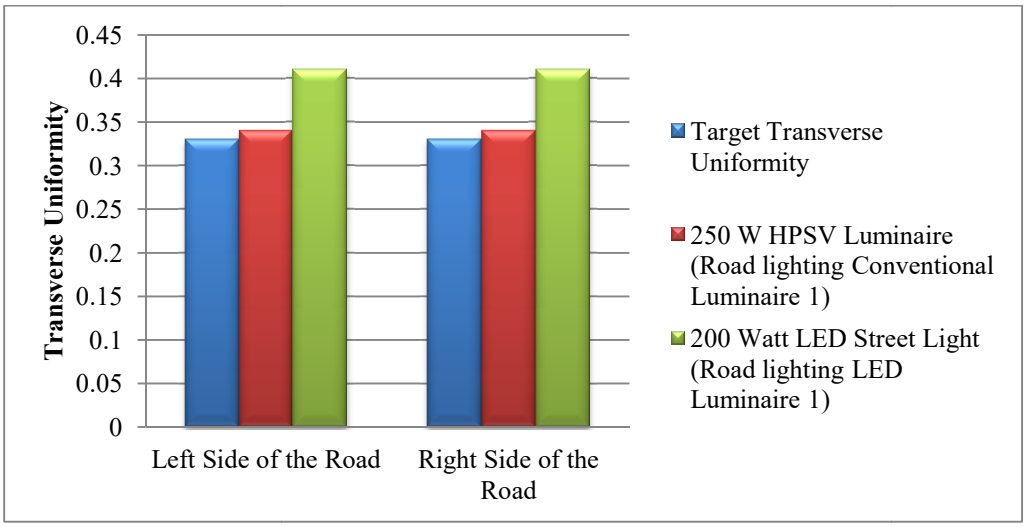


Fig. 9.27: Transverse Uniformity comparison of Road Stretch H to I

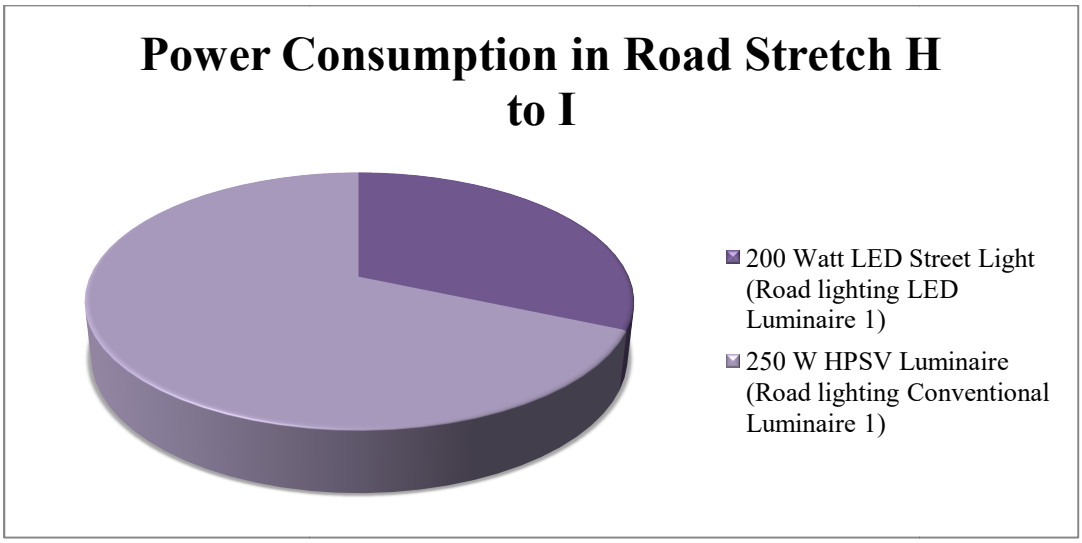


Fig. 9.28: Power Consumption comparison of Road Stretch H to I

In Fig. 9.28, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is approx 2.17 times of using LED luminaires.

➢ ***Road Stretch I to J***

The total distance between two points is 725 m and road width is 15 m. As per IS-1944 target illuminance is 30 Lux, uniformity is 0.4 and transverse uniformity is 0.33 throughout the road.

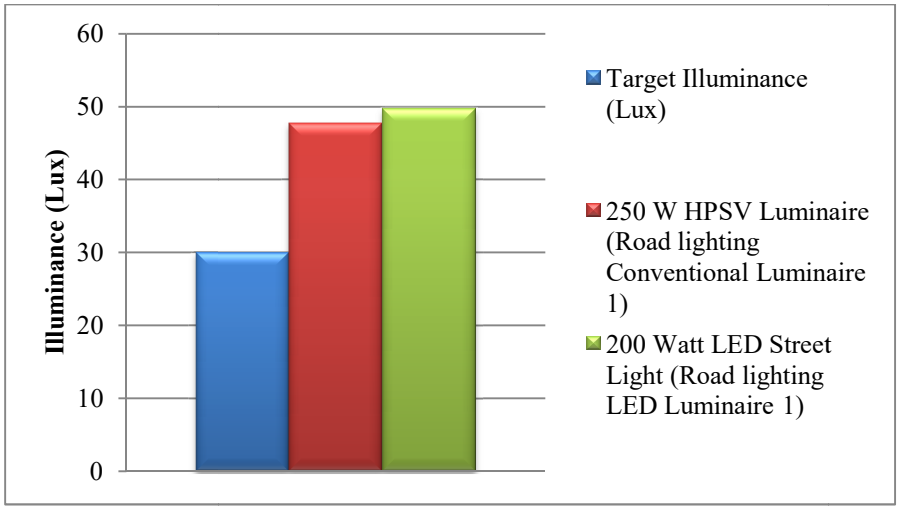


Fig. 9.29: Illuminance comparison of Road Stretch I to J

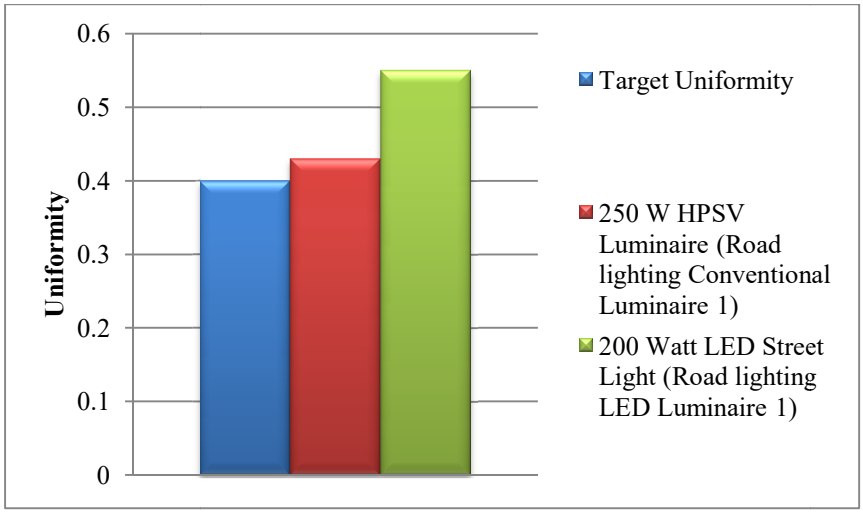


Fig. 9.30: Uniformity comparison of Road Stretch I to J

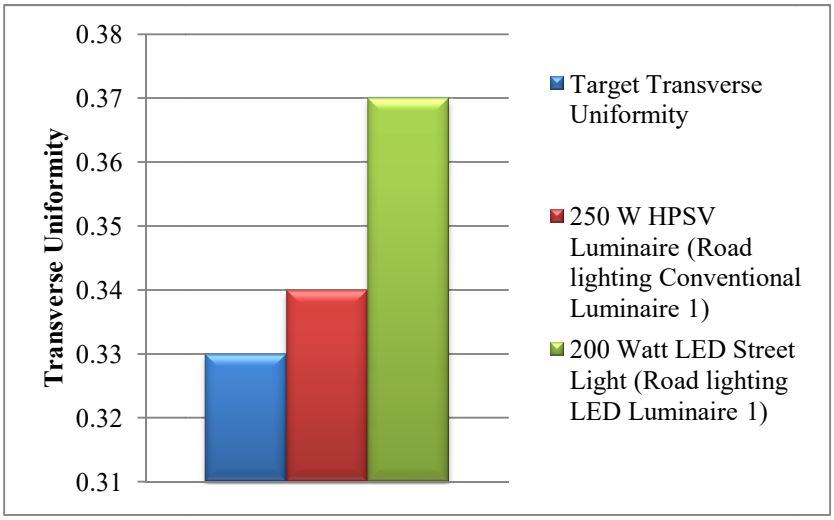


Fig. 9.31: Transverse Uniformity comparison of Road Stretch I to J

In Fig. 9.29 the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.30, uniformity comparison is shown where uniformity achieved by using LED Luminaires is higher than the conventional luminaires. Also target uniformity achieved in both cases. In Fig. 9.27, transverse uniformity comparison is shown where transverse uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target uniformity achieved in both cases.

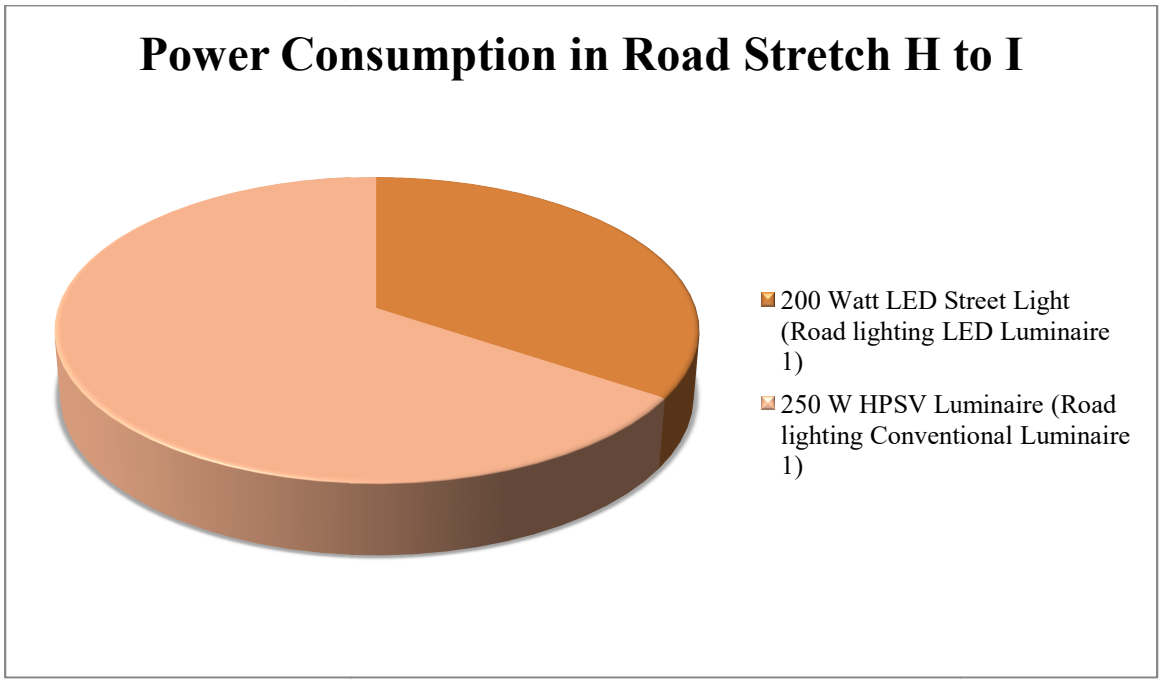


Fig. 9.32 Power Consumption comparison of H to I

In Fig. 9.32, Total Power Consumption comparison by using Conventional Luminaire and LED luminaires are shown where Power Consumption by using conventional luminaires is approx 1.91 times of using LED luminaires.

- **Total Power Consumption in Different Road Stretch by using Conventional Luminaires**

The total power consumption in different road stretch by using conventional luminaires is shown in Fig. 9.33. From the fig. 9.33 it can be stated that power consumption by using conventional luminaires is highest at road stretch B to C due to its highest road length.

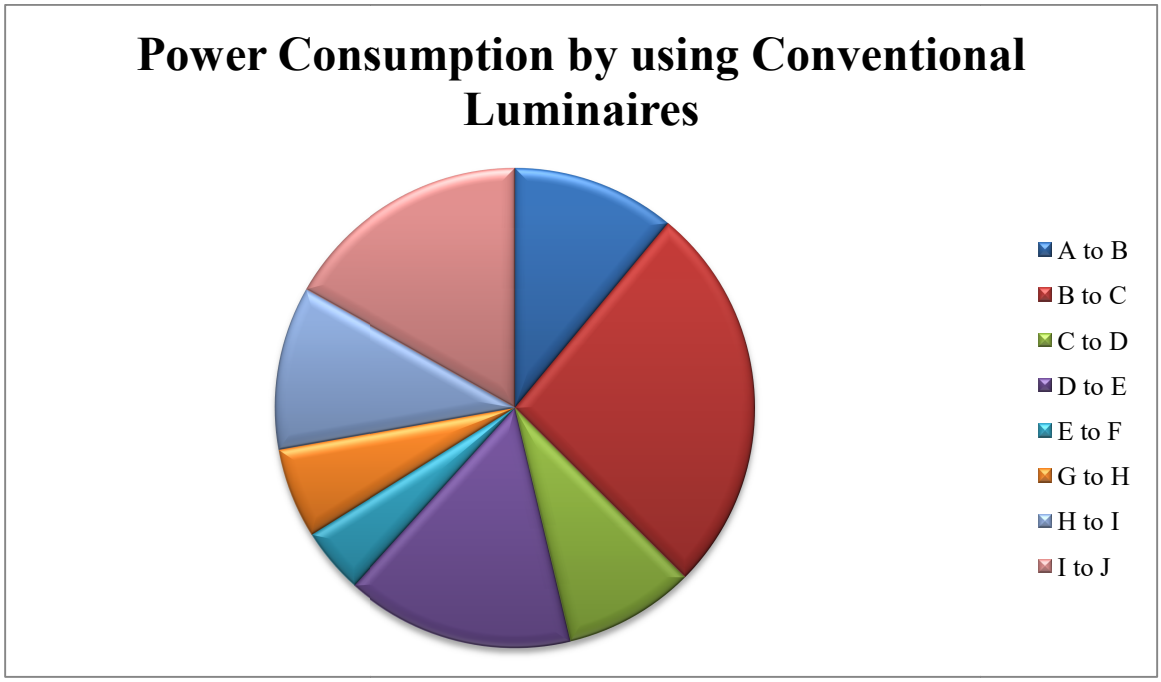


Fig. 9.33: Power Consumption Road Stretch-wise by using Conventional Luminaires

➢ **Total Power Consumption in Different Road Stretch by using Conventional Luminaires**

The total power consumption in different road stretch by using conventional luminaires is shown in Fig. 9.34. From the fig. 9.34 it can be stated that power consumption by using conventional luminaires is highest at road stretch B to C due to its highest road length.

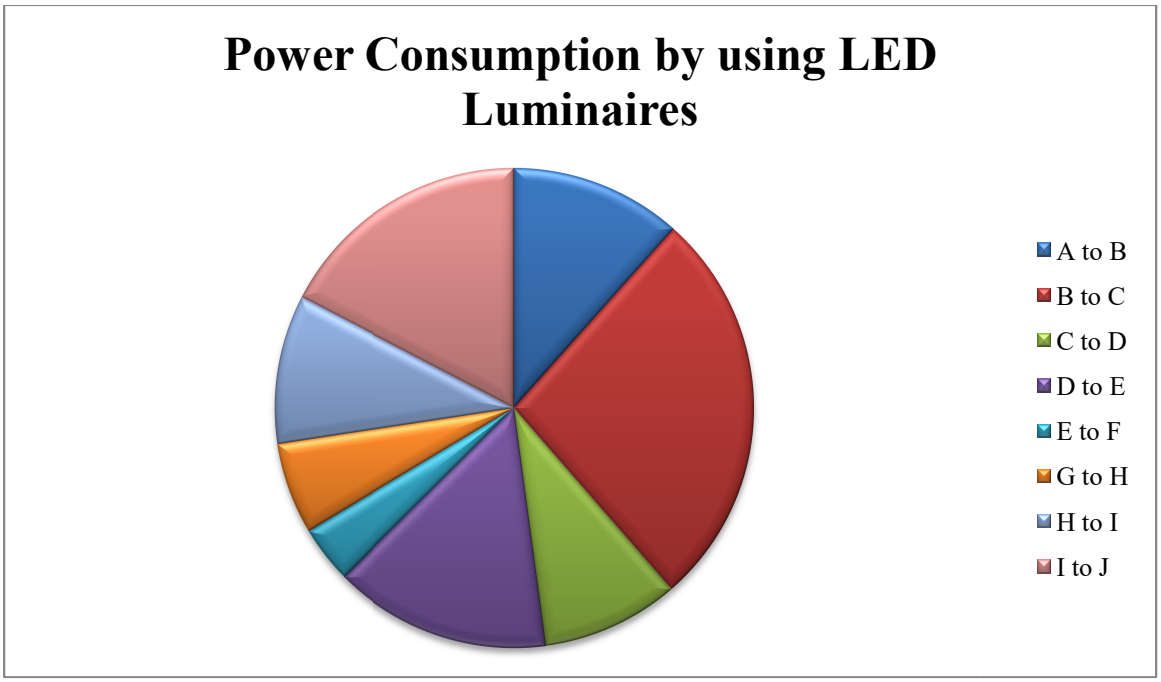


Fig. 9.34: Power Consumption Road Stretch-wise by using Conventional Luminaires

9.2.2 Economic Comparison between Conventional and LED Solution of Case Study on Road Lighting

In the field of engineering cost optimization is main motto because investment and operational cost play the most important role in the implementation of the project. To compare the economics of conventional and LED lighting solution for the above mentioned project payback calculation has been done to find the payback period of the project.

Payback Period: It compares installation cost to the expected yearly saving from the proposed system. It is expressed as amount of time required to pay for the incremental cost of the system with increased saving in terms of month or years.

- **Cost details of conventional luminaires used in the project**

Sl. No.	Luminaire	Qty	Price Per Fixture[55]	Total Cost
1	Road lighting Conventional Luminaire 1	363	3898	1414974

Total Purchase cost with conventional lamps & luminaires = Rs. 1414974

- **Cost details of LED luminaires used in the project**

Sl. No.	Luminaire	Qty	Price Per Fixture [56]	Total Cost
1	Road lighting LED Luminaire 1	259	25700	6656300

Total Purchase cost with LED lamps & luminaires = Rs. 6656300

- **Payback Period Calculation**

A	**Data**		
1	Luminaire	200 Watt LED Street Light Luminaire	250 Watt HPSV Street Light Luminaire
2	Lamp Type	LED	HPSV
3	Rated life of Lamp (hrs)	50000	15000
4	No of Luminaire	259	363
5	Daily operation Hours (hrs)	12	12
6	Rated power of Luminaire (kW)	0.2	0.282
7	Electricity Cost (Rs/kWh)	10	10
B	**Initial Cost (Rs)**		
1	Luminaire Cost	25700 [56]	3898 [55]
2	Lamp Cost (All lamps)	NA	370 [55]
3	Control Gear Cost	NA	2405
4	Lighting System Cost (B1+B2)	6656300	2422299
C	**Annual Power & Maintenance Cost (Rs)**		

1	Luminaire Energy Consumption Cost	2268840	4483630.80
2	Cost of Lamps Replaced Annualy	NA	39220
3	Maintenance Cost (Rs. 50 per Luminaire)	NA	18150
D	**Comparison**		
1	Present worth (B3)	6656300	2422299
2	Annual Running Cost (C1+C2+C3)	2268840	4541001
E	**Payback Time**		
0	Total Cost of operation at start	6656300	2422299
1	Total Cost of operation after 1st year	8925140	6963300
2	Total Cost of operation after 2nd year	11193980	11504301
3	Total Cost of operation after 3rd year	13462820	16045301
4	Total Cost of operation after 4th year	15731660	20586302

In Fig. 9.35 Annual total energy consumption cost comparison is shown where annual total energy consumption cost by using conventional luminaires is approx 1.98 times that of LED luminaires. Fig. 9.36 is plotted by taking the Cost in Rs. with respective to year where the intersection of two lines gives the Payback Period.

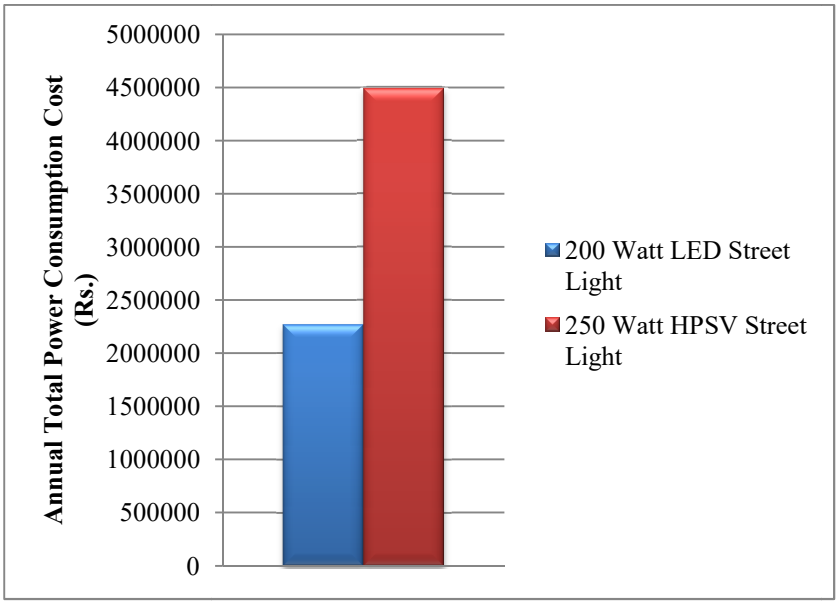


Fig. 9.35: Annual total power consumption cost comparison

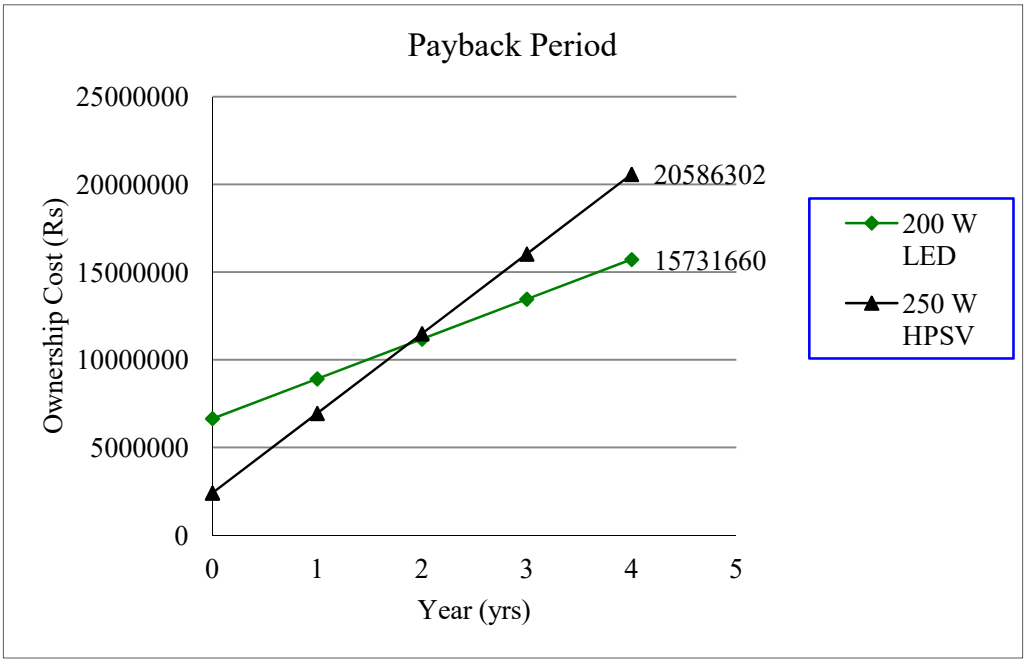


Fig. 9.36: Ownership Cost v/s Years

By using Break-even method, Payback Period by using LED luminaires is approx 2 years.

9.3 Result Analysis and Cost Analysis of Case Study on Thermal Power Plant

9.3.1 Result Analysis of Case Study on Thermal Power Plant

The Illuminance, Uniformity and Energy usage in between two simulations are the main focused comparison criteria.

- **Office Room**

Room Length: 5 m
Room Width: 4m
Room Height: 2.7m
Target Illuminance > 300 Lux
Standard Illuminance as per IS6665 > 500 Lux
Target Uniformity > 0.4

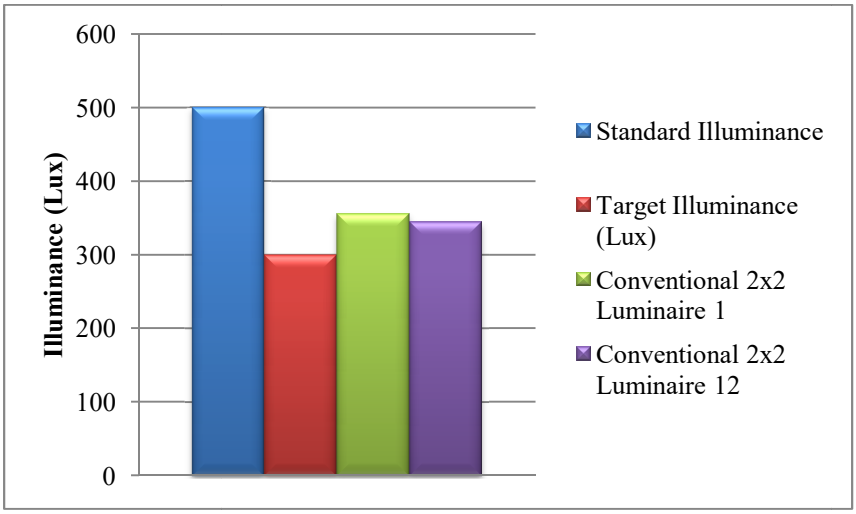


Fig. 9.37: Illuminance comparison of Office Room

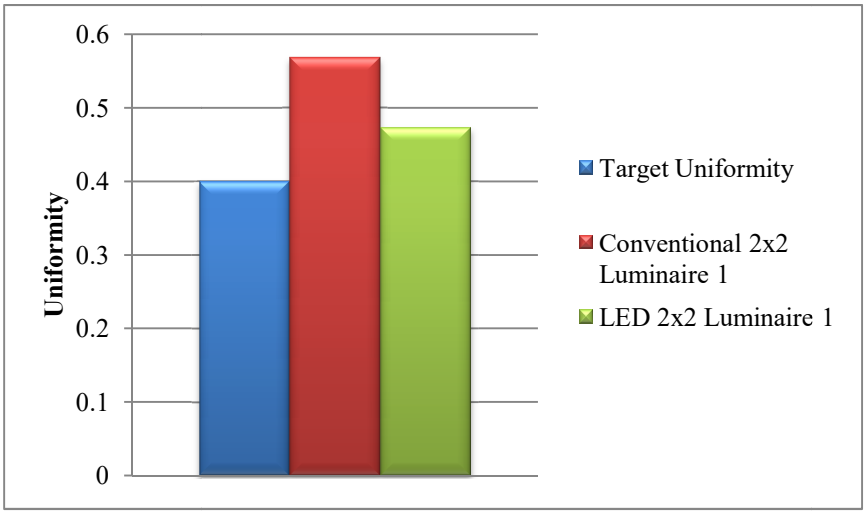


Fig. 9.38: Uniformity comparison of Office Room

In Fig. 9.37, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.38, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

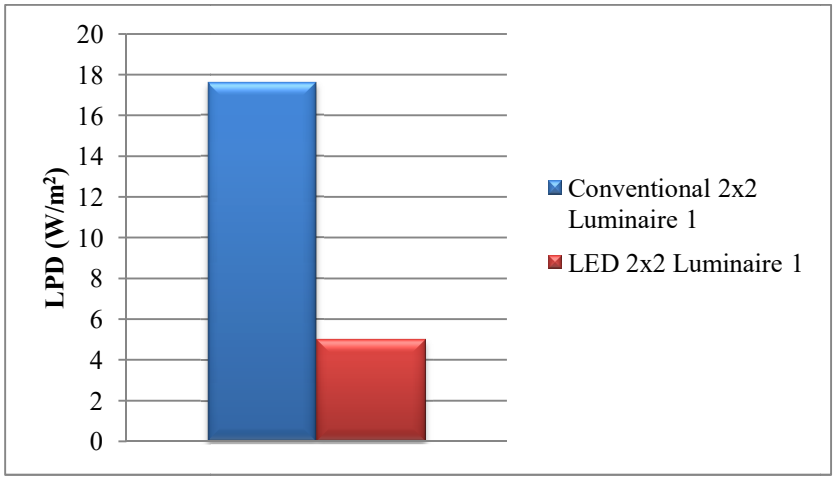


Fig. 9.39: LPD comparison of Office Room

In Fig. 9.39, LPD comparison is shown where LPD by using conventional luminaires is approx 3.51 times of using LED luminaires.

- **Battery Room**

Room Length: 8m
Room Width: 6m
Room Height: 5.5m
Target Illuminance (as per standard IS 6665) > 100 Lux
Target Uniformity > 0.4

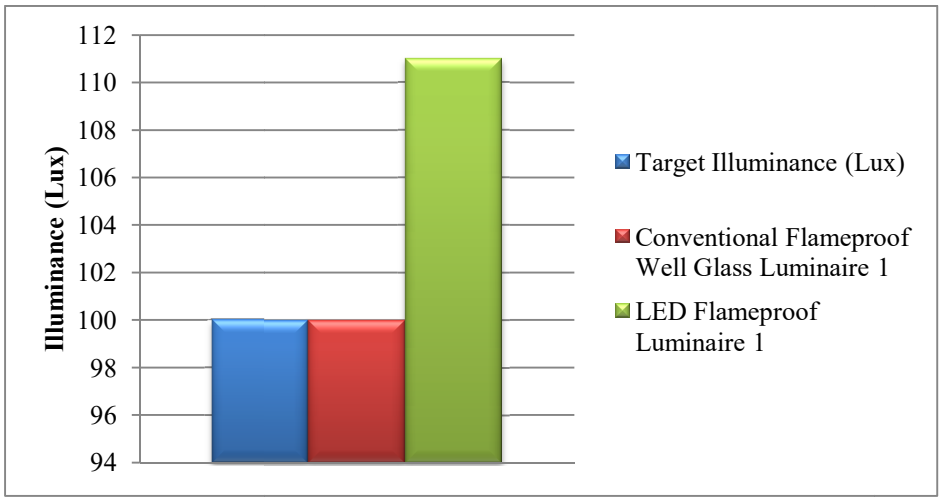


Fig. 9.40: Illuminance comparison of Battery Room

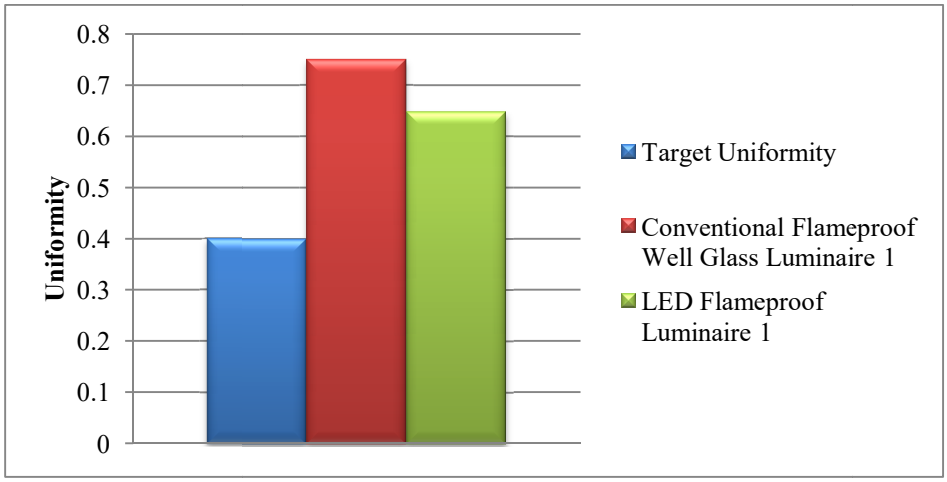


Fig. 9.41: Uniformity comparison of Office Room

In Fig. 9.40, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.41, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

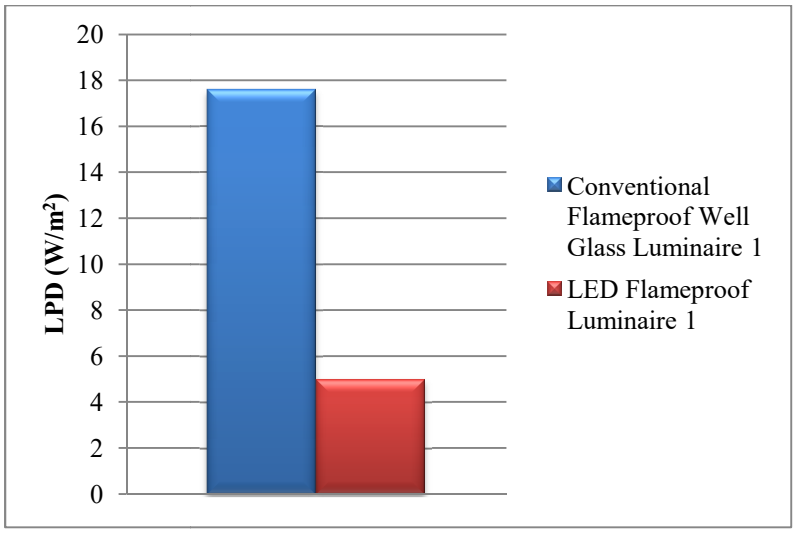


Fig. 9.42: LPD comparison of Battery Room

In Fig. 9.42, LPD comparison is shown where LPD by using conventional luminaires is 18.84 times of using LED luminaires.

- **Motor Control Centre**

Room Length: 6m
Room Width: 7m
Room Height: 5.5m
Target Illuminance > 200 Lux
Standard Illuminance (as per IS6665) > 150 Lux
Target Uniformity > 0.4

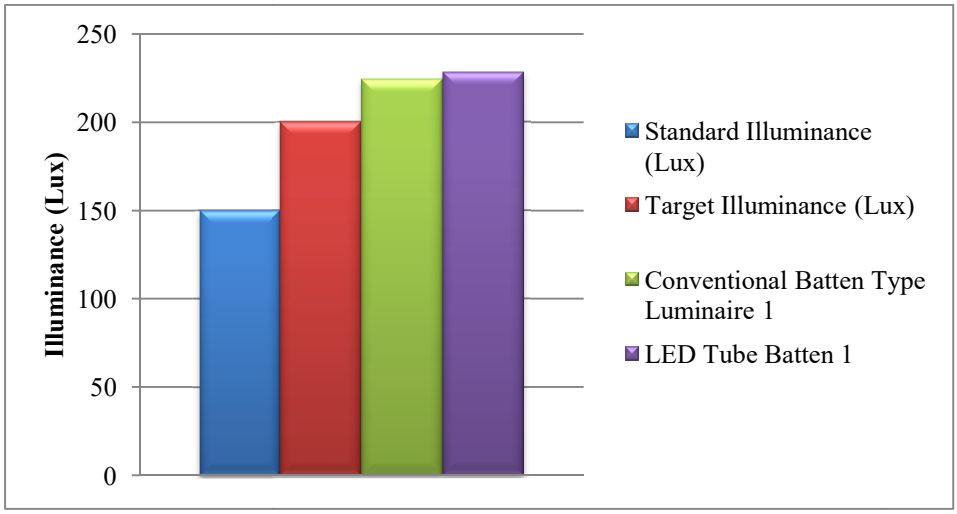


Fig. 9.43: Illuminance comparison of Motor Control Centre

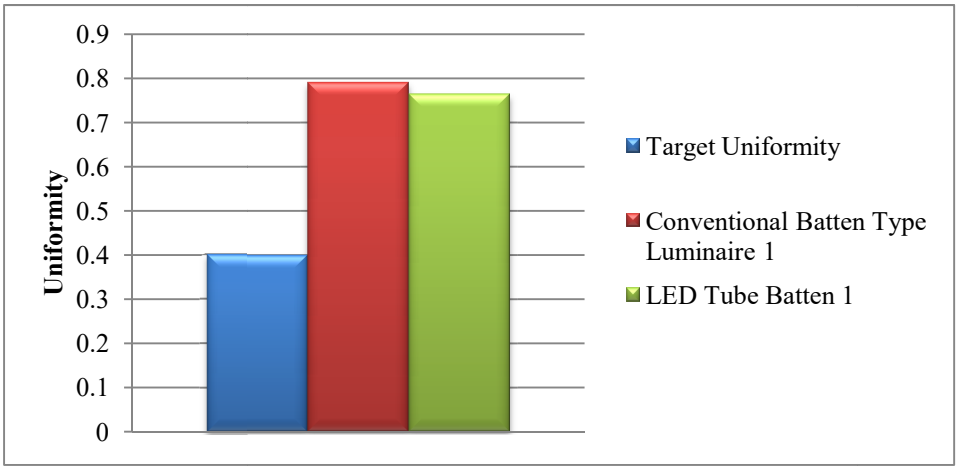


Fig. 9.44: Uniformity comparison of Motor Control Centre

In Fig. 9.43, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.44, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

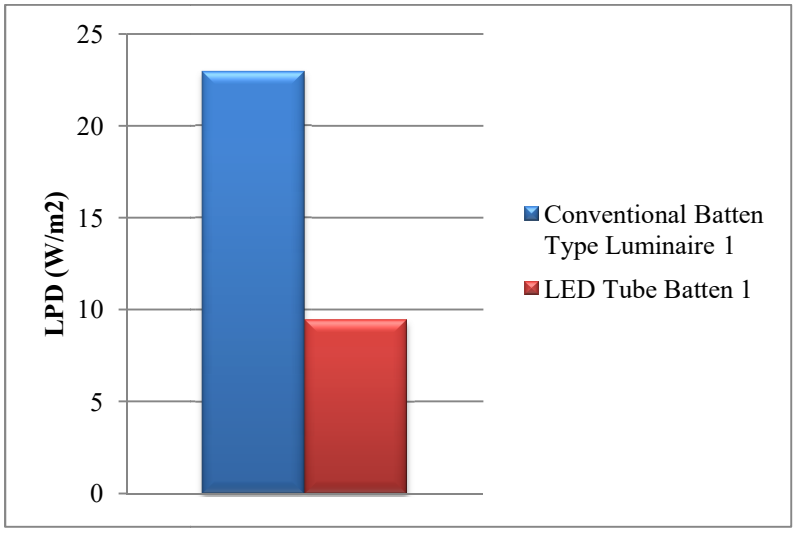


Fig. 9.45: LPD comparison of Motor Control Centre

In Fig. 9.45, LPD comparison is shown where LPD by using conventional luminaires is 2.41 times of using LED luminaires.

- **Transformer Room**

Room Length: 39.5m
Room Width: 8m
Room Height: 5.5m
Target Illuminance > 100 Lux
Standard Illuminance (as per IS 6665) > 150 Lux
Target Uniformity > 0.4

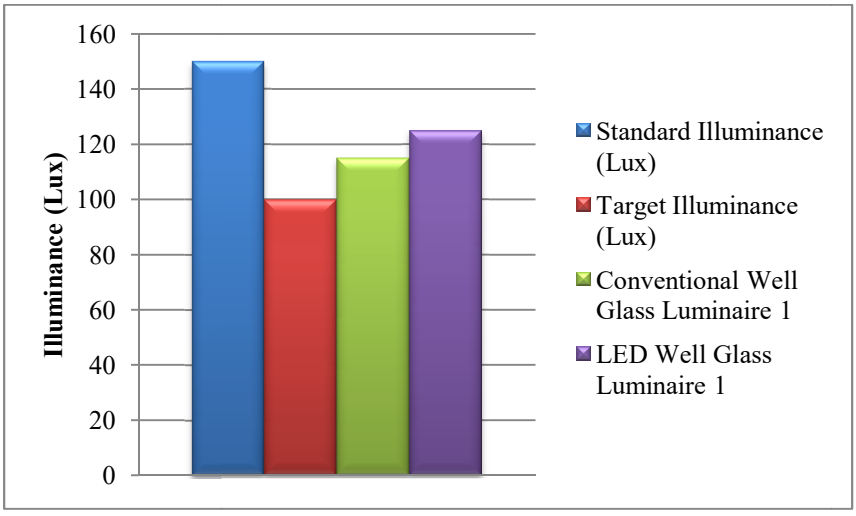


Fig. 9.46: Illuminance comparison of Transformer Room

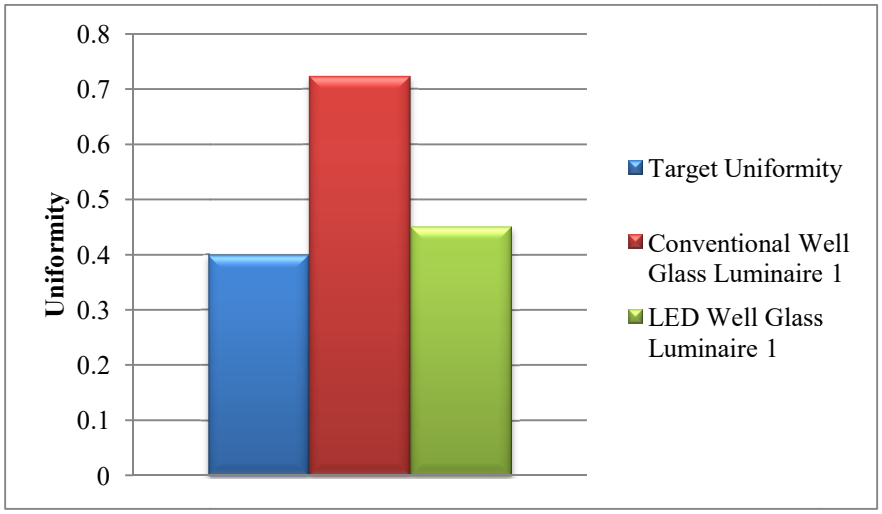


Fig. 9.47: Uniformity comparison of Transformer Room

In Fig. 9.46, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.In Fig. 9.47, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

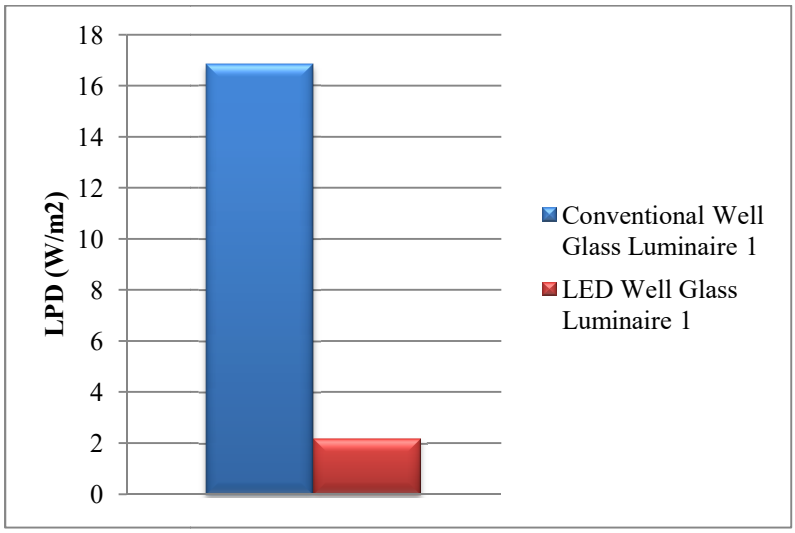


Fig. 9.48: LPD comparison of Transformer Room

In Fig. 9.48, LPD comparison is shown where LPD by using conventional luminaires is 7.53 times of using LED luminaires.

- **Pump House**

Room Length: 30m
Room Width: 10m
Room Height: 5.5m
Target Illuminance > 100 Lux
Standard Illuminance (as per IS6665) > 150 Lux
Target Uniformity > 0.4

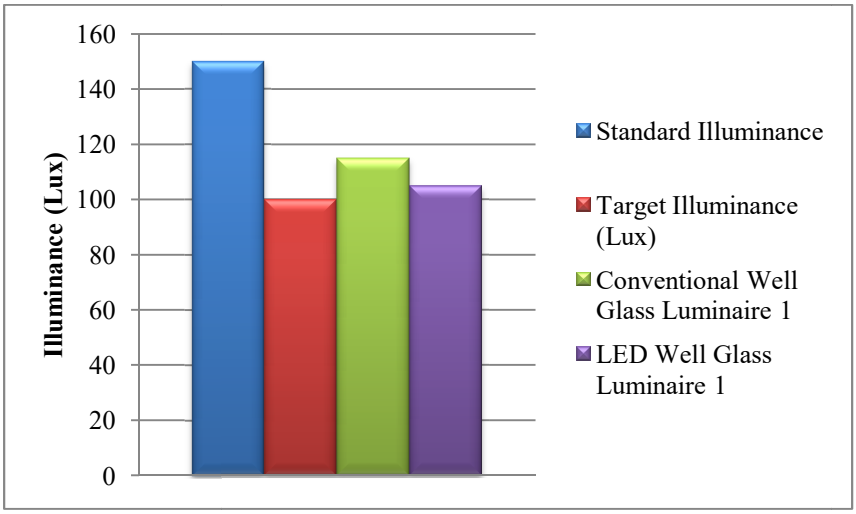


Fig. 9.49: Illuminance comparison of Pump House

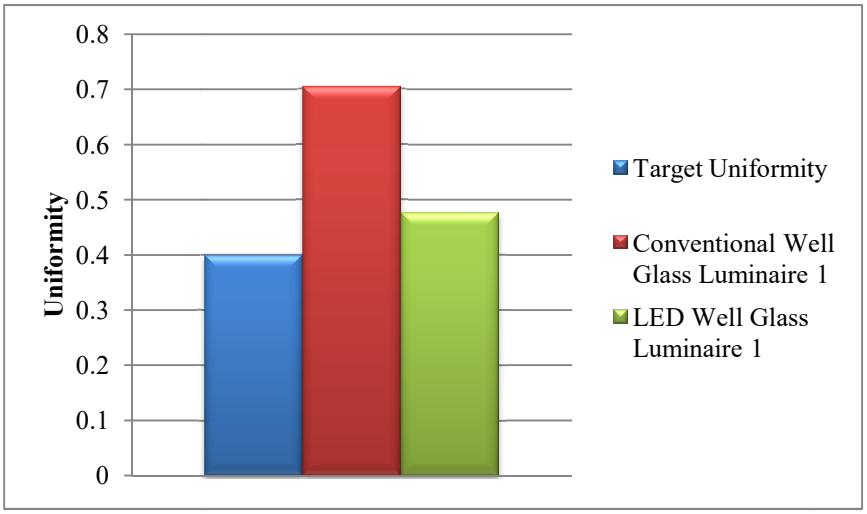


Fig. 9.50 Uniformity comparison of Pump House

In Fig. 9.49, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.In Fig. 9.50, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

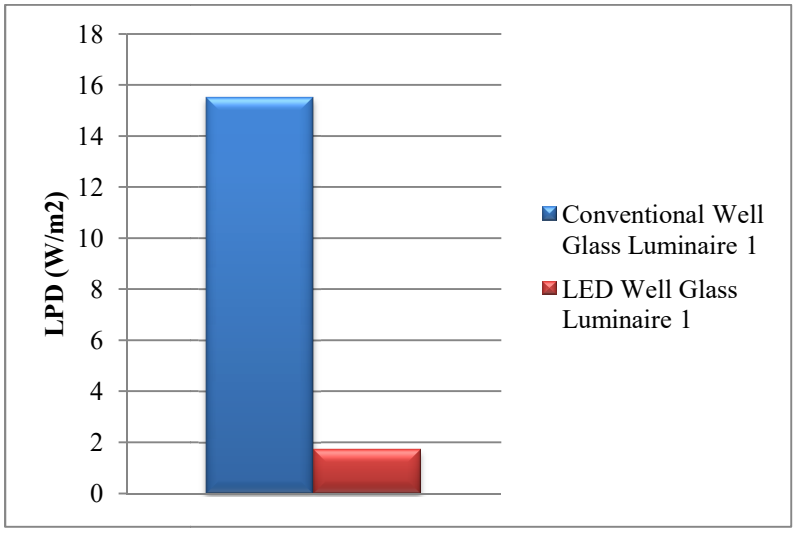


Fig. 9.51: LPD comparison of Pump House

In Fig. 9.51, LPD comparison is shown where LPD by using conventional luminaires is 8.87 times of using LED luminaires.

- **Drive House**

Room Length: 9.25m
Room Width: 9m
Room Height: 5.5m
Target Illuminance > 100 Lux
Standard Illuminance (as per IS6665) > 150 Lux
Target Uniformity > 0.4

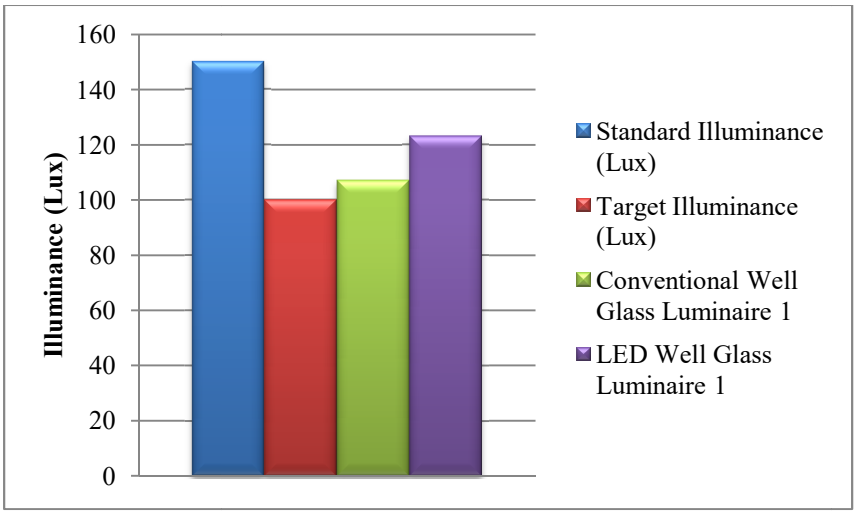


Fig. 9.52: Illuminance comparison of Drive House

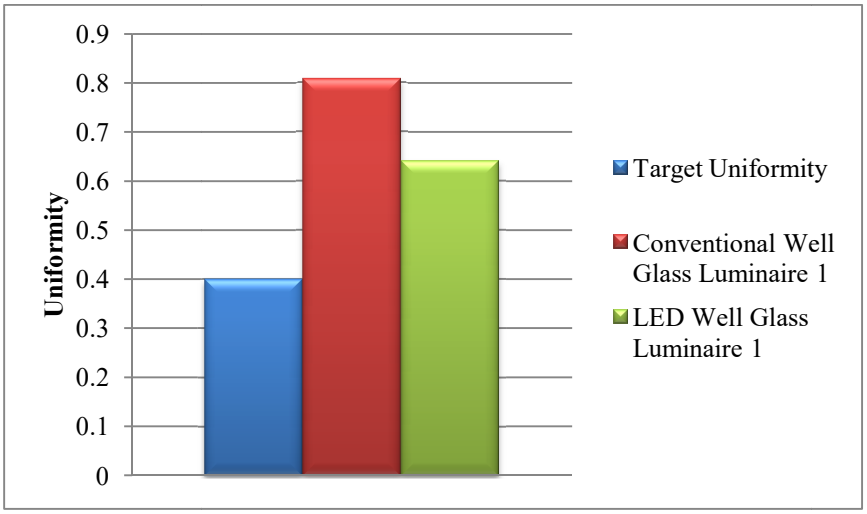


Fig. 9.53: Uniformity comparison of Drive House

In Fig. 9.52, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.53, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

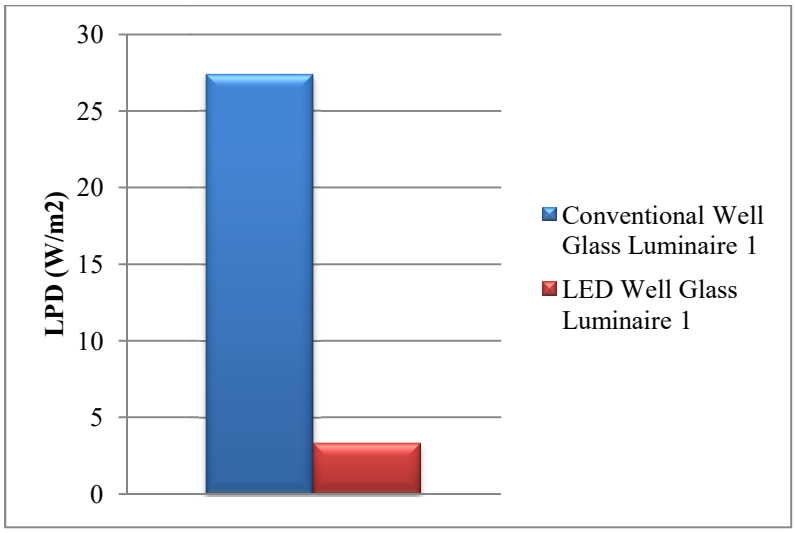


Fig. 9.54: LPD comparison of Drive House

In Fig. 9.54, LPD comparison is shown where LPD by using conventional luminaires is approx 8.18 times of using LED luminaires.

- **Corridor**

Room Length: 21m
Room Width: 2m
Room Height: 4.5m
Target Illuminance (as per IS 6665) > 150 Lux
Target Uniformity > 0.4

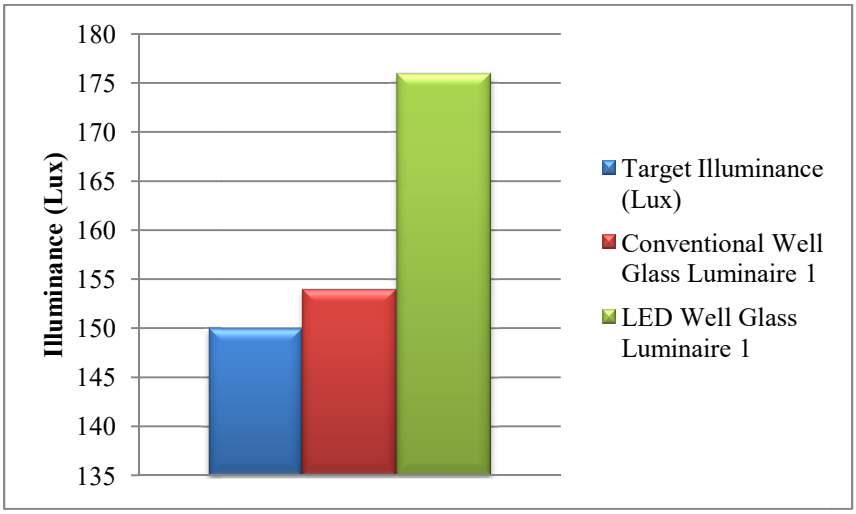


Fig. 9.55: Illuminance comparison of Corridor

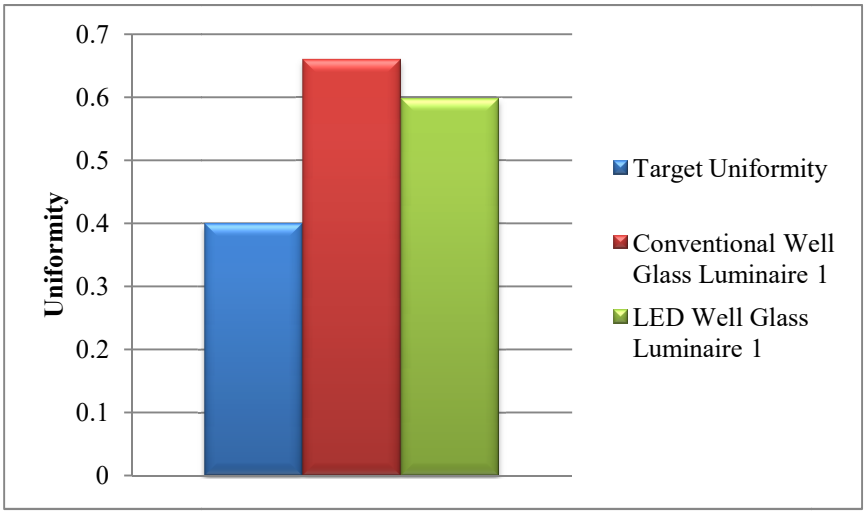


Fig. 9.56: Uniformity comparison of Corridor

In Fig. 9.55, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.In Fig. 9.56, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

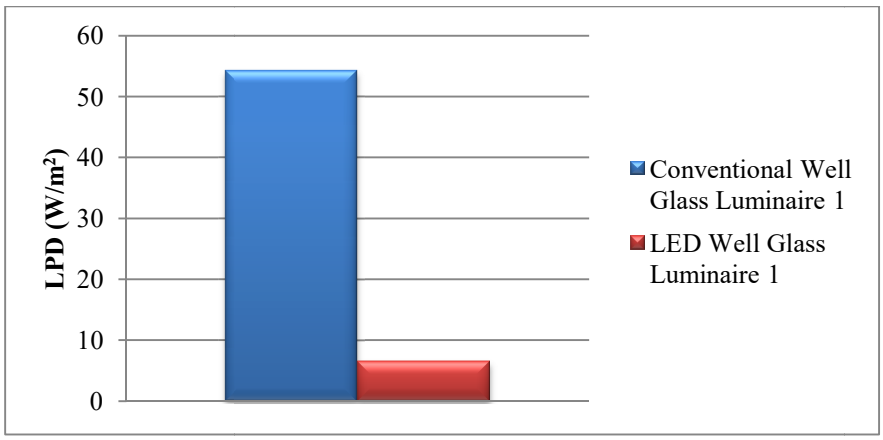


Fig. 9.57: LPD comparison of Corridor

In Fig. 9.57, LPD comparison is shown where LPD by using conventional luminaires is approx 8.16 times of using LED luminaires.

- **Switch Gear Room**

Room Length: 44.8m
Room Width: 4m
Room Height: 5.5m
Target Illuminance > 200 Lux
Standard Illuminance (as per IS 6665) > 150 Lux
Target Uniformity > 0.4

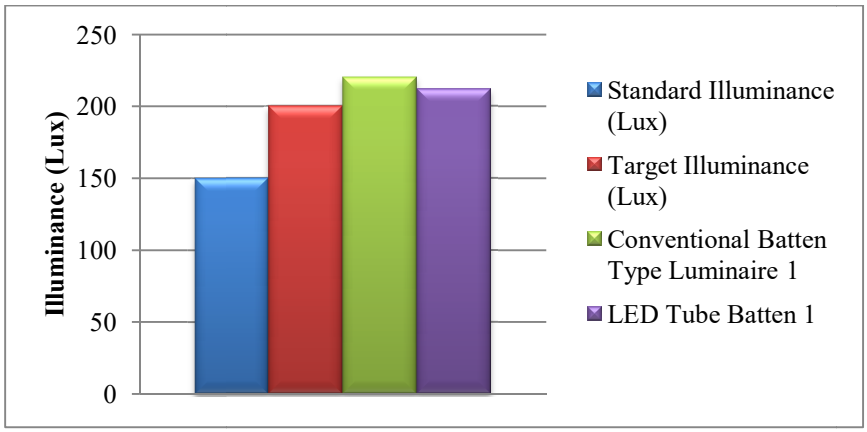


Fig. 9.58: Illuminance comparison of Switch Gear Room

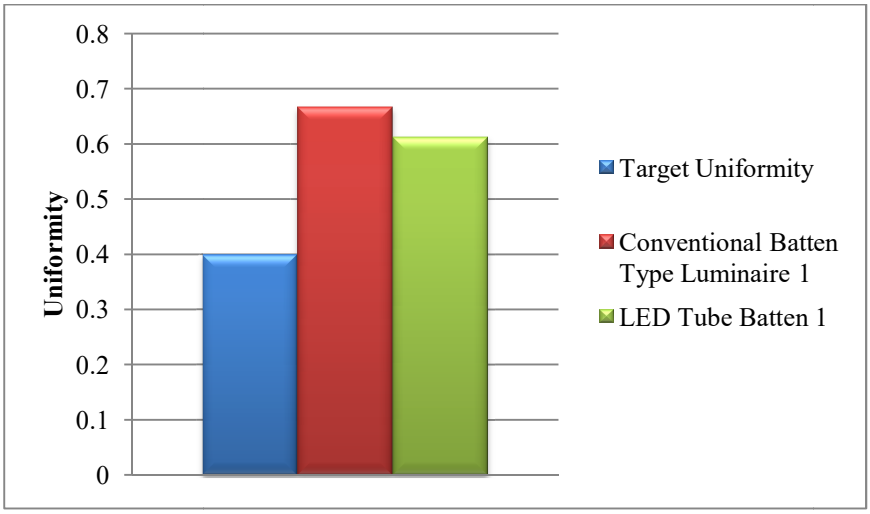


Fig. 9.59: Uniformity comparison of Switch Gear Room

In Fig. 9.58, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.In Fig. 9.59, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

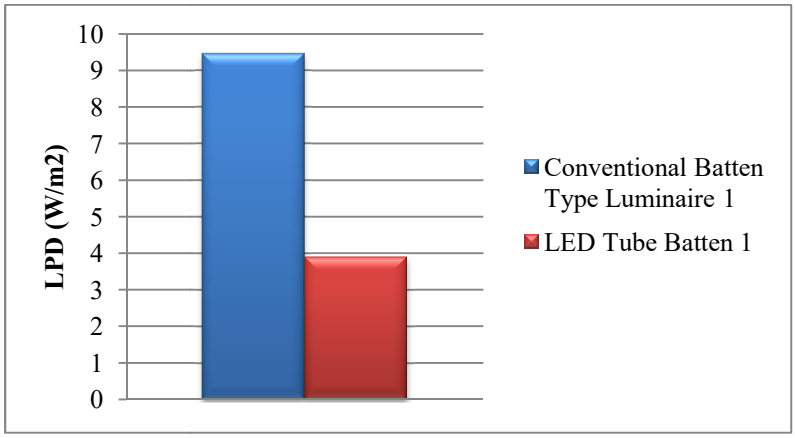


Fig. 9.60: LPD comparison of Switch Gear Room

In Fig. 9.60, LPD comparison is shown where LPD by using conventional luminaires is approx 2.42 times of using LED luminaires.

- **Cable Cellar Room**

Room Length: 29.89m
Room Width: 13.71m
Room Height: 2.5m
Target Illuminance > 200 Lux
Standard Illuminance (as per IS 6665) > 150 Lux
Target Uniformity > 0.4

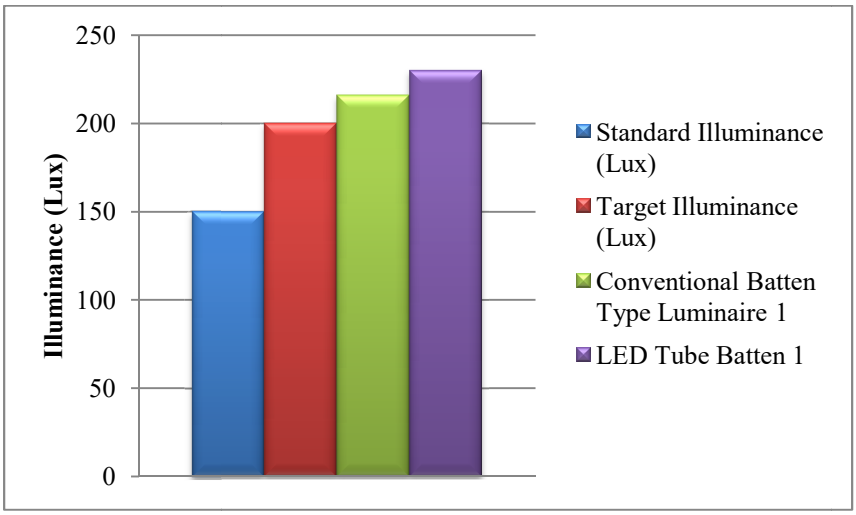


Fig. 9.61: Illuminance comparison of Cable Cellar Room

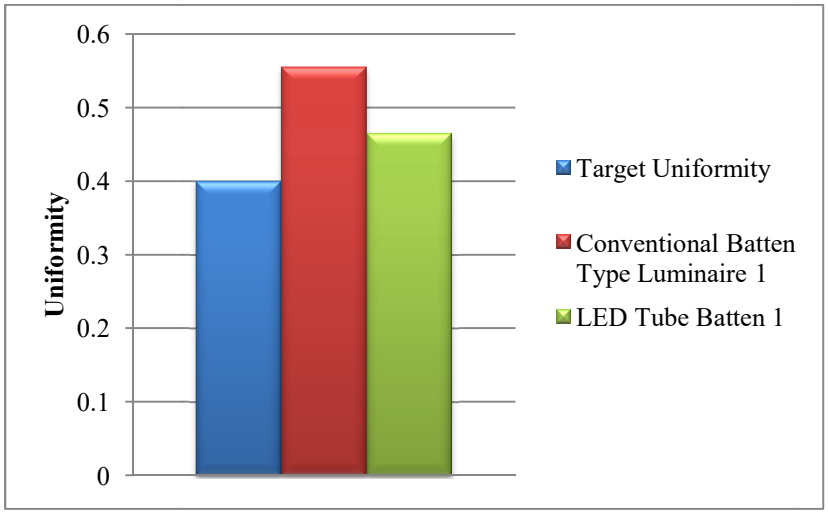


Fig. 9.62: Uniformity comparison of Cable Cellar Room

In Fig. 9.61, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.62, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

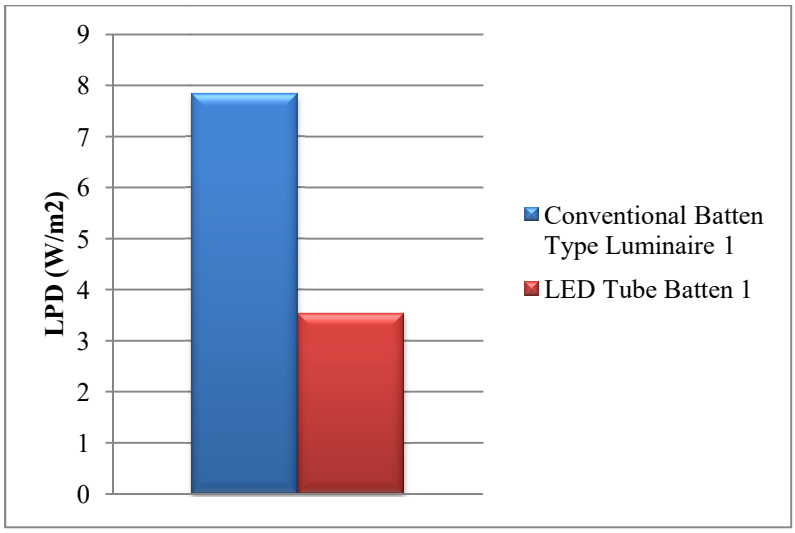


Fig. 9.63: LPD comparison of Cable Cellar Room

In Fig. 9.63, LPD comparison is shown where LPD by using conventional luminaires is approx 2.21 times of using LED luminaires.

- **Remote Input Output Room**

Room Length: 6m
Room Width: 4.5m
Room Height: 3.5m
Target Illuminance (as per IS 6665) > 300 Lux
Target Uniformity > 0.4

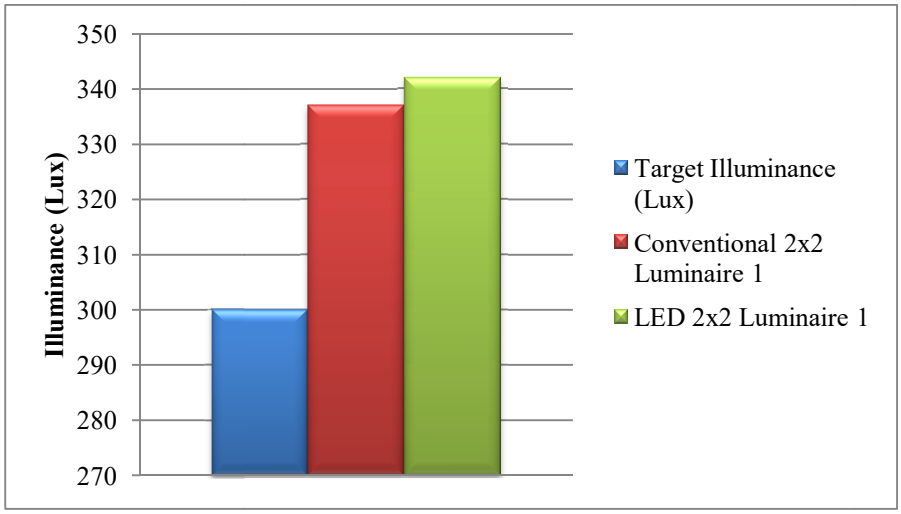


Fig. 9.64: Illuminance comparison of Remote Input Output Room

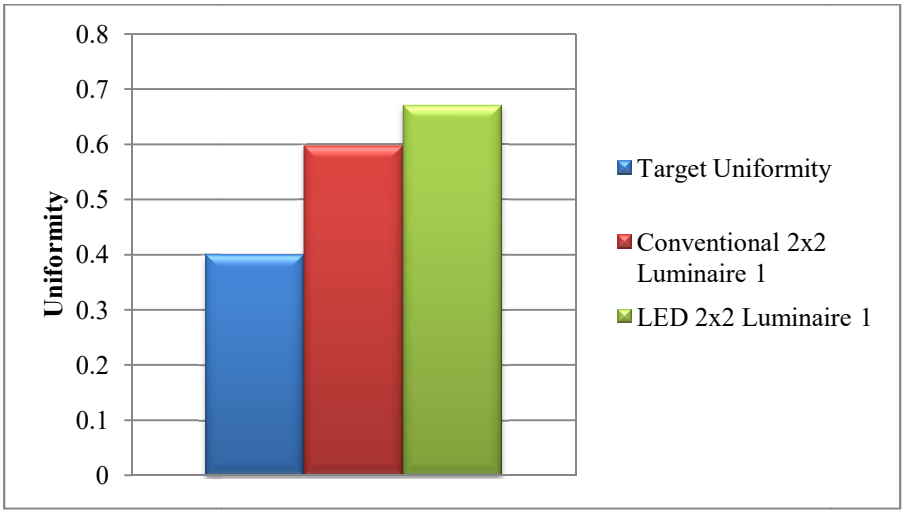


Fig. 9.65: Uniformity comparison of Remote Input Output Room

In Fig. 9.64, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.65, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

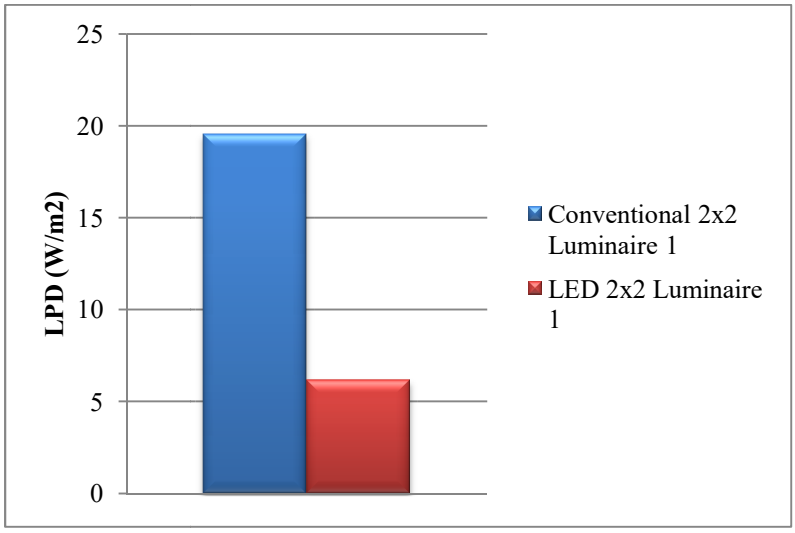


Fig. 9.66: LPD comparison of Remote Input Output Room

In Fig. 9.66, LPD comparison is shown where LPD by using conventional luminaires is approx 3.16 times of using LED luminaires.

- **Wagon Tripler Control Room**

Room Length: 7.47m
Room Width: 3.5m
Room Height: 3.5m
Target Illuminance > 350 Lux
Standard Illuminance (as per IS 6665) > 300 Lux
Target Uniformity > 0.4

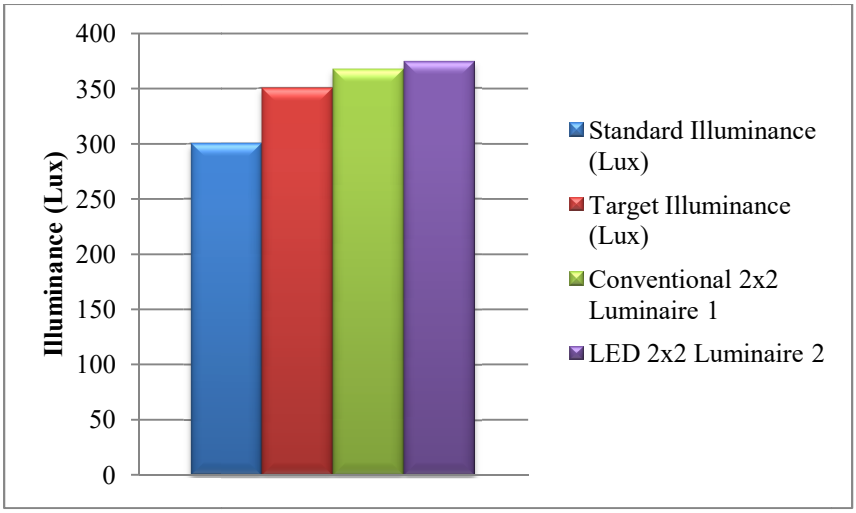


Fig. 9.67: Illuminance comparison of Wagon Tripler Control Room

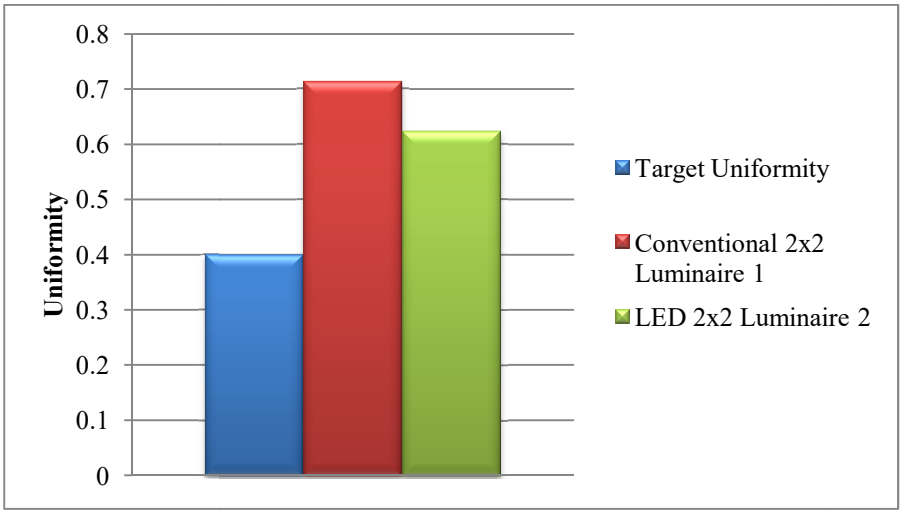


Fig. 9.68: Uniformity comparison of Wagon Tripler Control Room

In Fig. 9.67, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.68, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

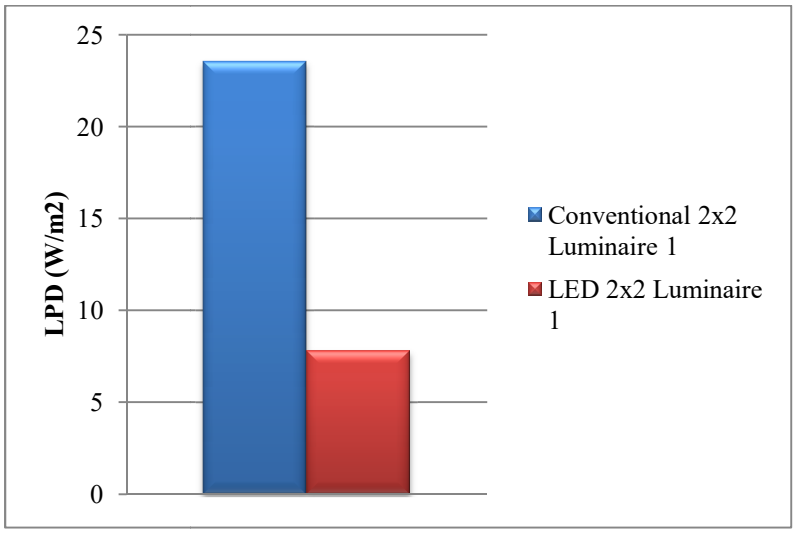


Fig. 9.69: LPD comparison of Wagon Tripler Control Room

In Fig. 9.69, LPD comparison is shown where LPD by using conventional luminaires is approx 3.01 times of using LED luminaires.

- **Transfer Point**

Room Length: 16m
Room Width: 11m
Room Height: 4.5m
Target Illuminance (as per IS 6665) > 100 Lux
Target Uniformity > 0.4

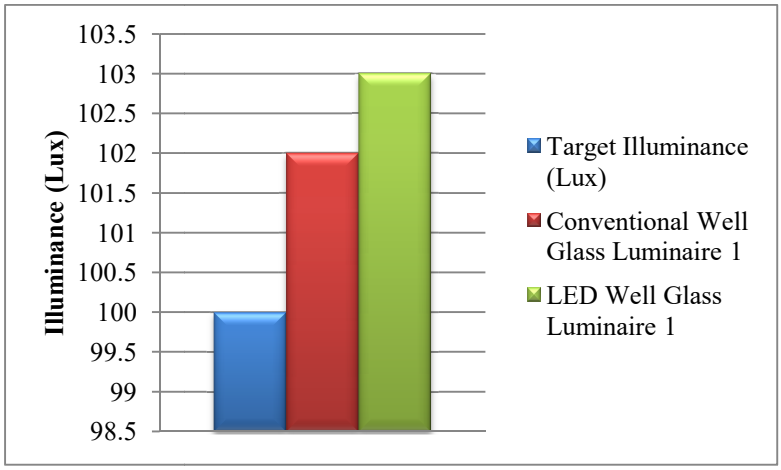


Fig. 9.70: Illuminance comparison of Transfer Point

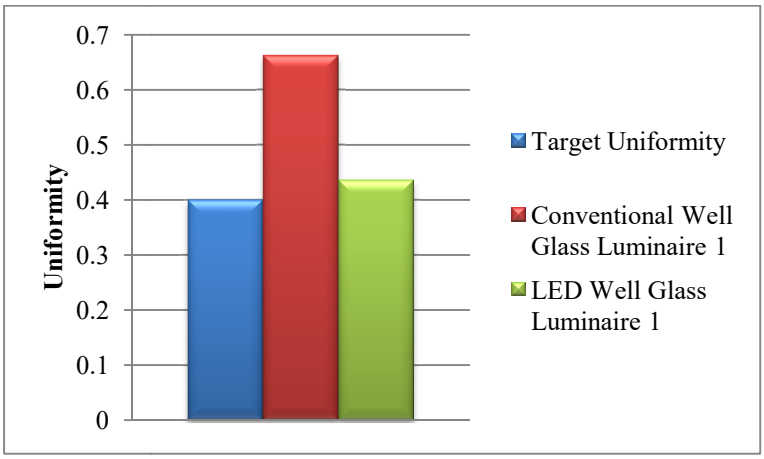


Fig. 9.71: Uniformity comparison of Transfer Point

In Fig. 9.70, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.71, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

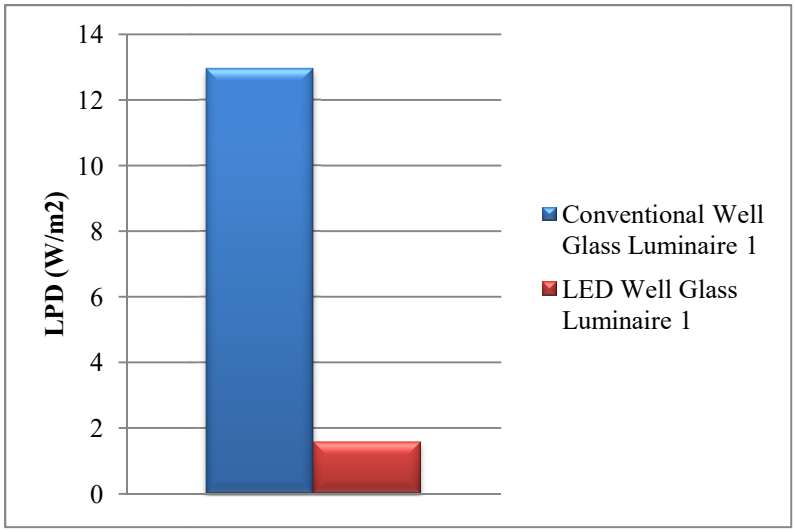


Fig. 9.72: LPD comparison of Transfer Point

In Fig. 9.72, LPD comparison is shown where LPD by using conventional luminaires is approx 8.14 times of using LED luminaires.

➢ **Junction Tower**

Room Length: 19m
Room Width: 14m
Room Height: 4.5m
Target Illuminance > 150 Lux
Standard Illuminance (as per IS 6665) > 100 Lux
Target Uniformity > 0.4

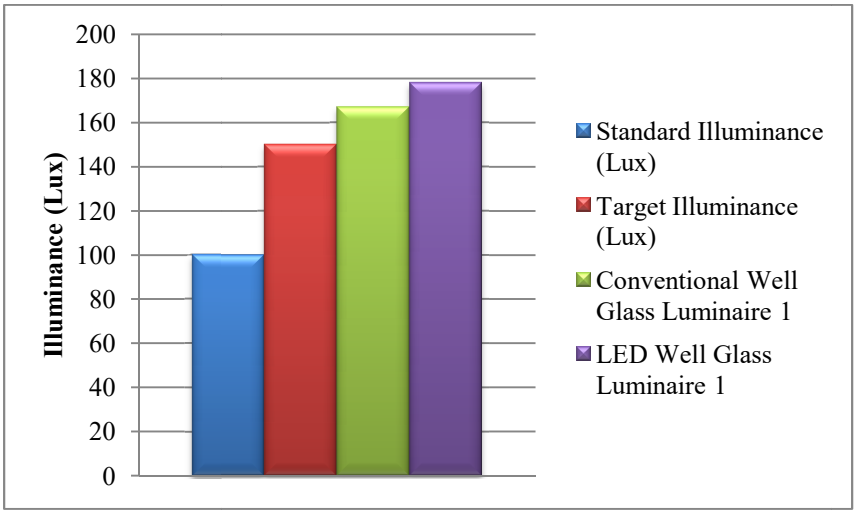


Fig. 9.73: Illuminance comparison of Junction Tower

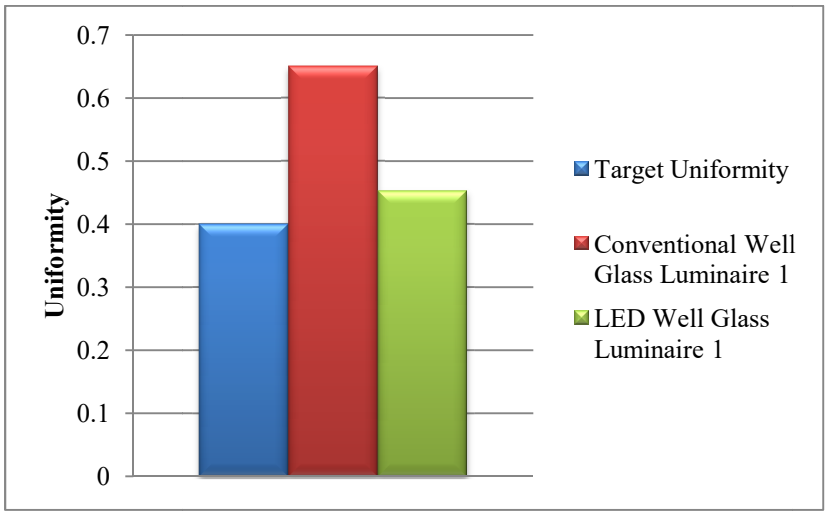


Fig. 9.74: Uniformity comparison of Junction Tower

In Fig. 9.73, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.74, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

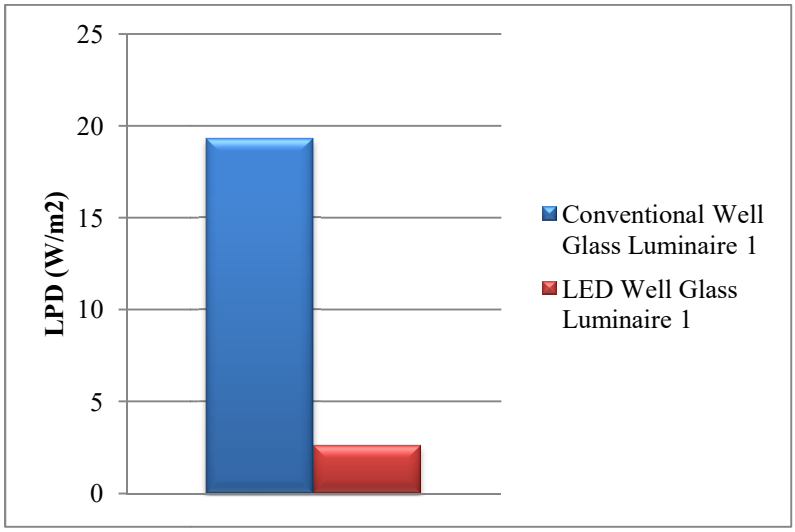


Fig. 9.75: LPD comparison of Junction Tower

In Fig. 9.75, LPD comparison is shown where LPD by using conventional luminaires is approx 7.36 times of using LED luminaires.

- **Bunker Area**

Room Length: 42m
Room Width: 12.75m
Room Height: 10m
Target Illuminance (as per IS 6665) > 100 Lux
Target Uniformity > 0.4

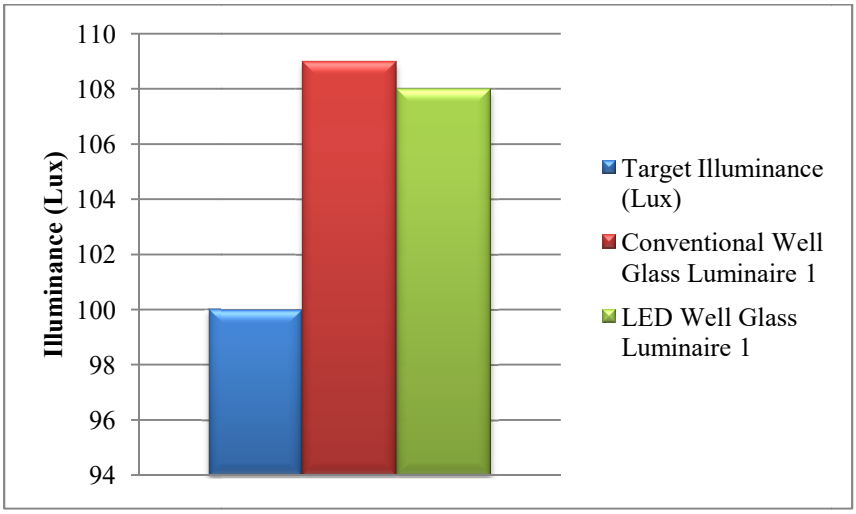


Fig. 9.76: Illuminance comparison of Bunker Area

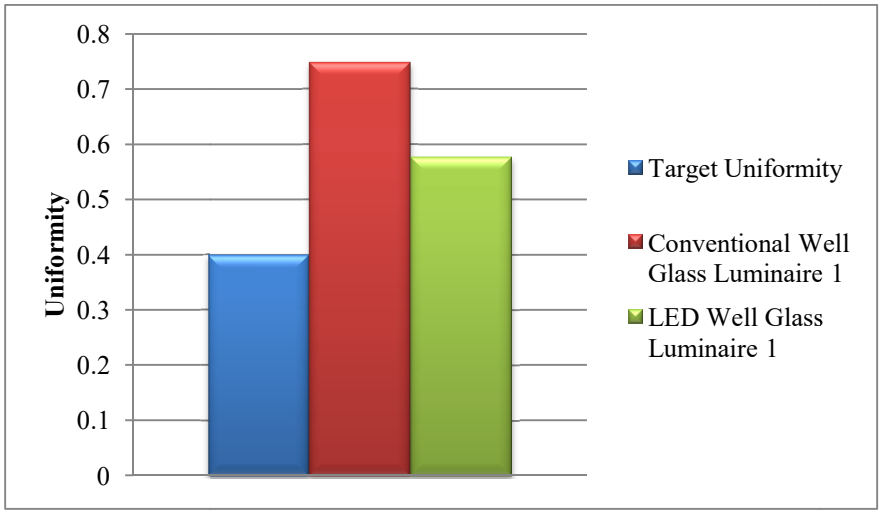


Fig. 9.77: Uniformity comparison of Bunker Area

In Fig. 9.76, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.77, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

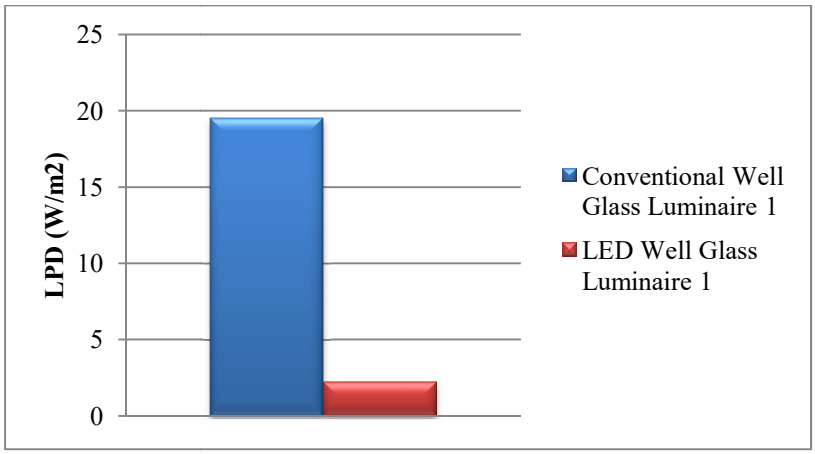


Fig. 9.78: LPD comparison of Bunker Area

In Fig. 9.78, LPD comparison is shown where LPD by using conventional luminaires is approx 8.43 times of using LED luminaires.

- **Crusher House**

Room Length: 32m
Room Width: 25m
Room Height: 8m
Target Illuminance (as per IS 6665) > 100 Lux
Target Uniformity > 0.4

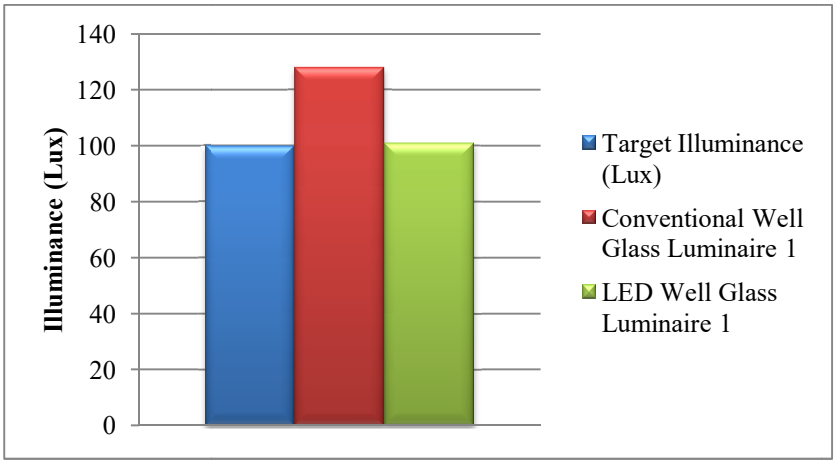


Fig. 9.79: Illuminance comparison of Crusher House

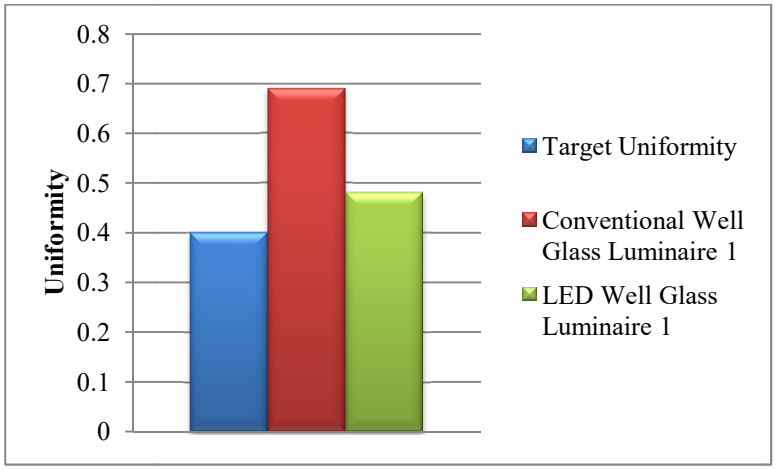


Fig. 9.80: Uniformity comparison of Crusher House

In Fig. 9.79, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.80, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

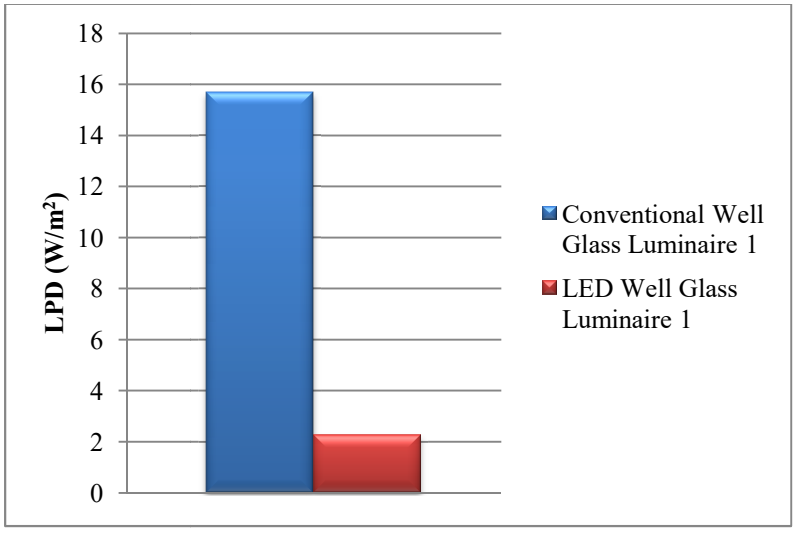


Fig. 9.81: LPD comparison of Crusher House

In Fig. 9.81, LPD comparison is shown where LPD by using conventional luminaires is approx 9.99 times of using LED luminaires.

- **Belt Conveyor**

Room Length: 268.7m
Room Width: 10m
Room Height: 3m
Target Illuminance > 70 Lux
Standard Illuminance (as per IS 6665) > 100 Lux

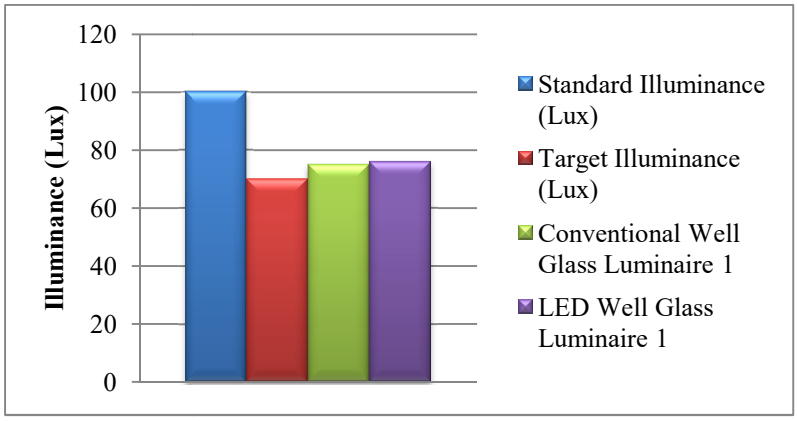


Fig. 9.82: Illuminance comparison of Belt Conveyor

In Fig. 9.82, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

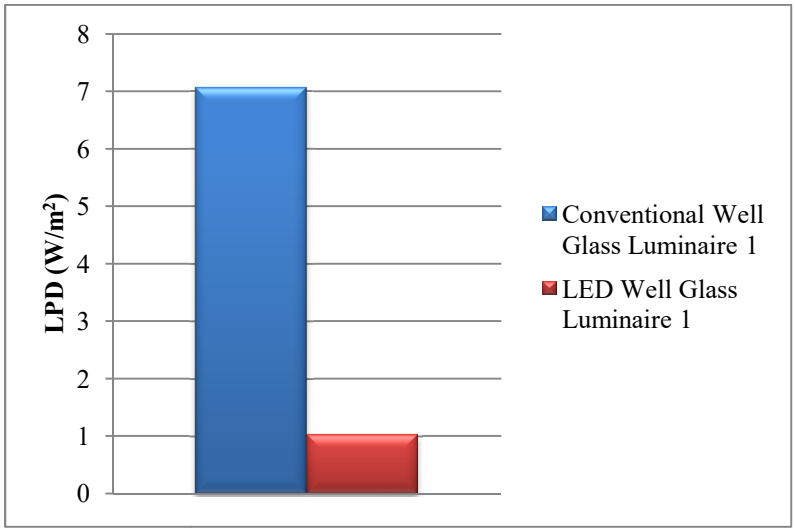


Fig. 9.83: LPD comparison of Belt Conveyor

In Fig. 9.83, LPD comparison is shown where LPD by using conventional luminaires is approx 6.79 times of using LED luminaires.

- **Pipe Conveyor**

Room Length: 70m
Room Width: 4m

Room Height: 3.2m
Target Illuminance > 70 Lux
Standard Illuminance (as per IS 6665) > 100 Lux

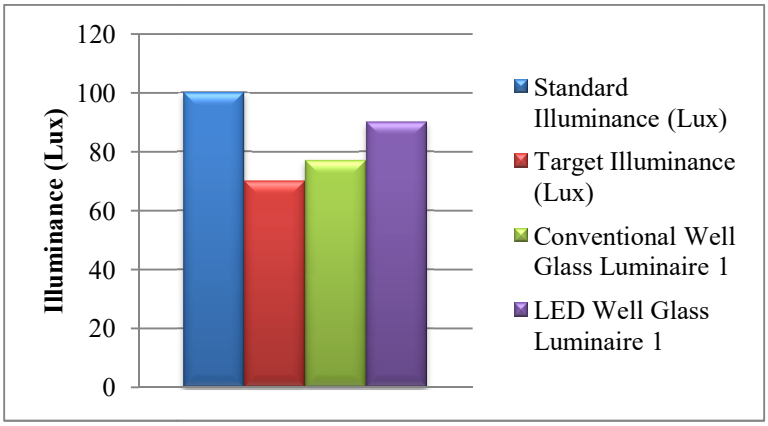


Fig. 9.84: Illuminance comparison of Pipe Conveyor

In Fig. 9.84, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

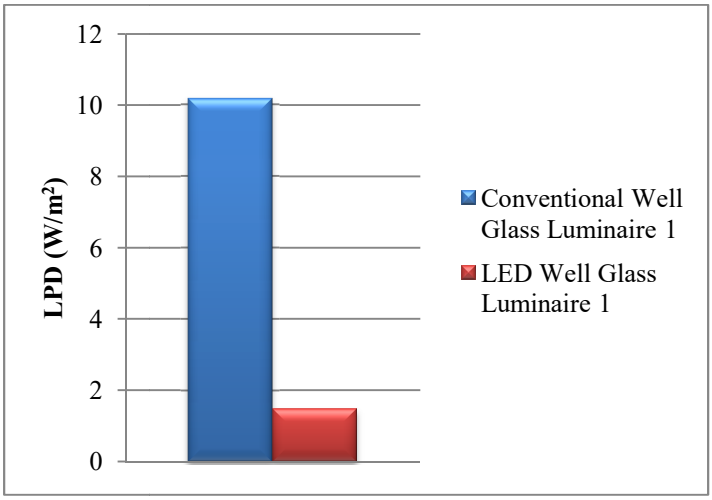


Fig. 9.85: LPD comparison of Pipe Conveyor

In Fig. 9.85, LPD comparison is shown where LPD by using conventional luminaires is approx 6.79 times of using LED luminaires.

- **Area-wise Power Consumption**

The area-wise power consumption by using Conventional Luminaires and LED Luminaires are shown in Fig. 9.86 and Fig. 9.87 respectively. From both figure, Belt Conveyor has maximum power consumption i.e. 23%.

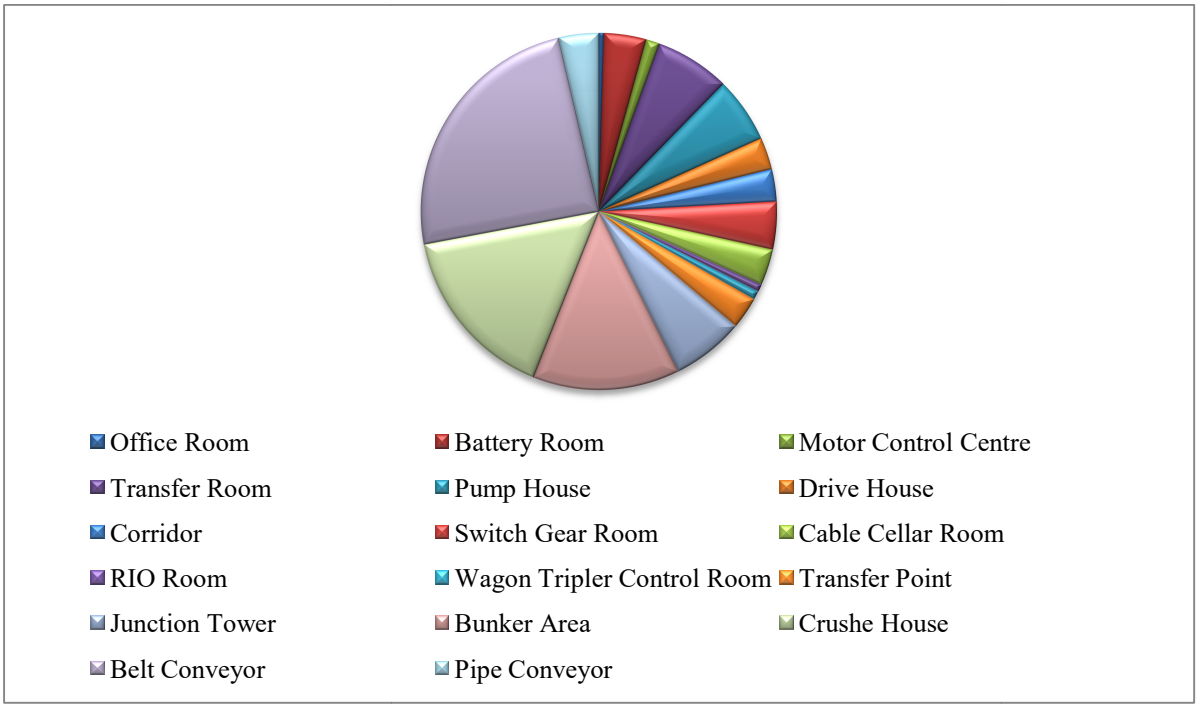


Fig. 9.86: Area-wise power consumption by using Conventional Luminaires

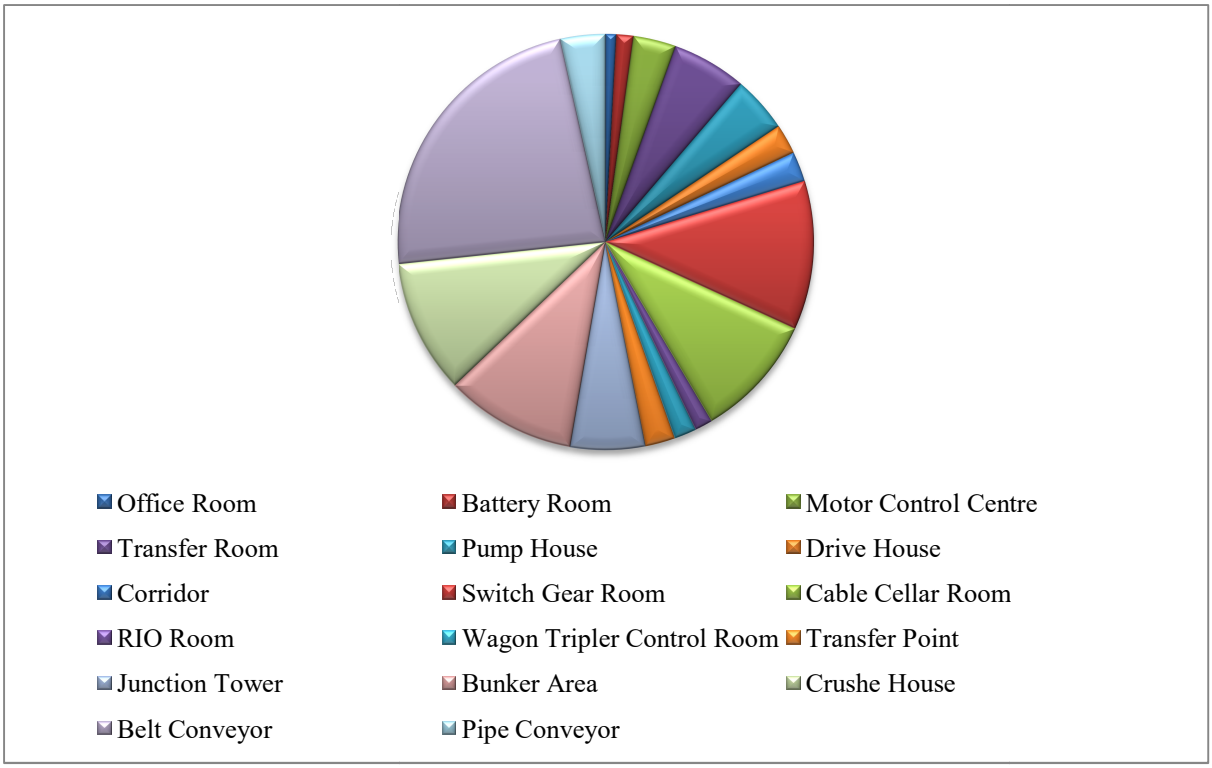


Fig. 9.87: Power Consumption by using LED Lumianire

9.3.2 Economic Comparison between Conventional and LED Solution of Case Study on Thermal Power Plant

- **Cost details of conventional luminaires used in the project**

Sl. No.	Luminaire	Qty	Price Per Fixture (Rs.) [55]	Total Cost (Rs.)
1	Conventional 2x2 Luminaire 1	15	3000	45000
2	Conventional Flameproof Well Glass Luminaire 1	17	3800	64600
3	Conventional Well Glass Luminaire 1	703	1405	987715
4	Conventional Batten Type Luminaire 1	129	527.5	68047.5

Total Purchase cost with conventional lamps & luminaires = Rs. 1165362.50

- **Cost details of LED luminaires used in the project**

Sl No.	Luminaire	Qty	Price Per Fixture (Rs.) [56]	Total Cost (Rs.)
1	LED Well Glass Luminaire 1	242	4000	968000
2	LED 2x2 Luminaire 1	8	6000	48000
3	LED 2x2 Luminaire 2	6	3700	22200
4	LED Tube Batten 1	89	1115	99235
5	LED Flameproof Luminaire	4	9300	37200

Total Purchase cost with LED lamps & luminaires = Rs. 1174635

- **Total annual operating cost (Rs) of LED Luminaires**

Sl. No.	Paramater	LED Luminaires				
1	**Luminaire**	**LED Well Glass Luminaire 1**	**LED 2x2 Luminaire 1**	**LED 2x2 Luminaire 2**	**LED Tube Batten 1**	**LED Flameproof Luminaire**
2	**Power Consumption Per Luminiare (Watt)**	34.9	33.4	34.2	33.2	39.7
3	**Quantity**	242	8	6	89	4
4	**Total Power Consumption (Watt)**	8445.8	267.2	205.2	2954.8	158.8
5	**Usage of system per day in hour**	24				
6	**Total working days per annum**	365				

7	**Total Energy Consumption per annum (KW-hr)**	73985.208	2340.672	1797.552	25884.048	1391.088
8	**Electricity Charges in Rs**	10				
9	**Operating Cost in Rs. per annum**	739852.08	23406.72	17975.52	258840.48	13910.88
10	**Total Annual Operating Cost (Rs.)**	1053985.68				

- **Total annual operating cost (Rs) of Conventional Luminaires**

Sl. No.	**Paramater**	**Conventional Luminaires**			
1	**Luminaire**	**Conventional 2x2 Luminaire 1**	**Conventional Flameproof Well Glass Luminaire 1**	**Conventional Well Glass Luminaire 1**	**Conventional Batten Type Luminaire 1**
2	**Power Consumption Per Luminiare (Watt)**	88	200	95	53.5
3	**Quantity**	15	17	703	129
4	**Total Power Consumption (Watt)**	1320	3400	66785	6901.5
5	**Usage of system per day in hour**	24			
6	**Total working days per annum**	365			
7	**Total Energy Consumption per annum (KW-hr)**	11563.2	29784	585036.6	60457.14
8	**Electricity Charges in Rs**	10			
9	**Operating Cost in Rs. per annum**	115632	297840	585036.60	604571.40
10	**Total Annual Operating Cost (Rs.)**	6868409.40			

In Fig. 9.88, annual cost comparison is shown where by using conventional luminaires; it is approx 6.52 times of using LED luminaires.

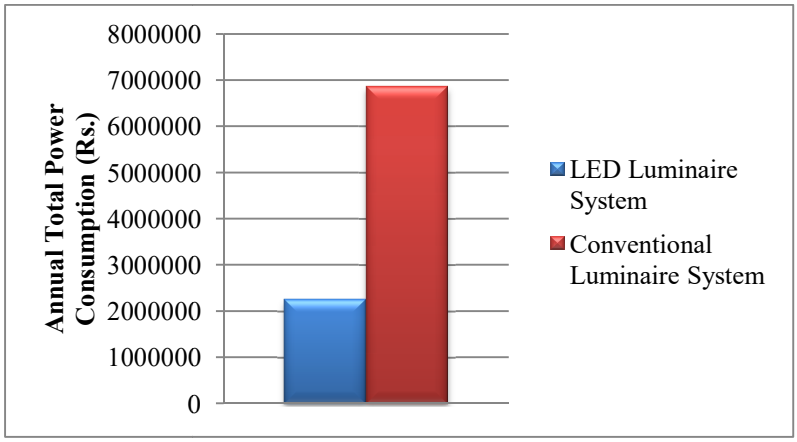


Fig. 9.88: Annual Operating Cost comparsion of Conventional and LED Luminaire System

- **Lamp Replacement and Maintenance Cost**

Sl. No.		Conventional 2x2 Luminaire 1	Conventional Flameproof Well Glass Luminaire 1	Conventional Well Glass Luminaire 1	Conventional Batten Type Luminaire 1
	Lamp Type	**2x 40W CFL**	**200W GLS**	**80W HPMV**	**36W FTL**
1	**Average Lamp Life**	6000	1000	8000	5000
2	**Number of lamps to be replaced per annum**	44	122	770	226
3	**Price per Lamp** [55]	240	12	130	40
4	**Cost of lamp replacement (Rs)**	10560	1464	100100	9040
5	**Average cost of maintenance Rs. 25 per luminaire (conventional) per year**	375	425	17575	3225
9	**Total Cost of replacement and maintenance (Rs)**	142764			

- **Payback Period Calculation**

Sl. No.	Annual Power & Maintenance Cost (Rs)	LED Luminaire System	Conventional Luminaire System
1	Luminaire Power Consumption Cost	1053985.68	6868409.4
2	Cost of Lamps Replaced Annualy and Annual Maintenance Cost	NA	142764
	Comparison		
1	Present worth	1174635	1165362.5

2	Annual Running Cost	1053986	7011173
	Payback Time		
0	Total Cost of operation at start	1174635	1165363
1	Total Cost of operation after 1st year	2228621	8176536
2	Total Cost of operation after 2nd year	3282606	15187709
3	Total Cost of operation after 3rd year	4336592	22198883
4	Total Cost of operation after 4th year	5390578	29210056

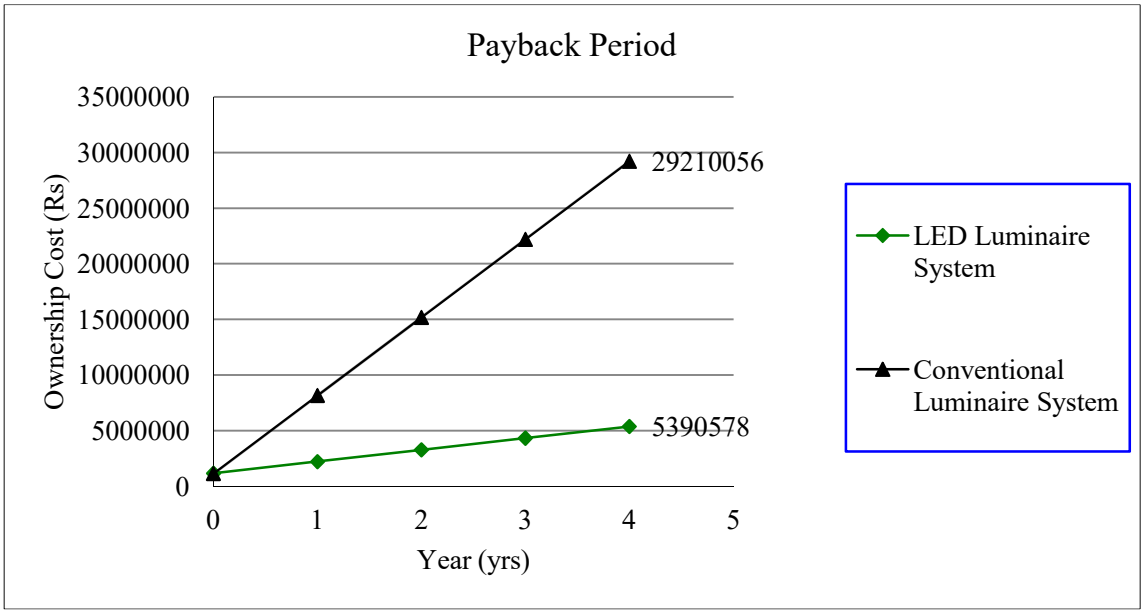


Fig. 9.89: Ownership Cost vs Years

From Fig. 9.89, it is observed that, the intersection of two lines is at approxmimately 2 months.
So, by Break Even Method, Payback period is approx 2 months.

9.4 Result Analysis and Cost Analysis of Case Study on Oil Refinery

9.4.1 Result Analysis of Case Study on Oil Refinery

The Illuminance, Uniformity and Energy usage in between two simulations are the main focused comparison criteria.

- **Office Room**

Room Length: 3.9m
Room Width: 3.7m
Room Height: 3m
Target Illuminance > 300 Lux
Standard Illuminance (as per IS 6665) > 500 Lux
Target Uniformity > 0.4

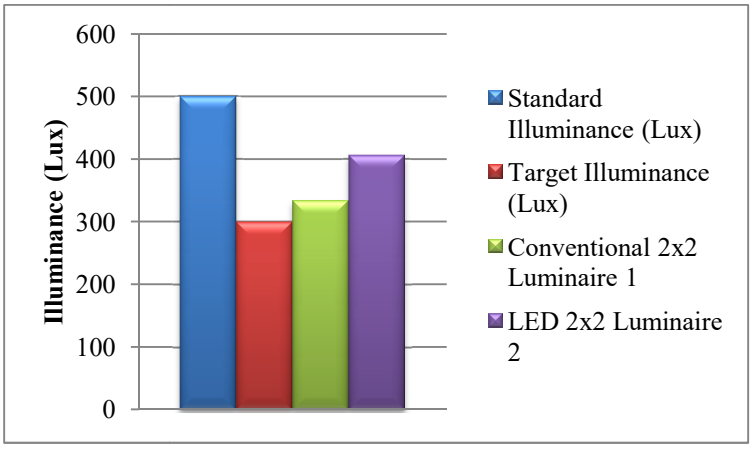


Fig. 9.90: Illuminance comparison of Office Room

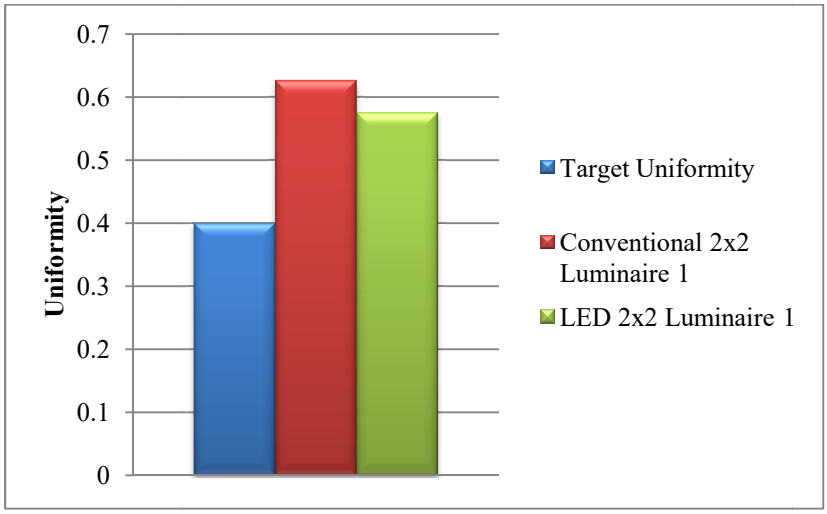


Fig. 9.91: Uniformity comparison of Office Room

In Fig. 9.90, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.91, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

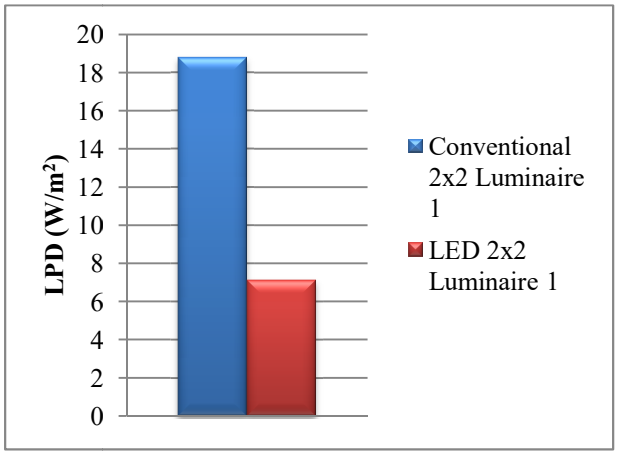


Fig. 9.92: LPD comparison of Office Room

In Fig. 9.92, LPD comparison is shown where LPD by using conventional luminaires is approx 2.63 times of using LED luminaires.

- **Electrical Workshop**

Room Length: 9.3m
Room Width: 7m
Room Height: 4m
Target Illuminance > 100 Lux
Target Uniformity > 0.4
Table 9.53 shows the Illumination parameters comparison and Table 9.54 shows the LPD comparison

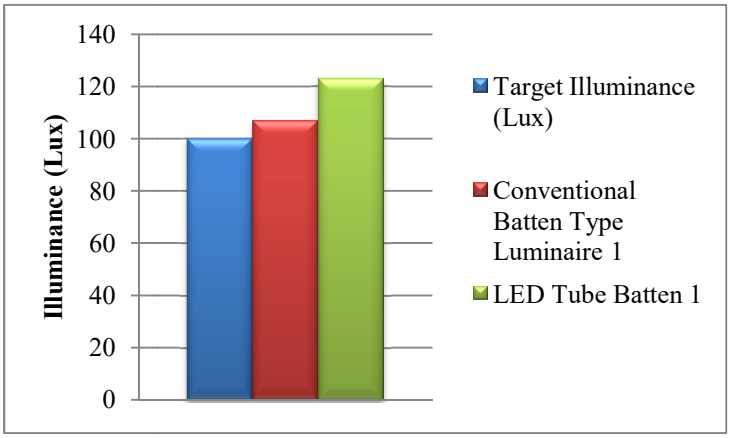


Fig. 9.93: Illuminance comparison of Electrical Workshop

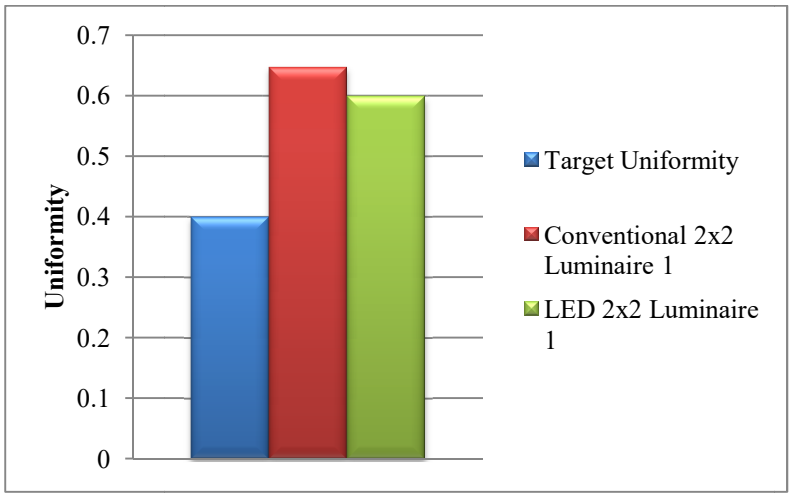


Fig. 9.94: Uniformity comparison of Electrical Workshop

In Fig. 9.93, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.94, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

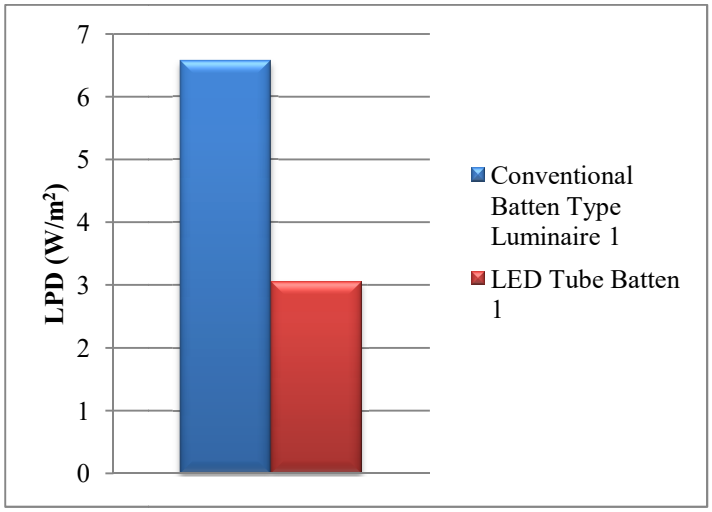


Fig. 9.95: LPD comparison of Electrical Workshop

In Fig. 9.95, LPD comparison is shown where LPD by using conventional luminaires is approx 2.18 times of using LED luminaires.

➢ **Radio Room**

Room Length: 6.60m
Room Width: 3.60m
Room Height: 4m
Target Illuminance > 100 Lux
Target Uniformity > 0.4

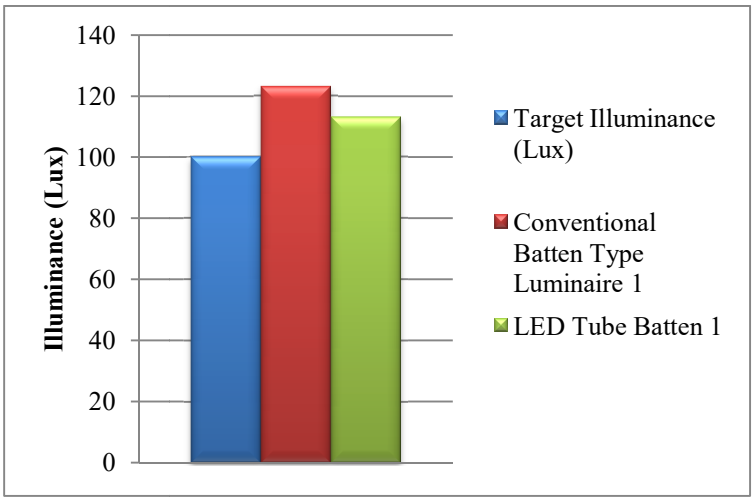


Fig. 9.96: Illuminance comparison of Radio Room

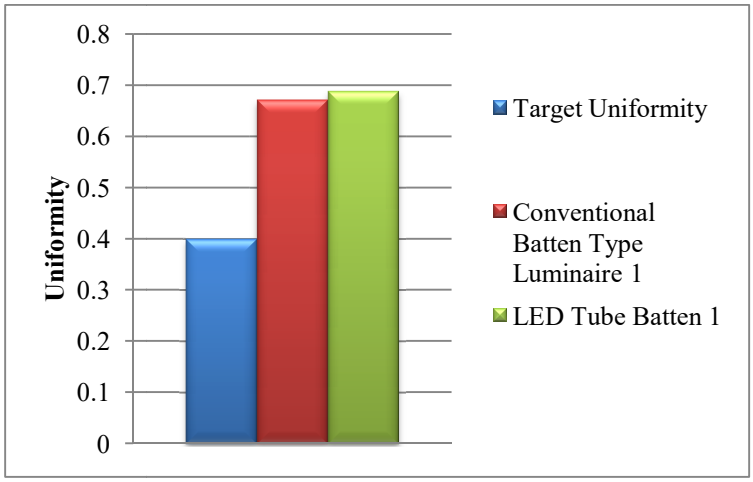


Fig. 9.97: Uniformity comparison of Radio Room

In Fig. 9.96, the average illuminance comparison is shown where average illuminance achieved by using Conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.97, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

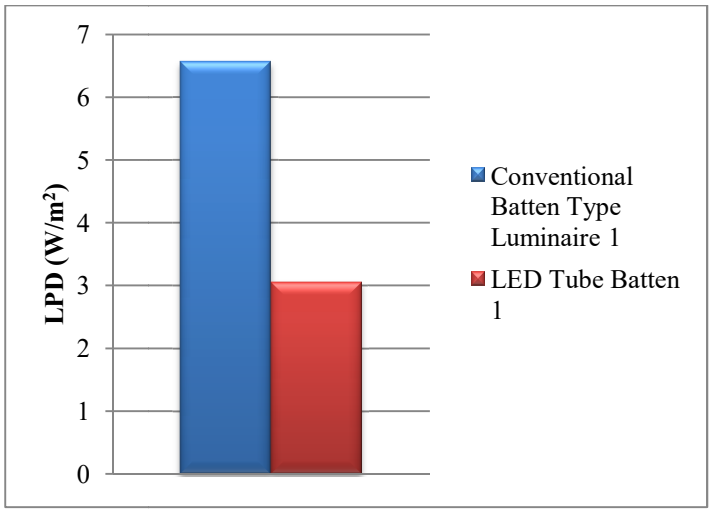


Fig. 9.98: LPD comparison of Radio Room

In Fig. 9.98, LPD comparison is shown where LPD by using conventional luminaires is approx 2.19 times of using LED luminaires.

➢ **PMCC HT and LT Room**

Room Length: 12.77m
Room Width: 5.50m
Room Height: 4m
Target Illuminance > 150 Lux
Target Uniformity > 0.4

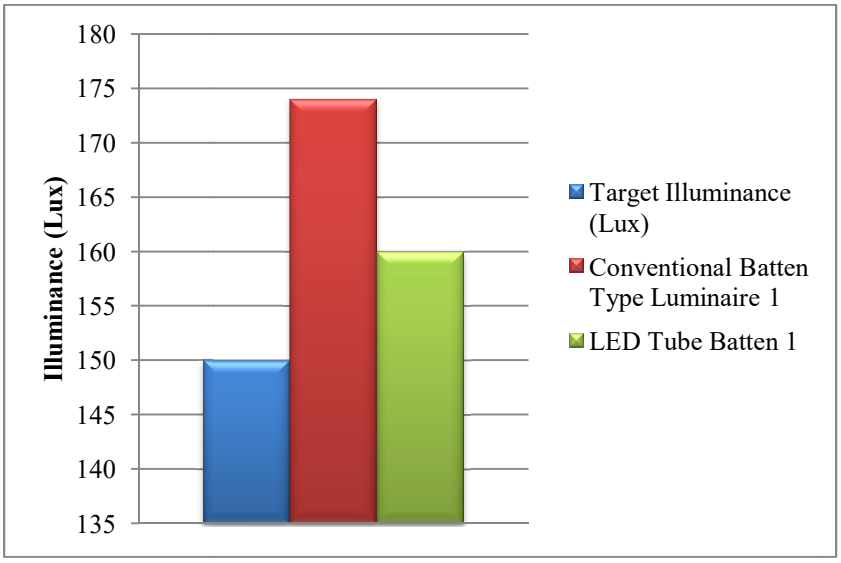


Fig. 9.99: Illuminance comparison of PMCC HT and LT Room

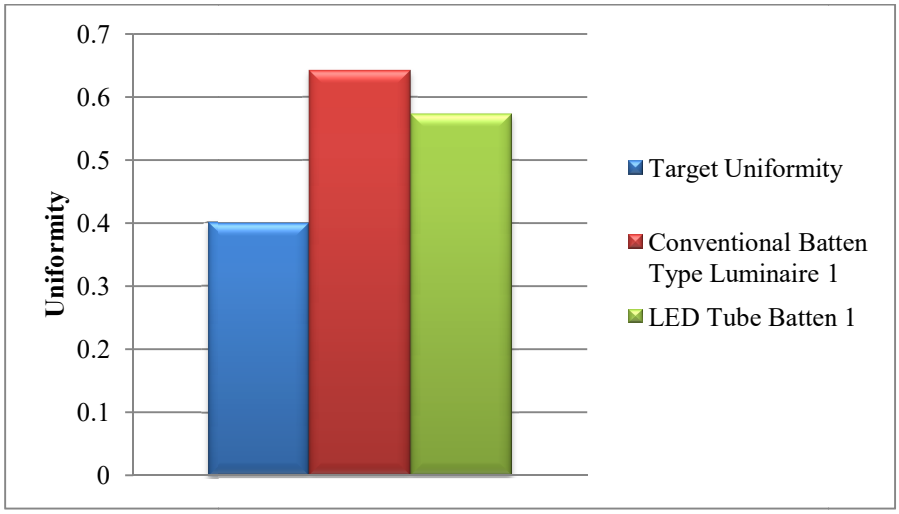


Fig. 9.100: Uniformity comparison of PMCC HT and LT Room

In Fig. 9.99, the average illuminance comparison is shown where average illuminance achieved by using Conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.100, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

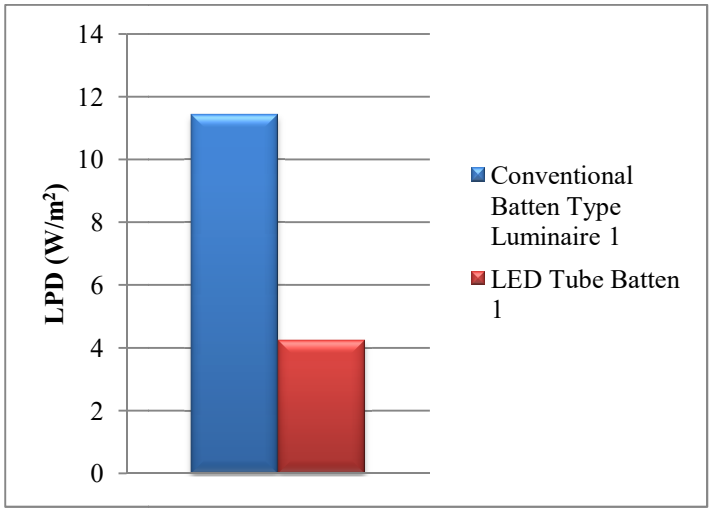


Fig. 9.101: LPD comparison of PMCC HT and LT Room

In Fig. 9.101, LPD comparison is shown where LPD by using conventional luminaires is approx 2.69 times of using LED luminaires.

- **Isolator Room**

Room Length: 11.50m
Room Width: 5.50m
Room Height: 4m
Target Illuminance > 70 Lux
Target Uniformity > 0.4

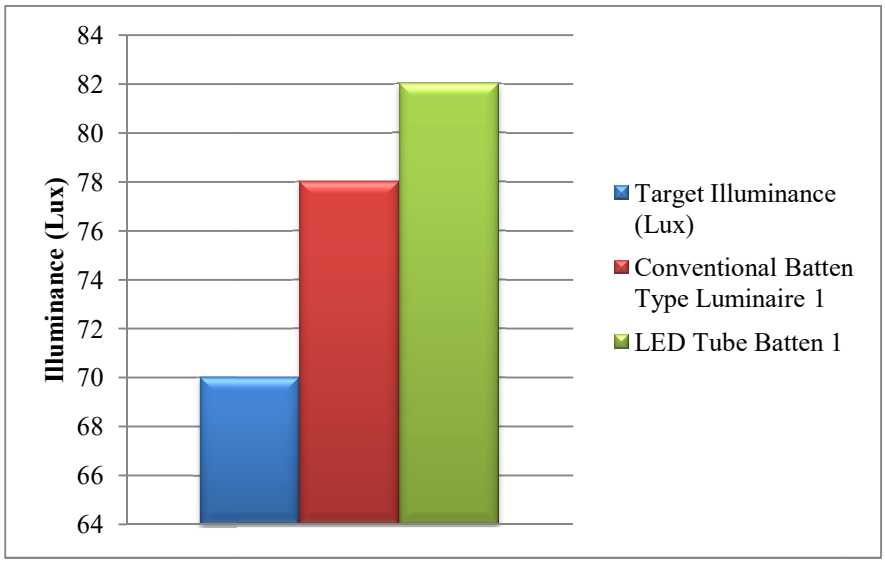


Fig. 9.102: Illuminance comparison of Isolator Room

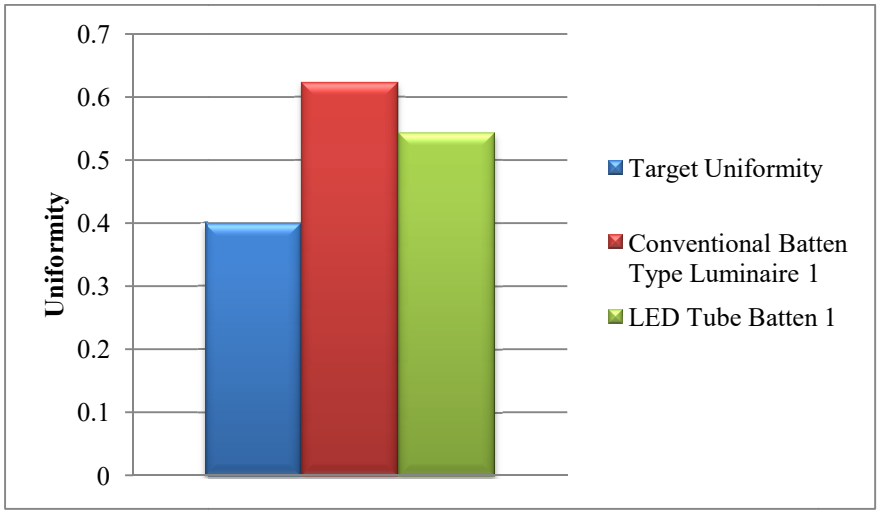


Fig. 9.103: Uniformity comparison of Isolator Room

In Fig. 9.102, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.103, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

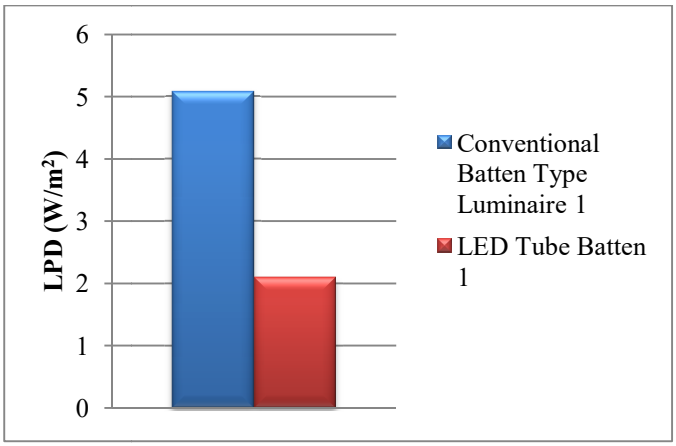


Fig. 9.104: LPD comparison of Isolator Room

In Fig. 9.104, LPD comparison is shown where LPD by using conventional luminaires is approx 2.42 times of using LED luminaires.

- **Variable Frequency Room**

Room Length: 10.50m
Room Width: 5.58m
Room Height: 4m
Target Illuminance > 100 Lux
Target Uniformity > 0.4

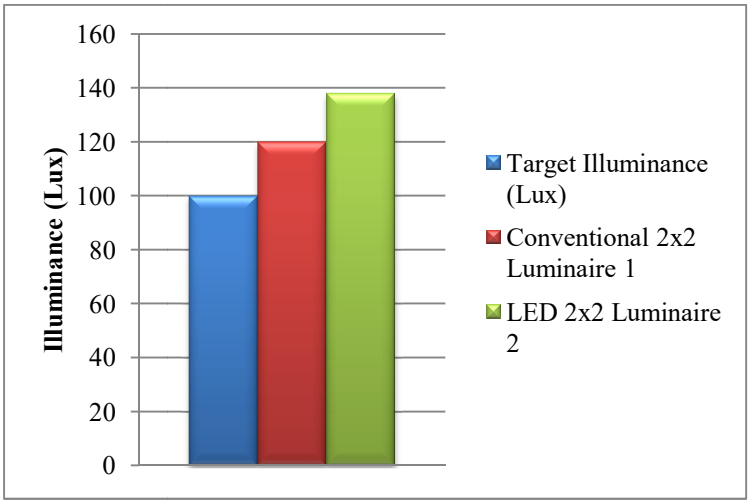


Fig. 9.105: Illuminance comparison of Variable Frequency Room

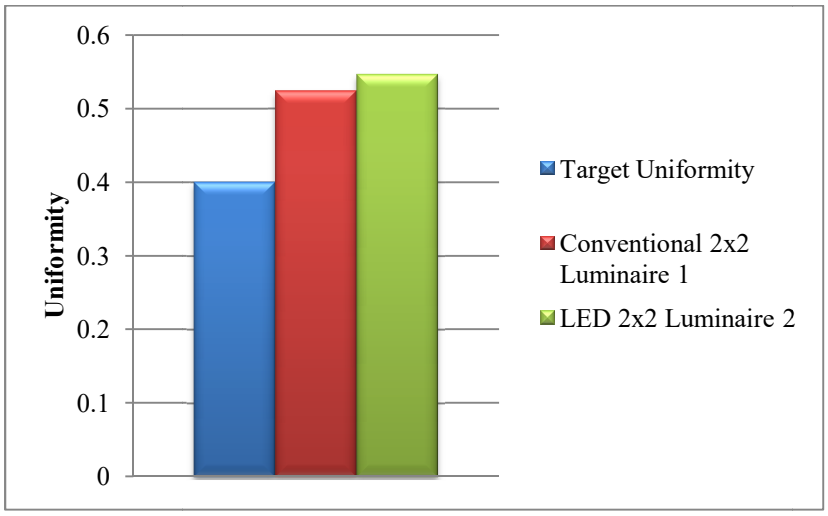


Fig. 9.106: Uniformity comparison of Variable Frequency Room

In Fig. 9.105, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

In Fig. 9.106, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

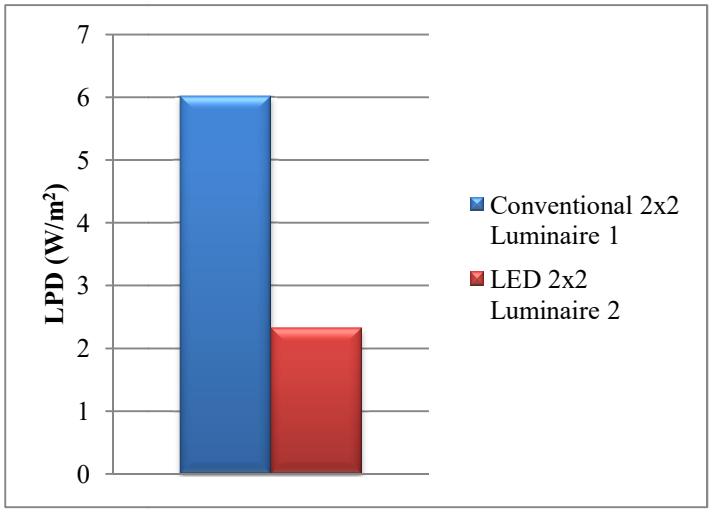


Fig. 9.107: LPD comparison of Variable Frequency Room

In Fig. 9.107, LPD comparison is shown where LPD by using conventional luminaires is approx 2.58 times of using LED luminaires.

- **Capacitor Room**

Room Length: 3.25m
Room Width: 5.04m
Room Height: 4m
Target Illuminance > 100 Lux
Target Uniformity > 0.4

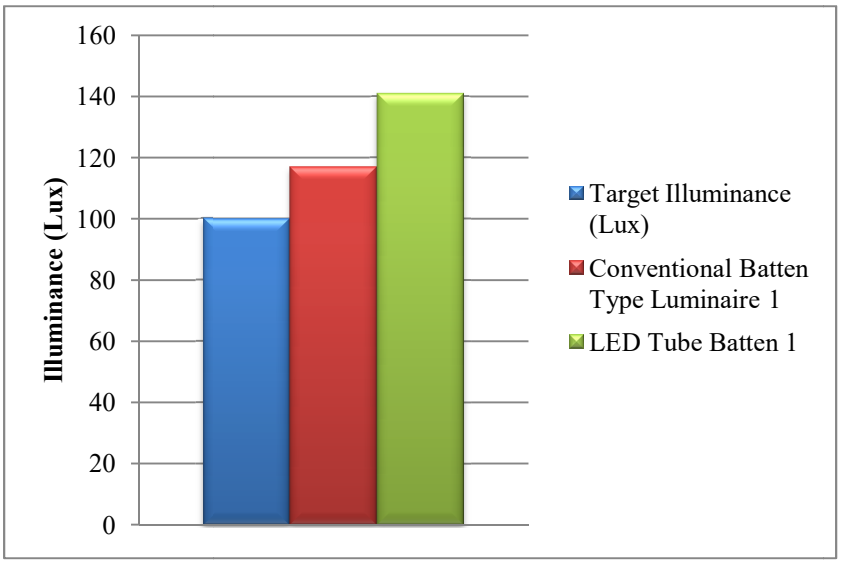


Fig. 9.108: Illuminance comparison of Capacitor Room

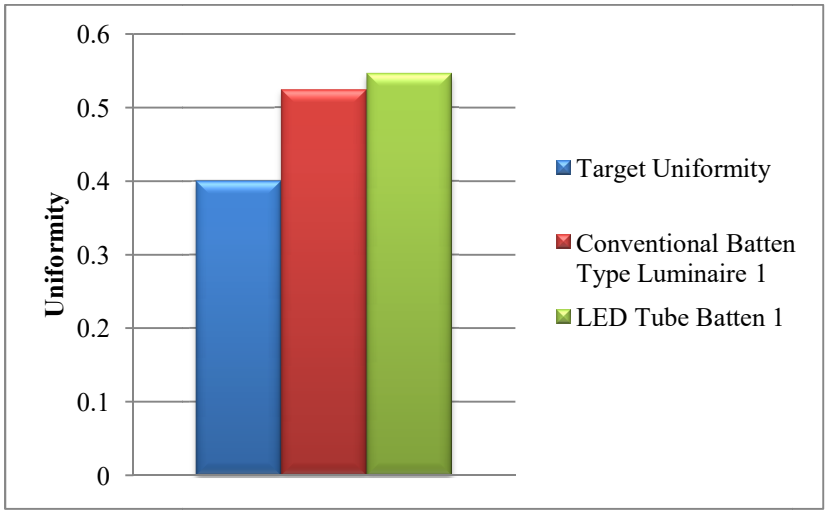


Fig. 9.109: Uniformity comparison of Capacitor Room

In Fig. 9.108, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.109, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

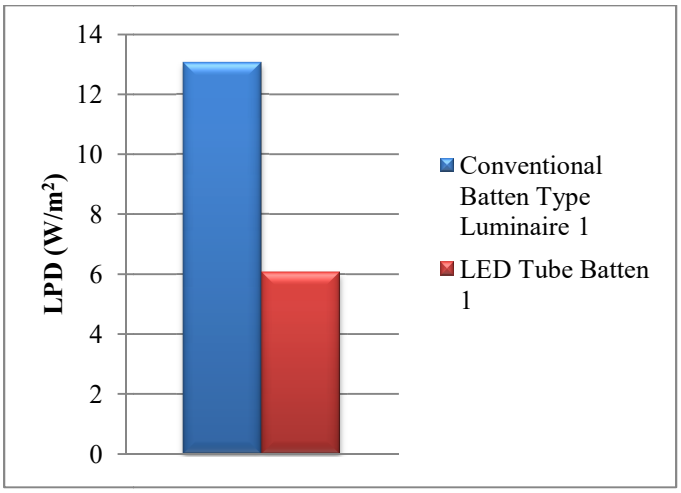


Fig. 9.110: LPD comparison of Capacitor Room

In Fig. 9.110, LPD comparison is shown where LPD by using conventional luminaires is approx 2.15 times of using LED luminaires.

- **PLC Room**

Room Length: 6.90m
Room Width: 5.38m
Room Height: 4m
Target Illuminance > 100 Lux
Target Uniformity > 0.4

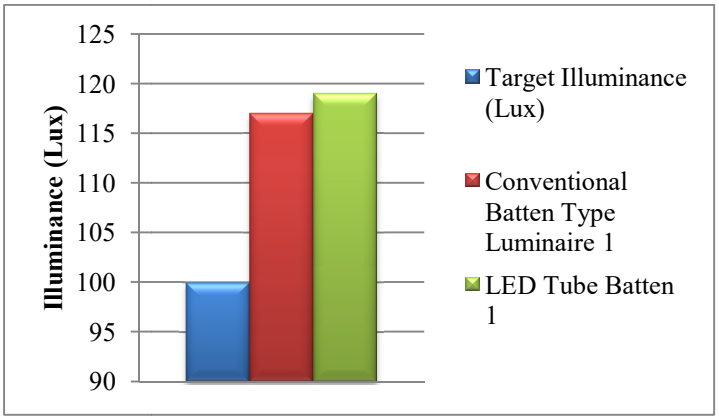


Fig. 9.111: Illuminance comparison of PLC Room

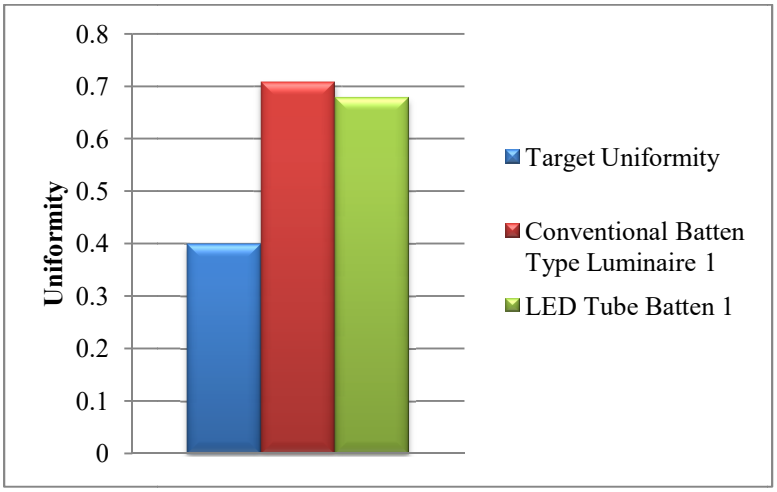


Fig. 9.112: Uniformity comparison of PLC Room

In Fig. 9.111, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.112, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

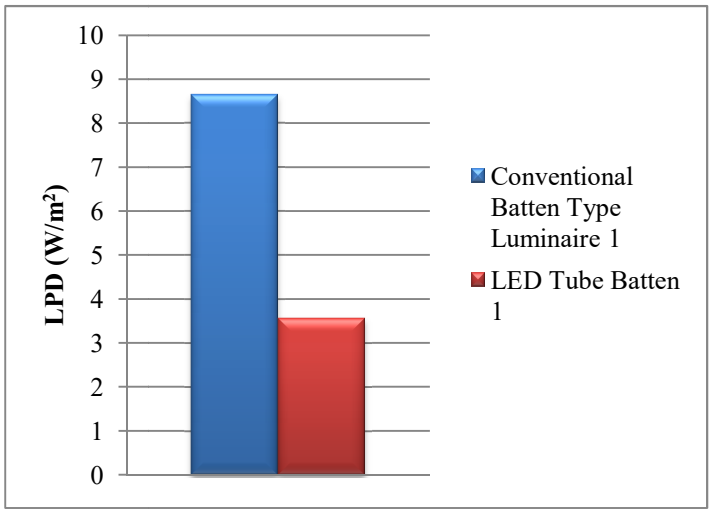


Fig. 9.113: LPD comparison of PLC Room

In Fig. 9.113, LPD comparison is shown where LPD by using conventional luminaires is approx 2.42 times of using LED luminaires.

➢ **HB Pump Shed**

Room Length: 25.20m
Room Width: 12.90m
Room Height: 4m
Target Illuminance > 150 Lux
Target Uniformity > 0.4
Table 9.67 shows the Illumination parameters comparison and Table 9.68 shows the LPD comparison

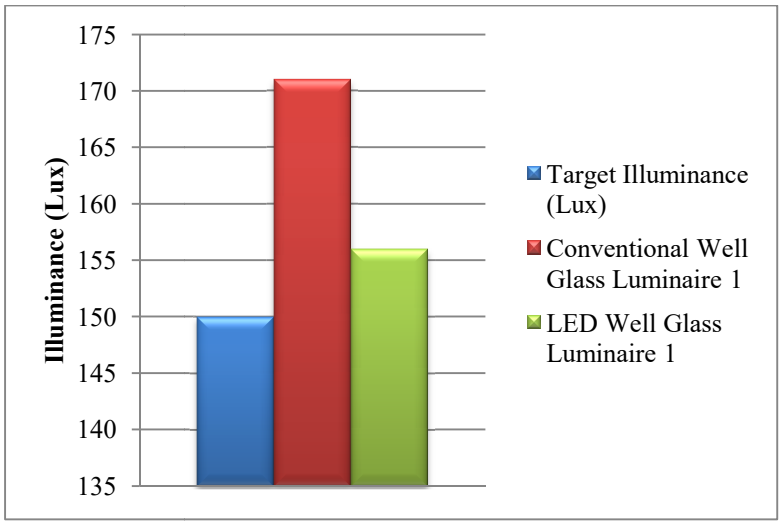


Fig. 9.114: Illuminance comparison of HB Pump Shed

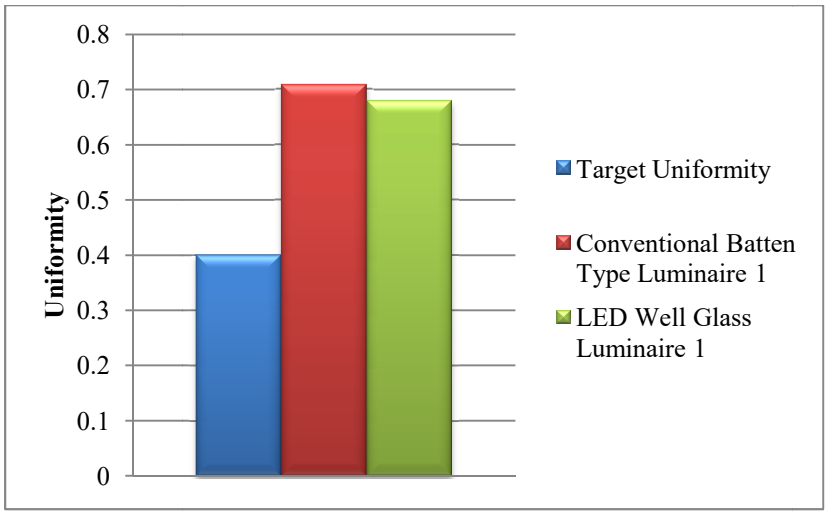


Fig. 9.115: Uniformity comparison of HB Pump Shed

In Fig. 9.114, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.115, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

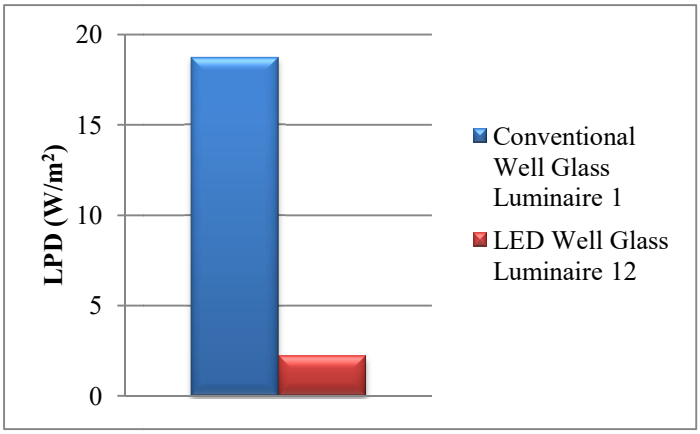


Fig. 9.116: LPD comparison of HB Pump Shed

In Fig. 9.116, LPD comparison is shown where LPD by using conventional luminaires is approx 8.31 times of using LED luminaires.

➢ **Area-wise Power Consumption**

The area-wise power consumption by using Conventional Luminaires and LED Luminaires are shown in Fig. 9.117 and Fig. 9.118 respectively. From both figure, HB Pump Shed has maximum power consumption i.e. 67% by using conventional luminaires and 38% by using LED luminaires.

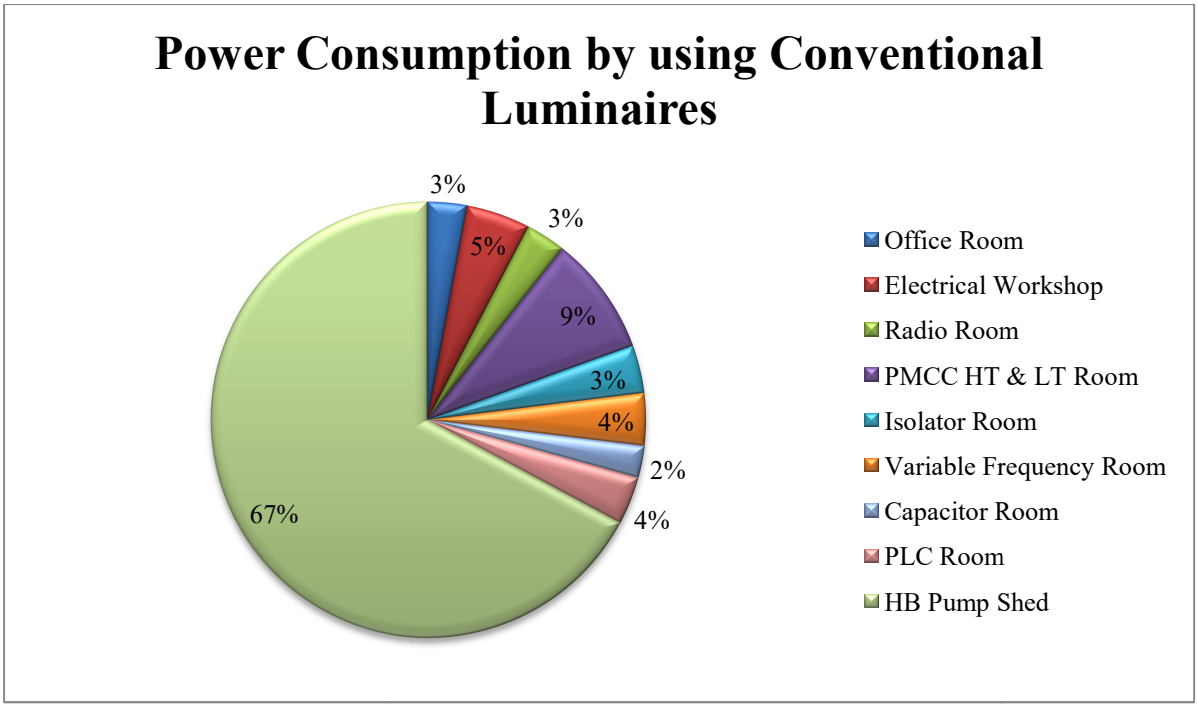


Fig. 9.117: Area-wise power consumption by using Conventional Luminaires

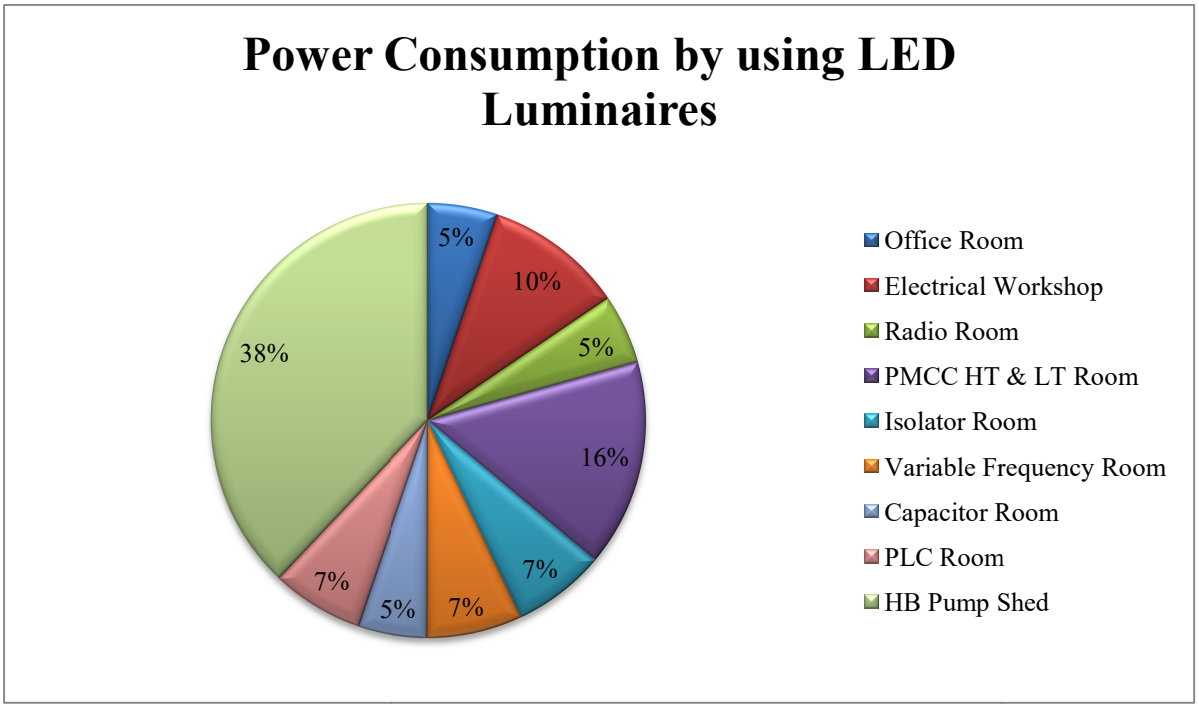


Fig. 9.118: Power Consumption by using LED Lumianire

9.4.2 Economic Comparison between Conventional and LED Solution of Case Study on Oil Refinery

➢ **Cost Details of Conventional Luminaires used in this Project**

Sl. No.	Luminaire	Qty	Price Per Fixture [55]	Total Cost
1	Conventional 2x2 Luminaire 1	6	3000	18000
3	Conventional Well Glass Luminaire 1	35	1405	49175
4	Conventional Batten Type Lumnaire 1	39	527.5	20572.5

Total Cost of Conventional Luminaires: Rs. 87747.50

➢ **Cost Details of LED Luminaires used in this project**

Sl. No.	Luminaire	Qty	Price Per Fixture [56]	Total Cost
1	LED Well Glass Luminaire 1	21	4000	84000
2	LED 2x2 Luminaire 1	3	6000	18000
3	LED 2x2 Luminaire 2	4	3700	14800
4	LED Tube Batten 1	29	1115	32335

Total Cost of LED Luminaires: Rs. 149135

➢ **Total Annual Operating Cost of LED Luminiares**

Sl. No.	Parameter	LED Luminaire			
		LED Well Glass Luminaire 1	LED 2x2 Luminiare 1	LED 2x2 Luminiare 2	LED Tube Batten 1

1	**Power Consumption per Luminaire (Watt)**	34.9	33.4	34.2	33.2
2	**Quantity**	21	3	4	29
3	**Total Power Consumption (Watt)**	732.9	100.2	136.8	962.8
4	**Usage of system per day in hours**	24			
5	**Total Working Days per annum**	365			
6	**Total Energy Consumption per annum (KWh)**	6420.204	877.752	1198.368	8434.128
7	**Electricity Charges (Rs.)**	10			
8	**Operating cost per annum (Rs.)**	64202.04	8777.52	11983.68	84341.28
9	**Total Annual Operating Cost (Rs.)**	169304.52			

- **Total Annual Operating Cost of Conventional Luminiares**

Sl. No.	**Parameter**	**Conventional Luminaires**		
		Conventional 2x2 Luminaire 1	**Conventional Well Glass Luminaire 1**	**Conventional Batten Type Lumnaire 1**
1	**Power Consumption per Luminaire (Watt)**	88	95	53.5
2	**Quantity**	6	35	39
3	**Total Power Consumption (Watt)**	528	3325	2086.5
4	**Usage of system per day in hours**	24		
5	**Total Working Days per annum**	365		
6	**Total Power Consumption per annum (KWh)**	4625.28	29127	18277.74
7	**Electricity Charges (Rs.)**	10		
8	**Operating cost per annum (Rs.)**	46252.80	291270	182777.4
9	**Total Annual Operating Cost (Rs.)**	520300.20		

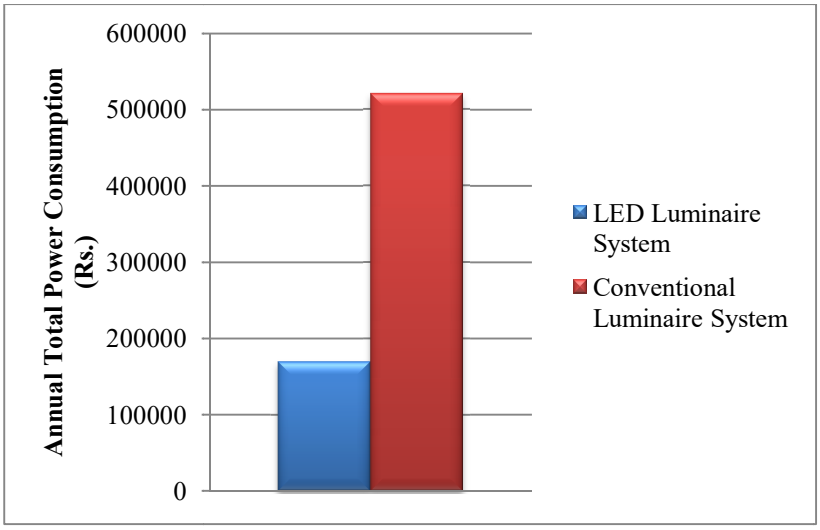


Fig. 9.119: Annual Operating Cost Comparison

Fig. 9.119 shows the annual operating cost comparison where by using conventional lumnaires, annual operating cost is 3.03times of using LED luminaires.

➢ **Lamp Replacement and Annual Maintenance Cost**

Sl. No.		CRCLU240EB/S	IWV1508IHBC	IGP1414HSB
	Lamp Type	**2x 40W CFL**	**80W HPMV**	**36W FTL**
1	**Average Lamp Life**	6000	8000	5000
2	**Number of lamps to be replaced per annum**	18	38	68
3	**Price per Lamp**	240	130	40
4	**Cost of lamp replacement (Rs)**	4320	4940	2720
5	**Average cost of maintenance Rs. 25 per luminaire (conventional) per year**	150	875	975
9	**Total Cost of replacement and maintenance (Rs)**	13980		

➢ **Payback Period Calculation**

Sl. No.	Annual Power & Maintenance Cost (Rs)	LED Luminaire System	Conventional Luminaire System
1	Luminaire Power Consumption Cost	169304.52	520300.2
2	Cost of Lamps Replaced Annualy and Annual Maintenance COst	NA	13980

	Comparison		
1	Present worth	87748	149135
2	Annual Running Cost (	169305	534280
E	**Payback Time**		
0	Total Cost of operation at start	87748	149135
1	Total Cost of operation after 1st year	257052	683415
2	Total Cost of operation after 2nd year	426357	1217695
3	Total Cost of operation after 3rd year	595661	1751976
4	Total Cost of operation after 4th year	764966	2286256

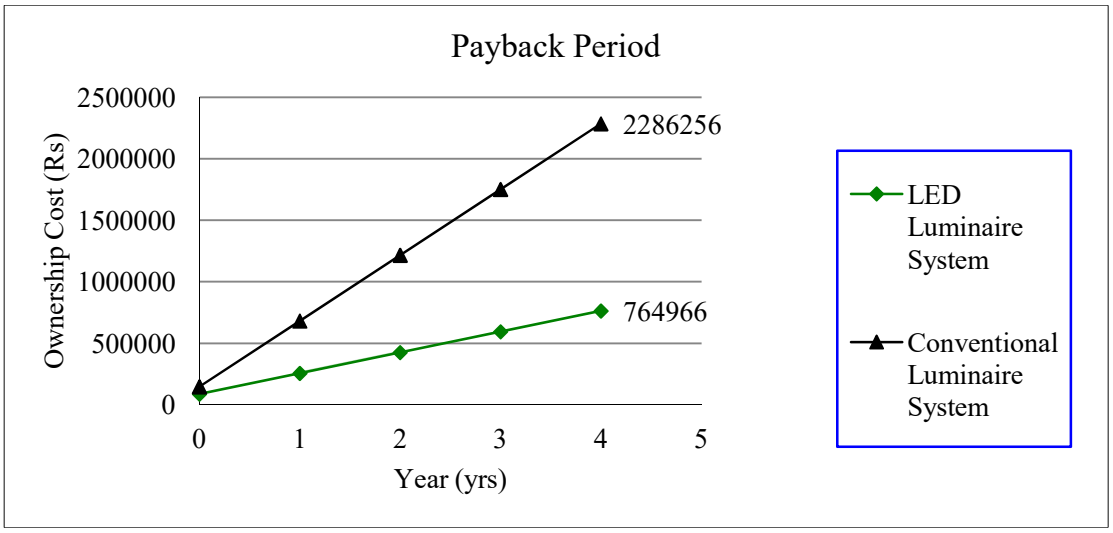


Fig. 9.120: Ownership Cost vs Years

From Fig. 9.120, the intersection of these lines is at approximately 1 month.
So, by Break Even Method, **the Payback Period is approx. 1 month**.

9.5 Result Analysis and Cost Analysis of Case Study on Metro Railway Station

9.5.1 Result Analysis of Metro Railway Station

In this case study, all target illuminances are as per DMRC Standards (Table 7.4)

9.5.1 .1 Platform and Staircase Area

9.5.1.1.1 Platform Area

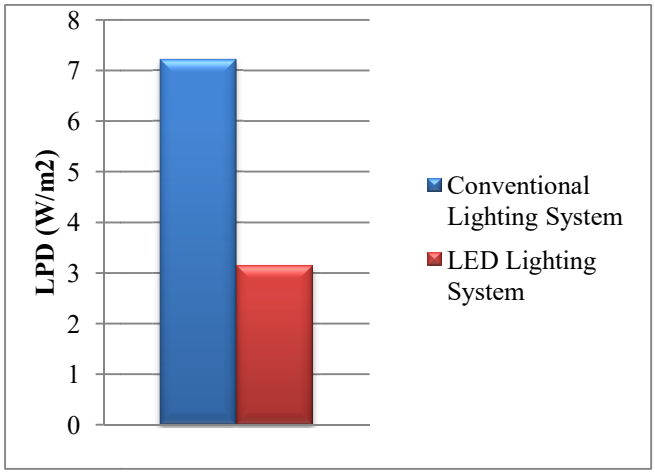


Fig. 9.121: LPD Comparison in Platform Area

In Fig. 9.121, LPD comparison is shown where LPD by using conventional luminaires is 2.29 times of using LED luminaires.

- **Passage Area**

Target Illuminance > 250 Lux

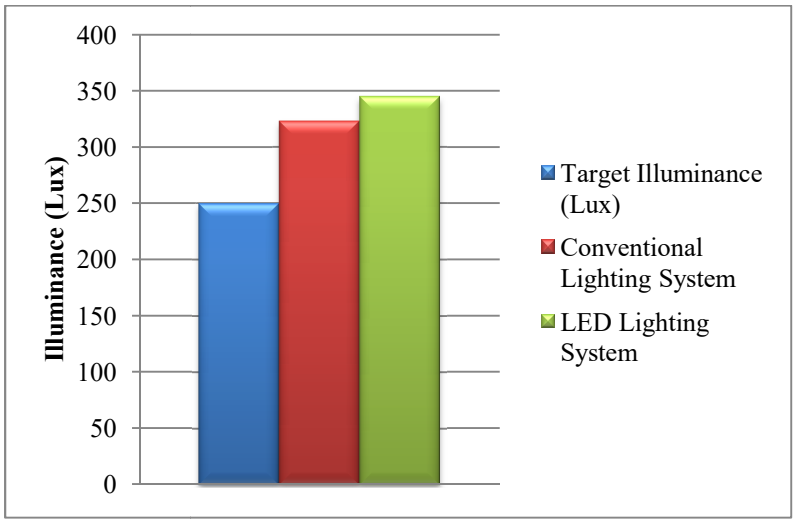


Fig. 9.122: Illuminance comparison of Passage Area

In Fig. 9.122, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

- **Platform 1 Front**

Target Illuminance > 250 Lux

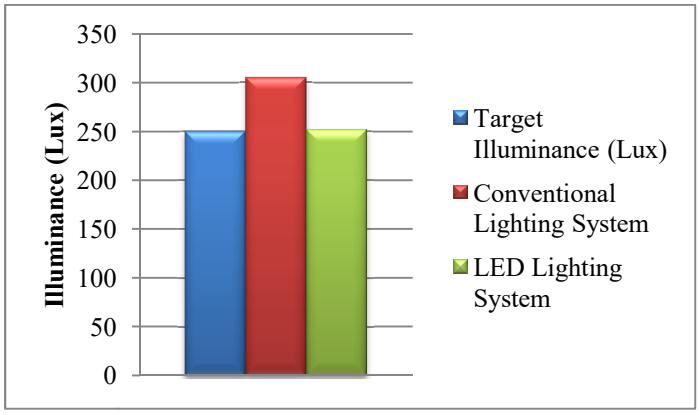


Fig. 9.123: Illuminance comparison of Platform 1 Front

In Fig. 9.123, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

- **Platform 2 Front**

Target Illuminance > 250 Lux

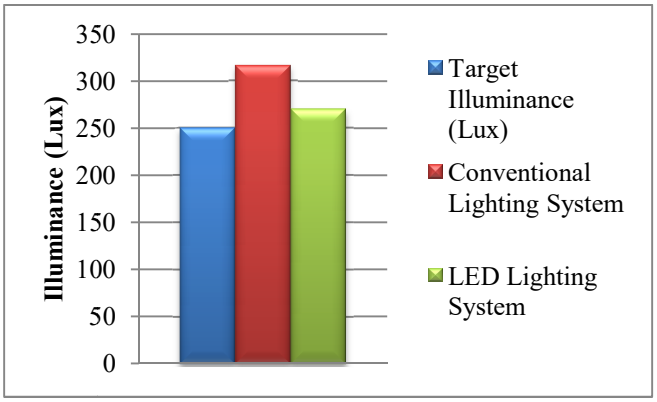


Fig. 9.124: Illuminance comparison of Platform 2 Front

In Fig. 9.124, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

- **Platform 2 Rear**

Target Illuminance > 250 Lux

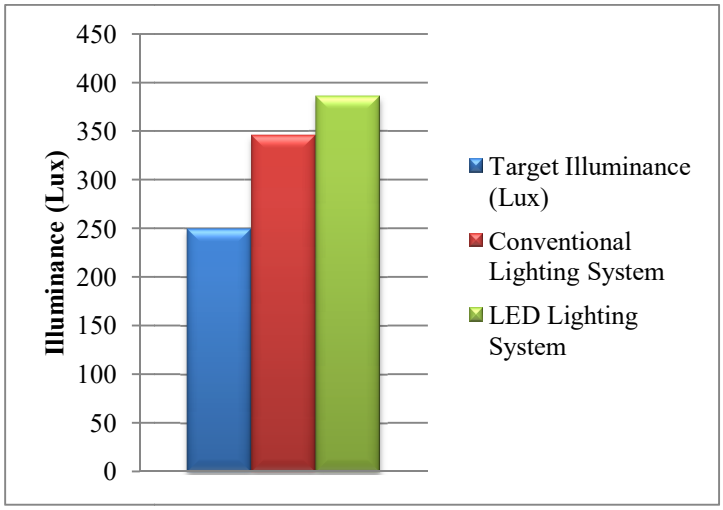


Fig. 9.125: Illuminance comparison of Platform 2 Rear

In Fig. 9.125, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

- **Platform 1 Rear**

Target Illuminance > 250 Lux

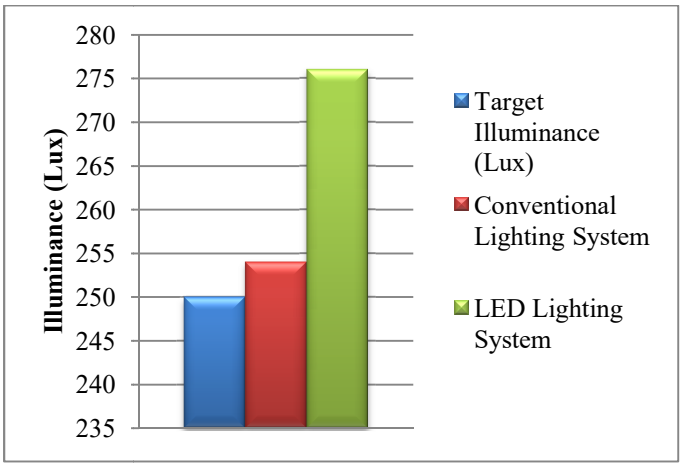


Fig. 9.126: Illuminance comparison of Platform 1 Rear

In Fig. 9.126, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

9.5.1.1.2 Staircase Area

- **Staircase- Platform 1 Left**

The energy comparison is shown in Table 9.75 and in Fig. 9.127, LPD comparison is shown.In Tabl

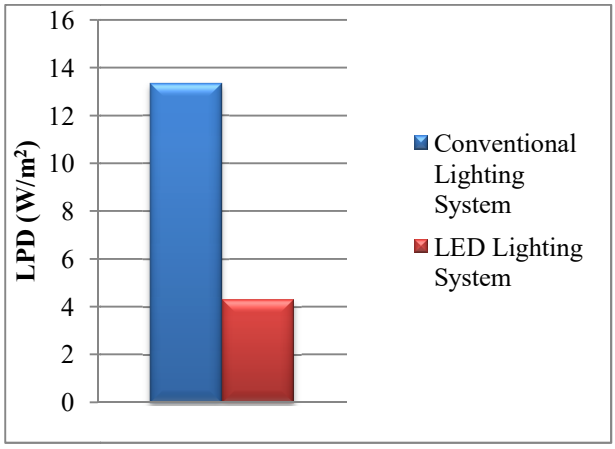


Fig. 9.127: LPD comparison of Staircase- Platform 1 Left

In Fig. 9.127, LPD comparison is shown where LPD by using conventional luminaires is approx 3.09 times of using LED luminaires.

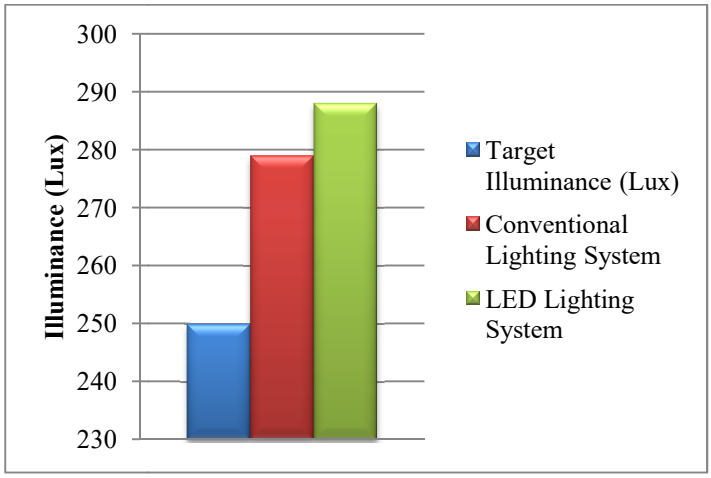


Fig. 9.128: Illuminance Comparison of Staircase (Staircase- Platform 1 Left)

In Fig. 9.128, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

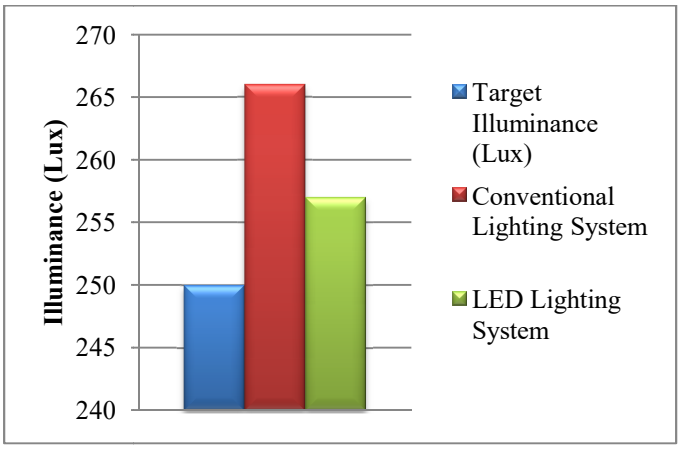


Fig. 9.129: Illuminance Comparison of Escalator (Staircase- Platform 1 Left)

In Fig. 9.129, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

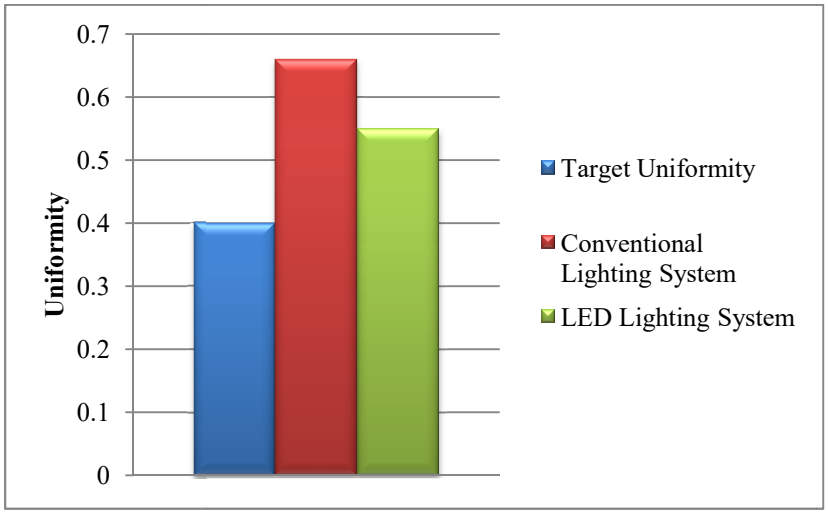


Fig. 9.130: Uniformity Comparison of Staircase (Staircase- Platform 1 Left)

In Fig. 9.130, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

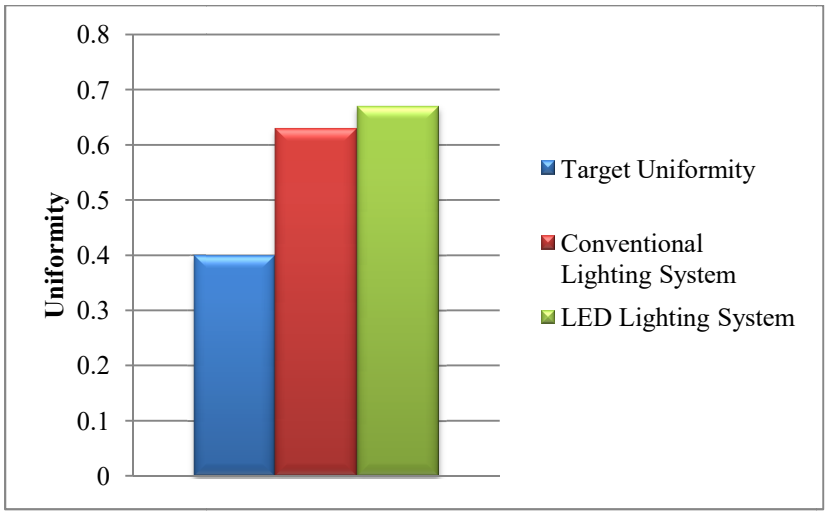


Fig. 9.131: Uniformity Comparison of Escalator (Staircase- Platform 1 Left)

In Fig. 9.131, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

- **Staircase- Platform 1 Right**

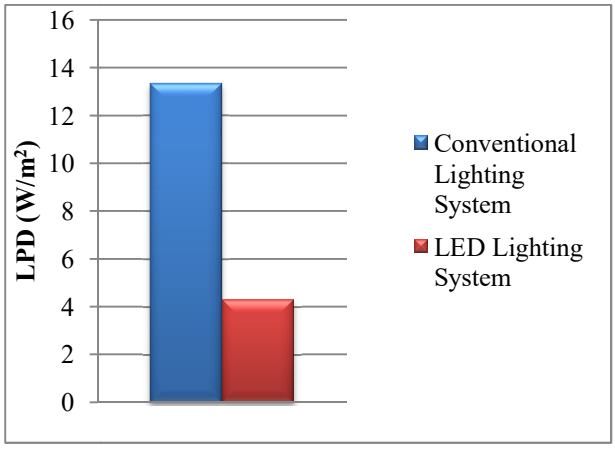


Fig. 9.132: LPD comparison of Staircase- Platform 1 Right

In Fig. 9.132, LPD comparison is shown where LPD by using conventional luminaires is approx 3.09 times of using LED luminaires.

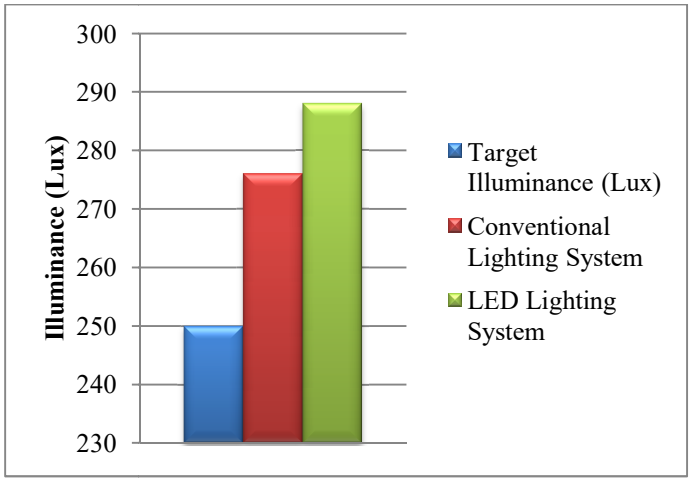


Fig. 9.133: Illuminance Comparison of Staircase (Staircase- Platform 1 Right)

In Fig. 9.133, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

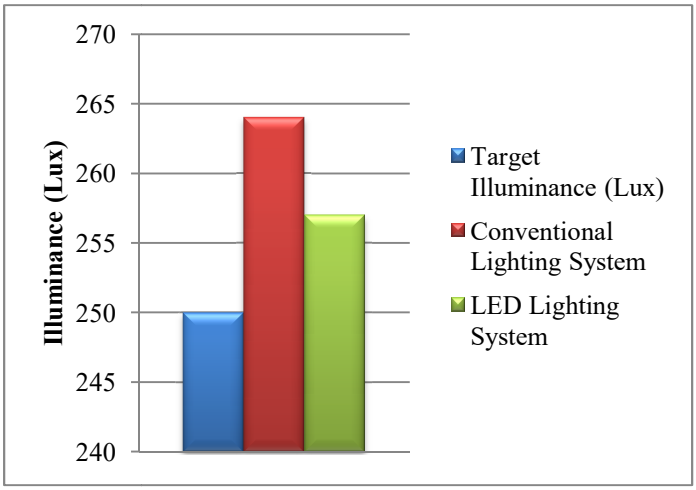


Fig. 9.134: Illuminance Comparison of Escalator (Staircase- Platform 1 Right)

In Fig. 9.134, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

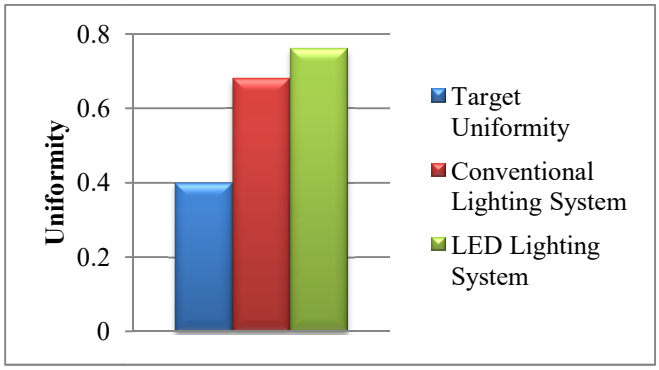


Fig. 9.135: Uniformity Comparison of Staircase (Staircase- Platform 1 Right)

In Fig. 9.135, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

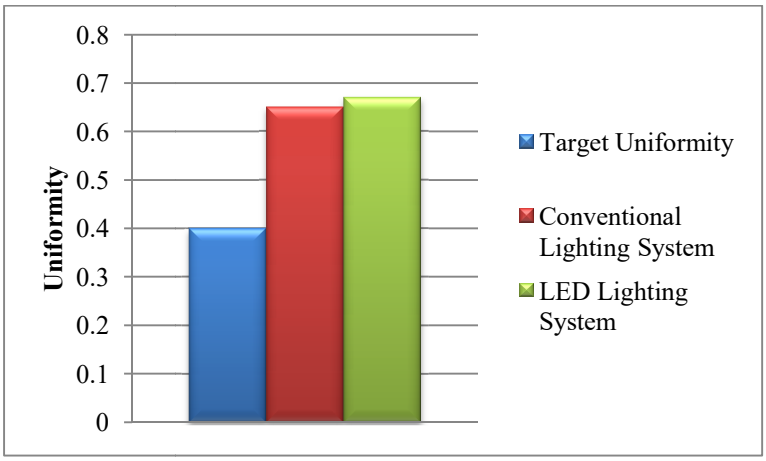


Fig. 9.136: Uniformity Comparison of Escalator (Staircase- Platform 1Right)

In Fig. 9.136, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

- **Staircase- Platform 2 Left**

The energy comparison is shown in Table 9.79 and in Fig. 9.137, LPD comparison is shown.In Table

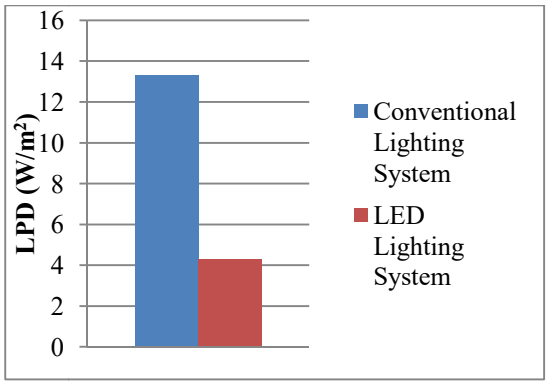


Fig. 9.137: LPD comparison of Staircase- Platform 2 Left

In Fig. 9.137, LPD comparison is shown where LPD by using conventional luminaires is 208.79% higher than using LED luminaires.

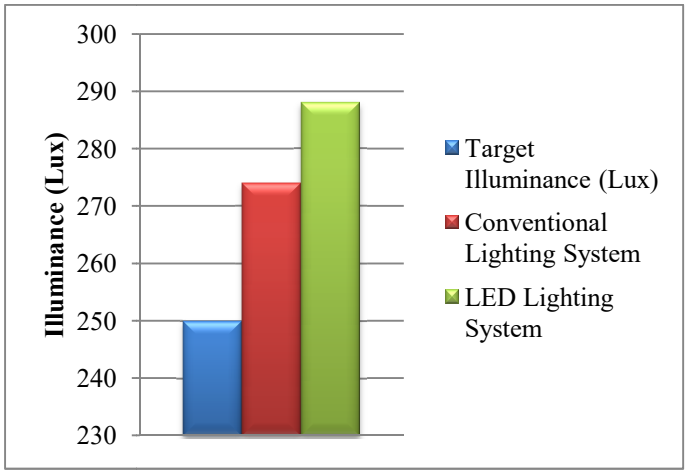


Fig. 9.138: Illuminance Comparison of Staircase (Staircase- Platform 2 Left)

In Fig. 9.138, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

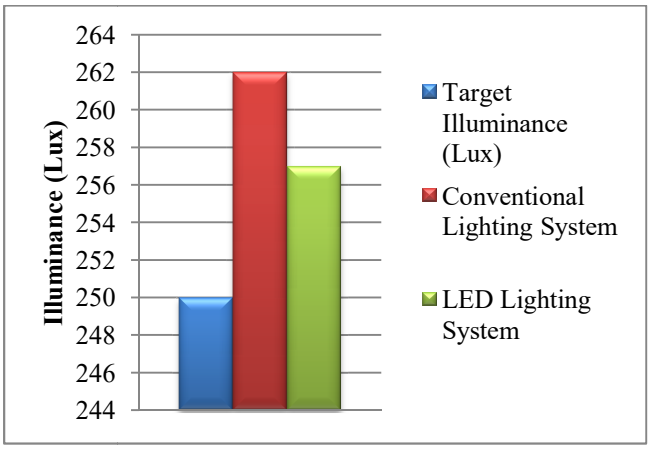


Fig. 9.139: Illuminance Comparison of Escalator (Staircase- Platform 2 Left)

In Fig. 9.139, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

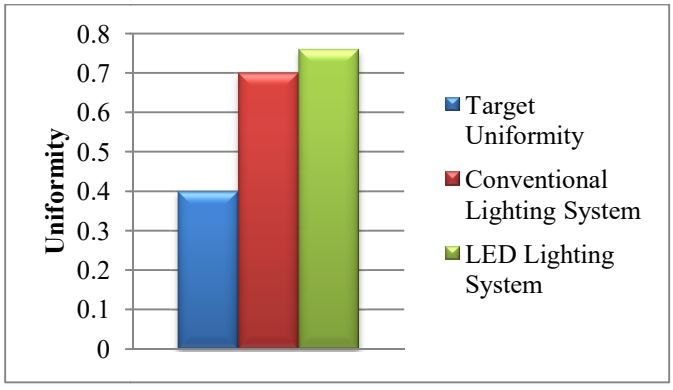


Fig. 9.140: Uniformity Comparison of Staircase (Staircase- Platform 2 Left)

In Fig. 9.140, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

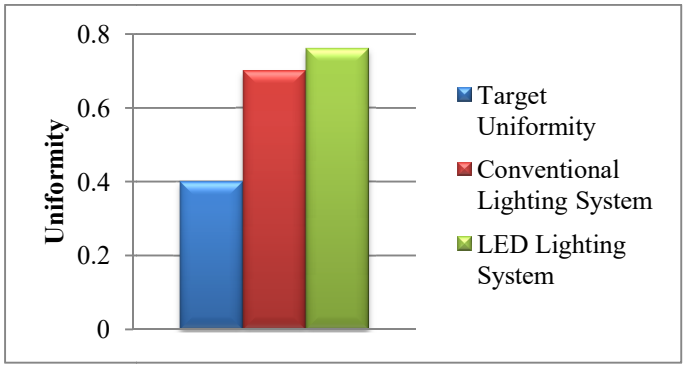


Fig. 9.141: Uniformity Comparison of Escalator (Staircase- Platform 2 Left)

In Fig. 9.141, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

- **Staircase- Platform 2 Right**

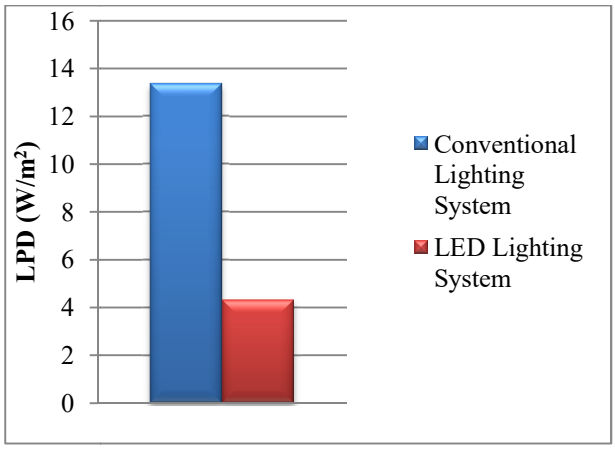


Fig. 9.142: LPD comparison of Staircase- Platform 2 Right

In Fig. 9.142, LPD comparison is shown where LPD by using conventional luminaires is 208.79% higher than using LED luminaires.

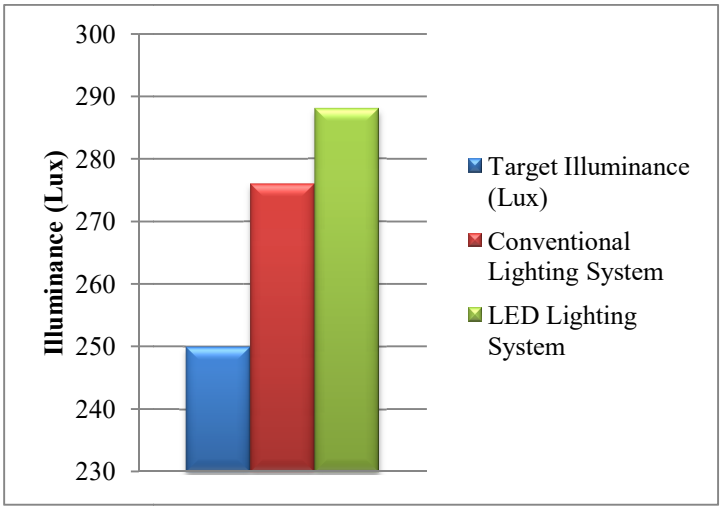


Fig.9.143: Illuminance Comparison of Staircase (Staircase- Platform 2 Right)

In Fig. 9.143, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

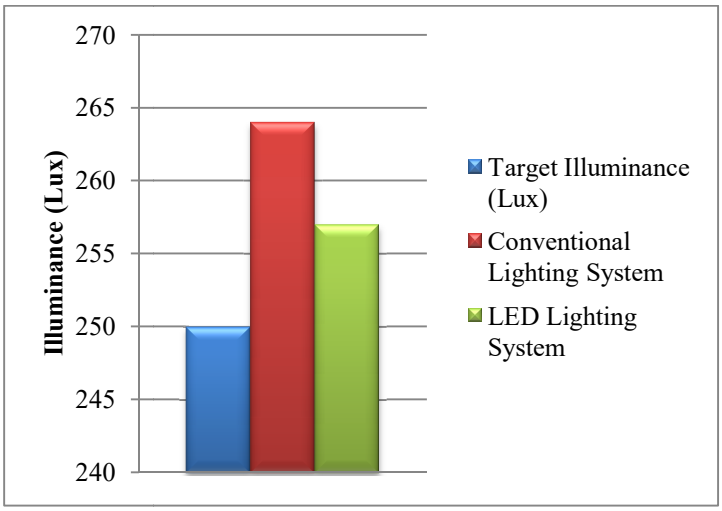


Fig. 9.144: Illuminance Comparison of Escalator (Staircase- Platform 2 Right)

In Fig. 9.144, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

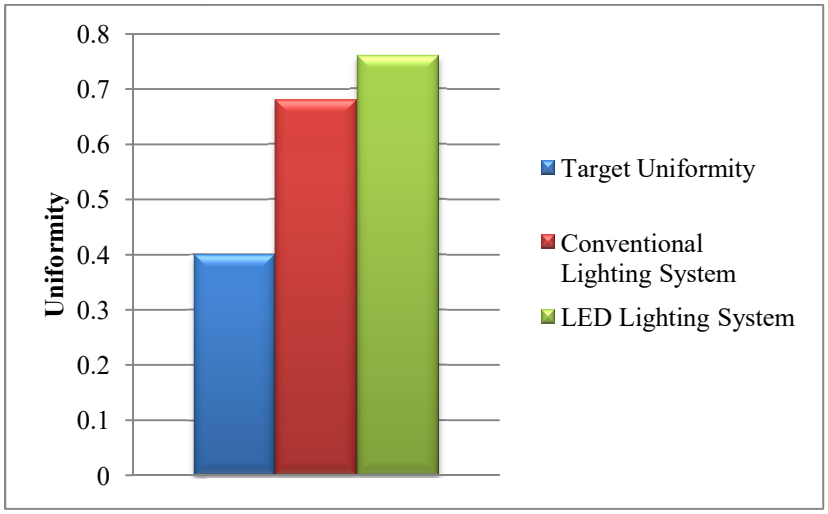


Fig. 9.145: Uniformity Comparison of Staircase (Staircase- Platform 2 Right)

In Fig. 9.145, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

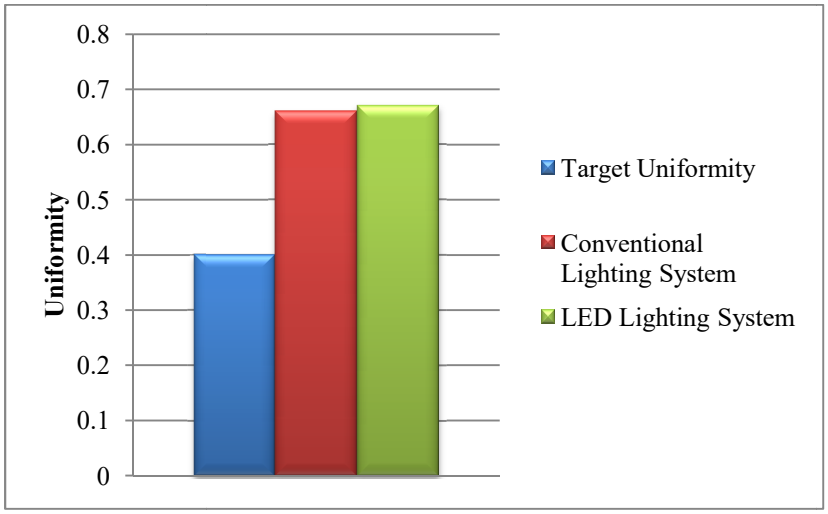


Fig. 9.146: Uniformity Comparison of Escalator (Staircase- Platform 2 Right)

In Fig. 9.146, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

9.5.1.2 Concourse Area

- **Auxiliary Substation**

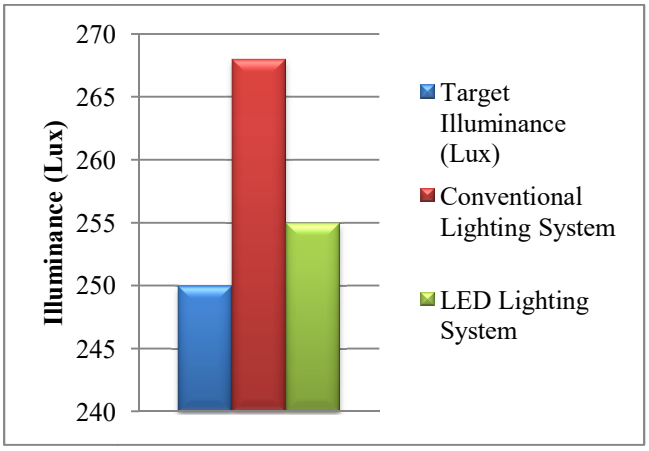


Fig. 9.147: Illuminance Comparison of Auxiliary Substation

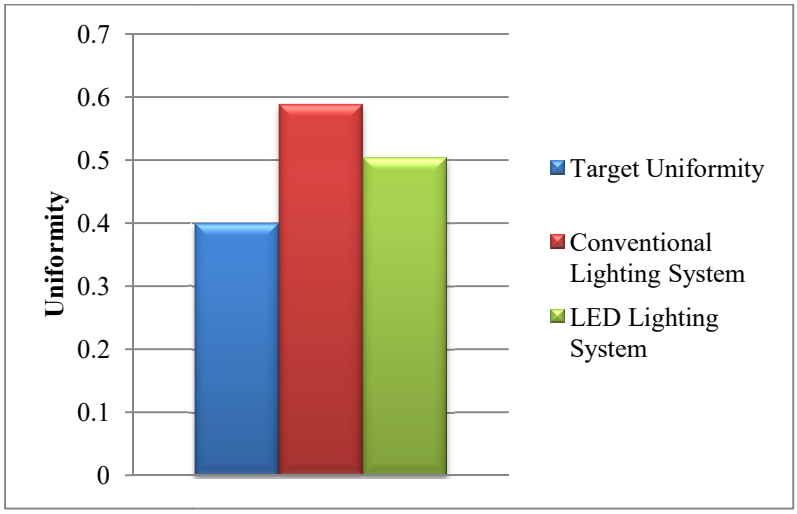


Fig. 9.148: Uniformity Comparison of Auxiliary Substation

In Fig. 9.147, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.148, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

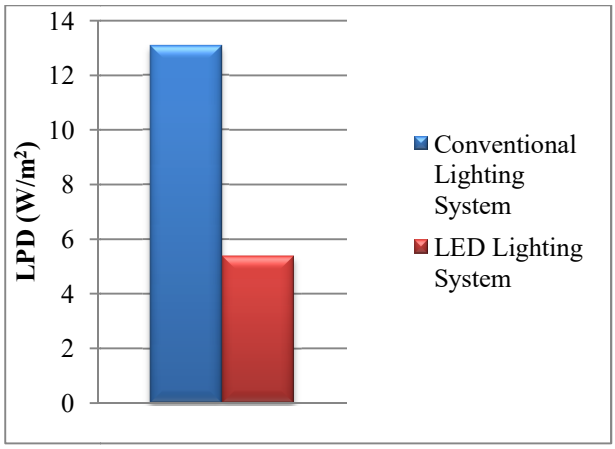


Fig. 9.149: LPD Comparison of Auxiliary Substation

In Fig. 9.149, LPD comparison is shown where LPD by using conventional luminaires is approx 2.43 times of using LED luminaires.

- **Lobby Area**

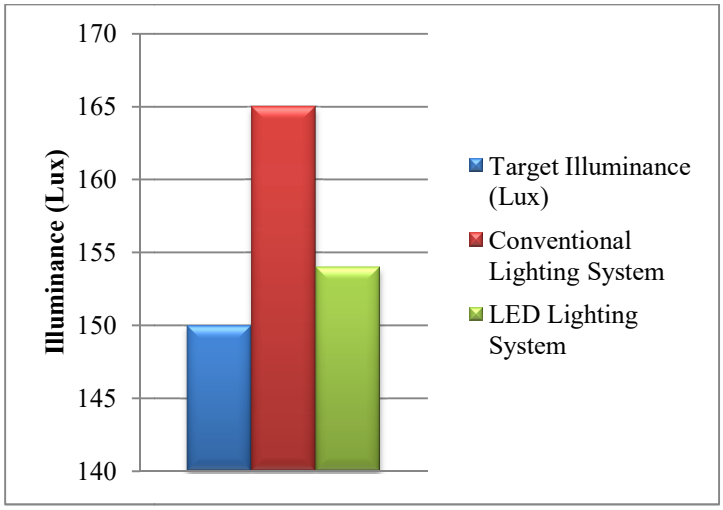


Fig. 9.150: Illuminance Comparison of Lobby Area

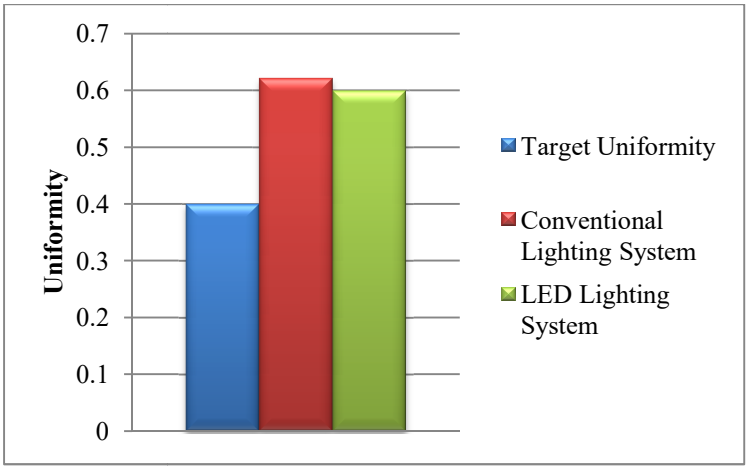


Fig. 9.151: Uniformity Comparison of Lobby Area

In Fig. 9.150, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.151, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

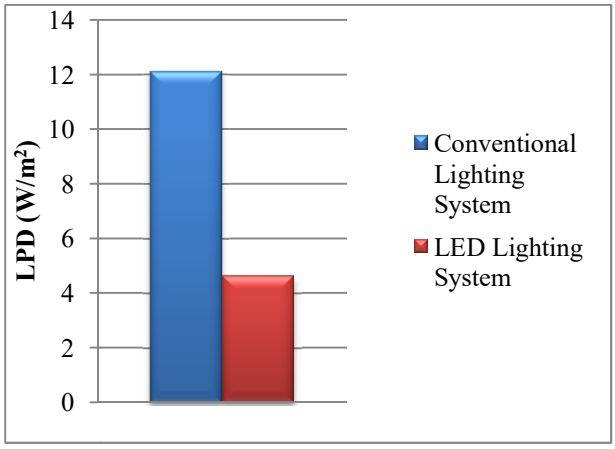


Fig. 9.152: LPD Comparison of Lobby Area

In Fig. 9.152, LPD comparison is shown where LPD by using conventional luminaires is approx 2.6 times of using LED luminaires.

- **Unpaid Area 1**

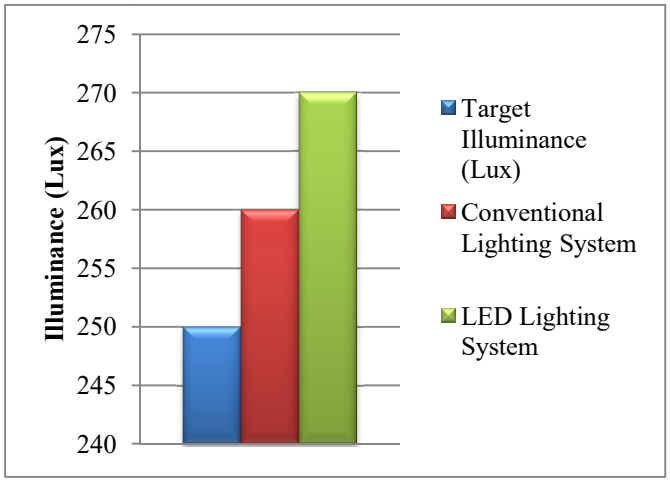


Fig. 9.153: Illuminance Comparison of Unpaid Area 1

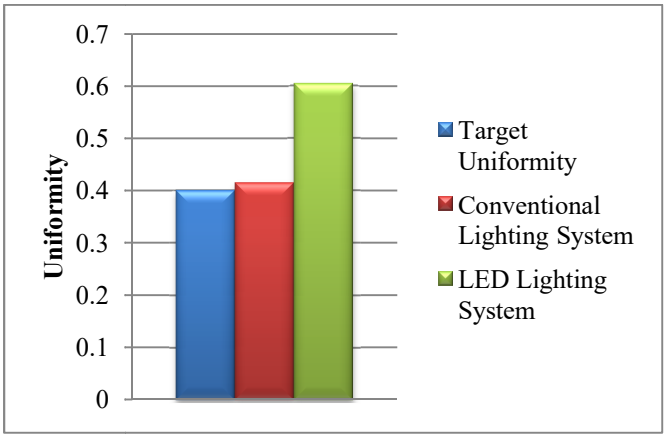


Fig. 9.154: Uniformity Comparison of Unpaid Area 1

In Fig. 9.153, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.154, the uniformity comparison is shown where uniformity achieved by using

LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

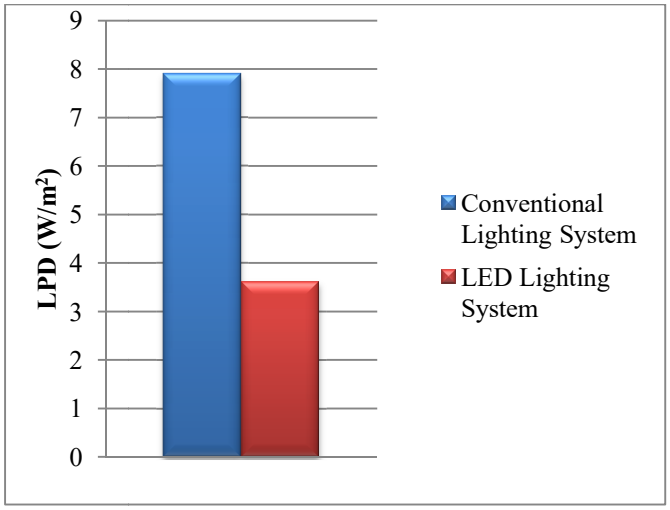


Fig. 9.155: LPD Comparison of Unpaid Area 1

In Fig. 9.155, LPD comparison is shown where LPD by using conventional luminaires is approx 2.18 times of using LED luminaires.

- **Unpaid Area 2**

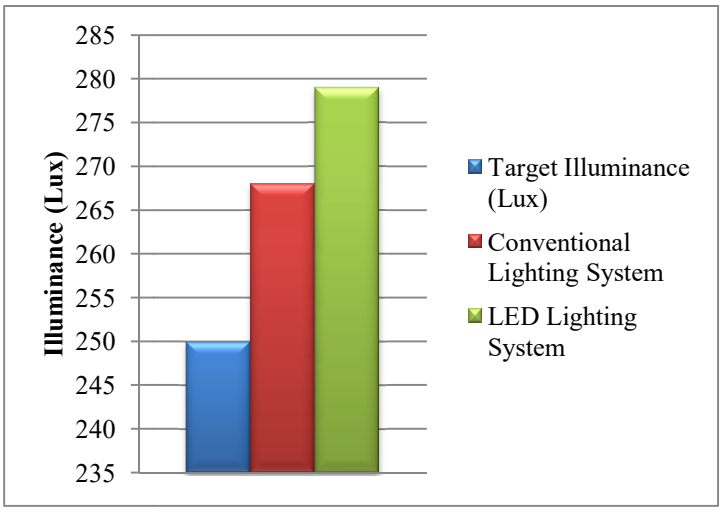


Fig. 9.156: Illuminance Comparison of Unpaid Area 2

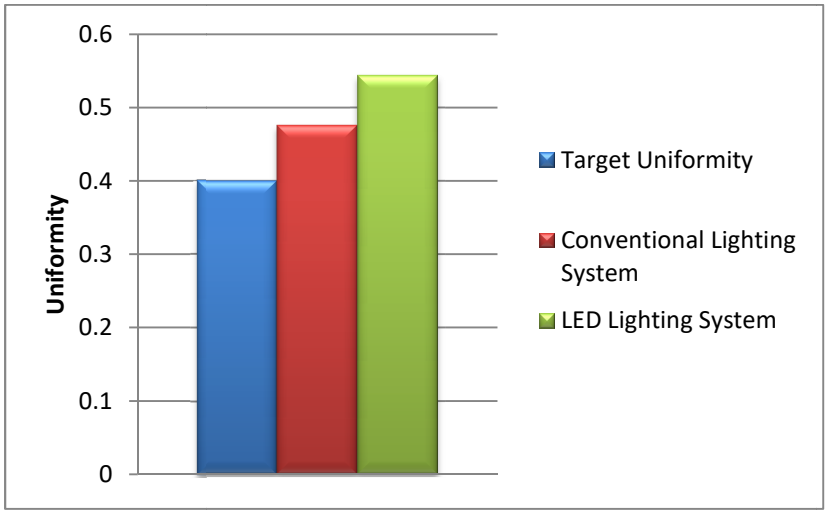


Fig. 9.157: Uniformity Comparison of Unpaid Area 2

In Fig. 9.156, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.157, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

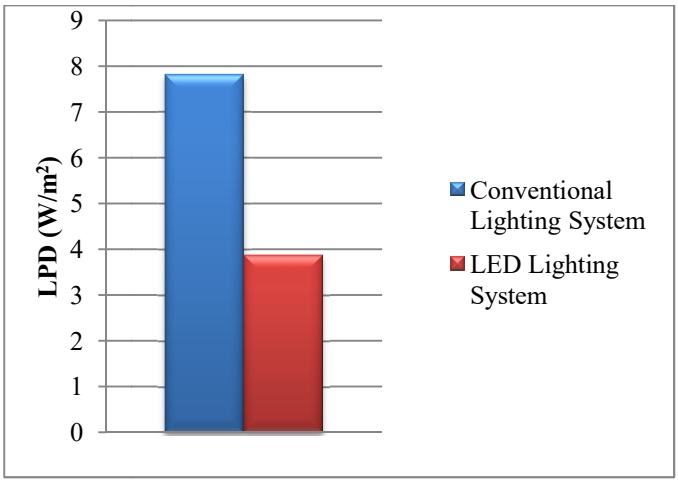


Fig. 9.158: LPD Comparison of Unpaid Area 2

In Fig. 9.158, LPD comparison is shown where LPD by using conventional luminaires is approx 2.02 times of using LED luminaires.

- **Concourse Paid Area (3m Height)**

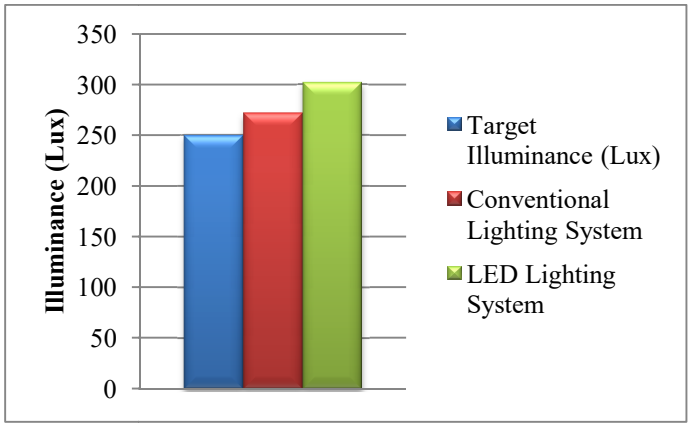


Fig. 9.159: Illuminance Comparison of Concourse Paid Area (3m Height)

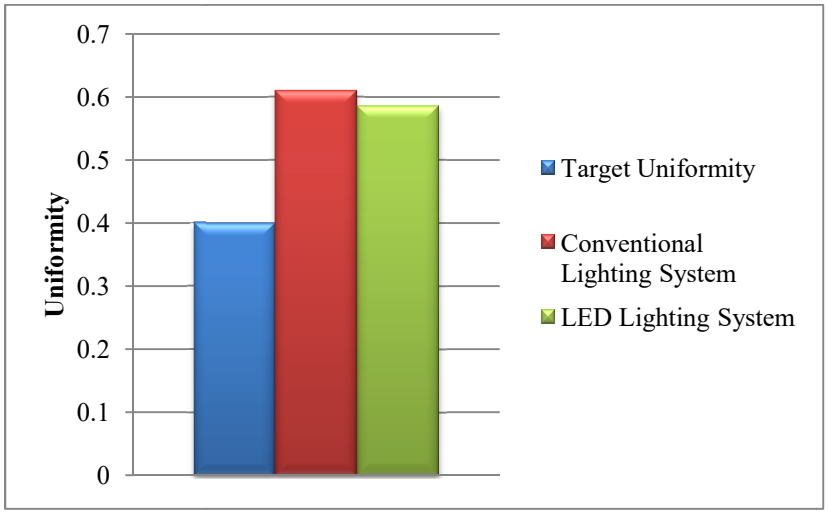


Fig. 9.160: Uniformity Comparison of Concourse Paid Area (3m Height)

In Fig. 9.159, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.160, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

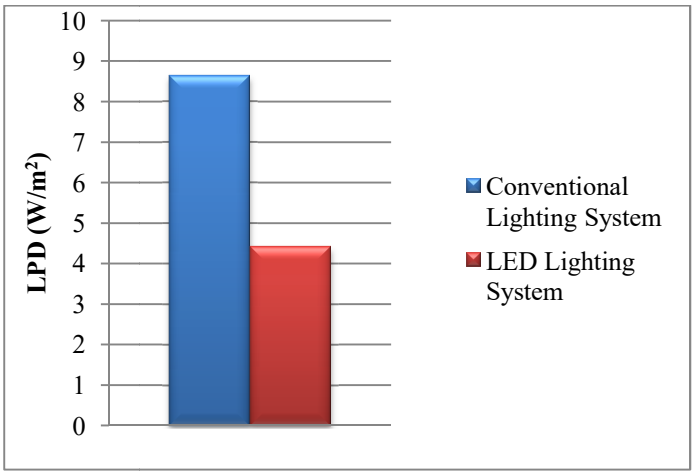


Fig. 9.161: LPD Comparison of Concourse Paid Area (3m Height)

In Fig. 9.161, LPD comparison is shown where LPD by using conventional luminaires is approx 1.95 times of using LED luminaires.

- **Concourse Paid Area (4.3m Height)**

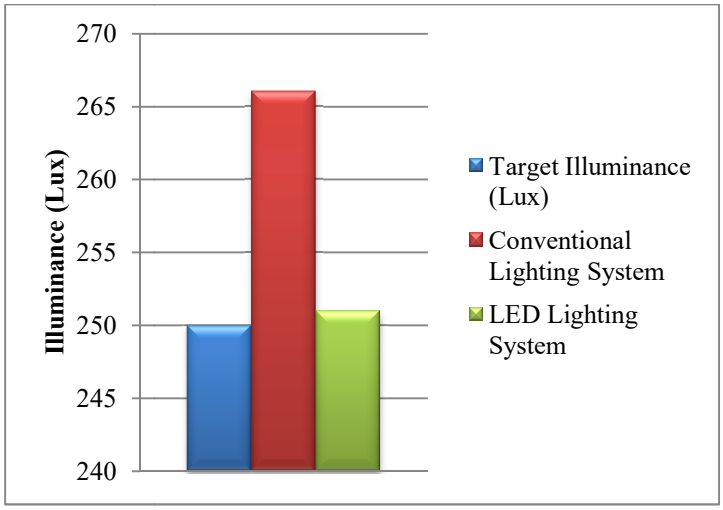


Fig. 9.162: Illuminance Comparison of Concourse Paid Area (4.3m Height)

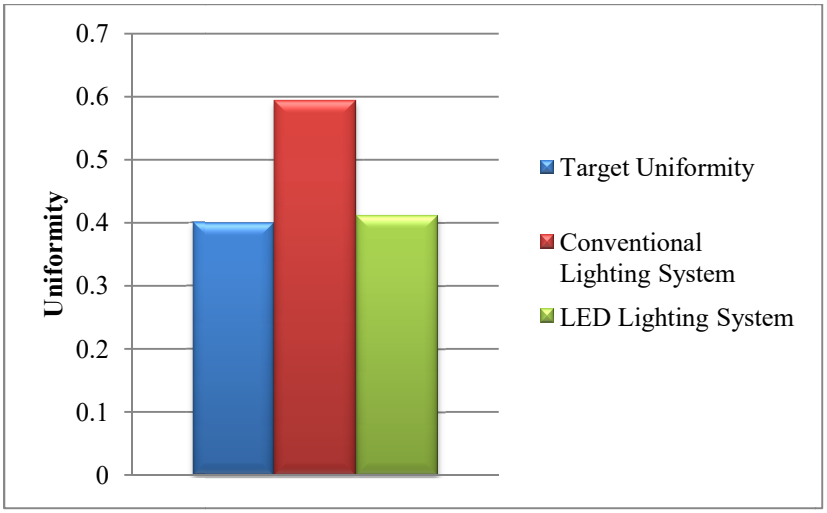


Fig. 9.163: Uniformity Comparison of Concourse Paid Area (4.3m Height)

In Fig. 9.162, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.163, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

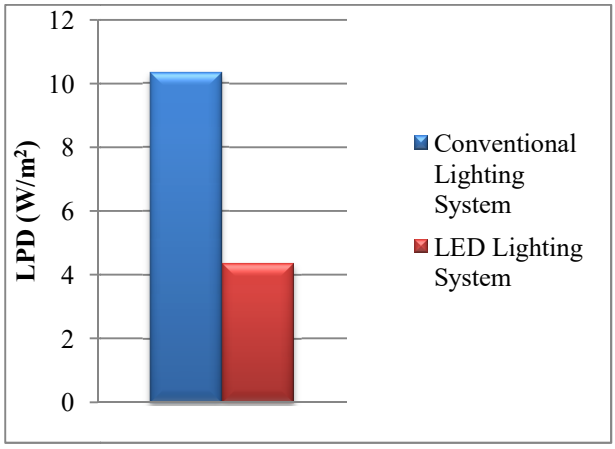


Fig. 9.164: LPD Comparison of Concourse Paid Area (4.3m Height)

In Fig. 9.164, LPD comparison is shown where LPD by using conventional luminaires is approx 2.37 times of using LED luminaires.

- **Concourse Paid Area (4.3m Height)**

The Illuminance parameter comparison is shown in Table 9.95 and Power Consumption comparison is

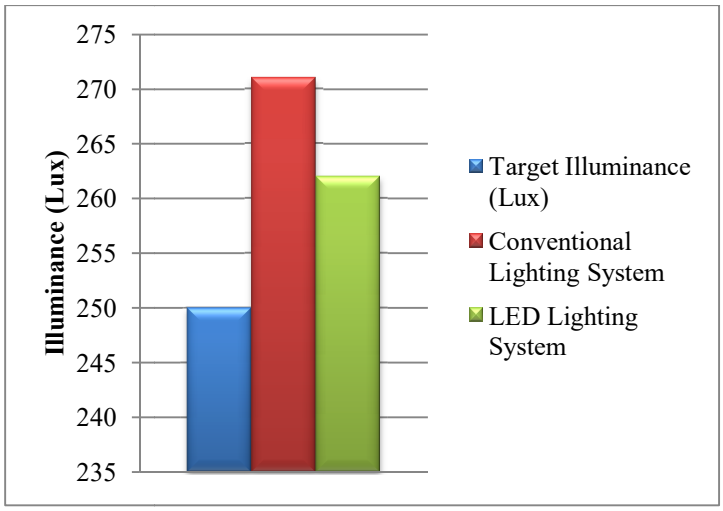


Fig. 9.165: Illuminance Comparison of Concourse Paid Area (4.3m Height)

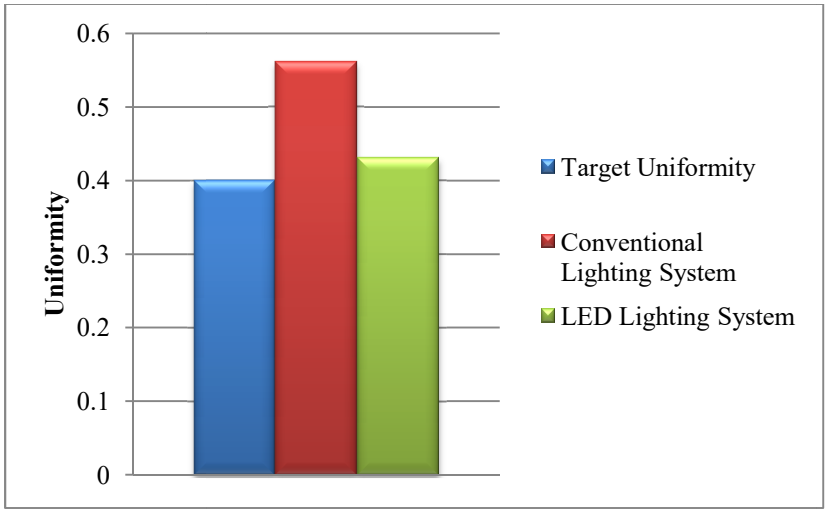


Fig. 9.166: Uniformity Comparison of Concourse Paid Area (4.3m Height)

In Fig. 9.165, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.166, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

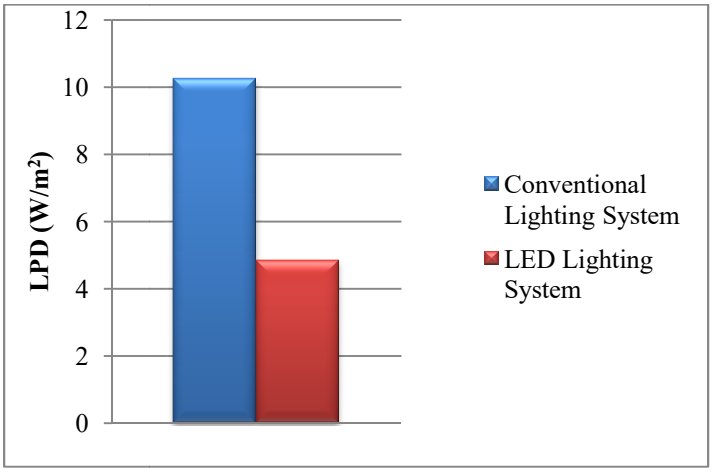


Fig. 9.167: LPD Comparison of Concourse Paid Area (4.3m Height)

In Fig. 9.167, LPD comparison is shown where LPD by using conventional luminaires is approx 2.12 times of using LED luminaires.

- **Station Entrances 1**

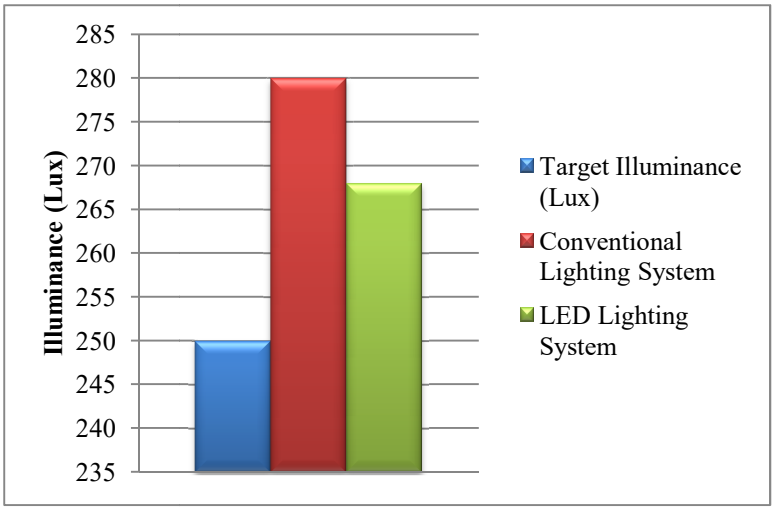


Fig. 9.168: Illuminance Comparison of Station Entrances 1

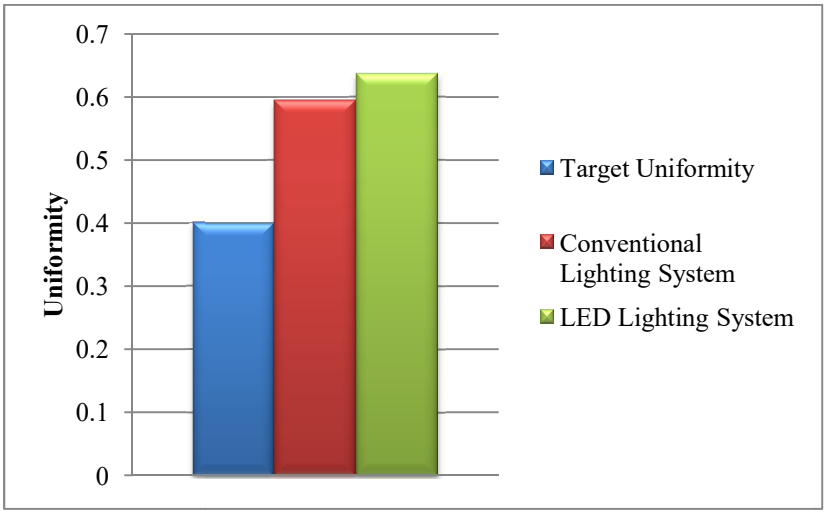


Fig. 9.169: Uniformity Comparison of Station Entrances 1

In Fig. 9.168, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.169, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

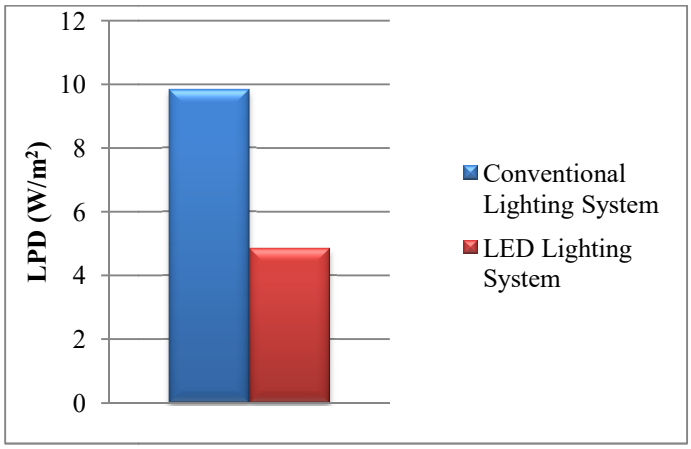


Fig. 9.170: LPD Comparison of Station Entrances 1

In Fig. 9.170 LPD comparison is shown where LPD by using conventional luminaires is approx 2.26 times of using LED luminaires.

- **Electrical UPS**

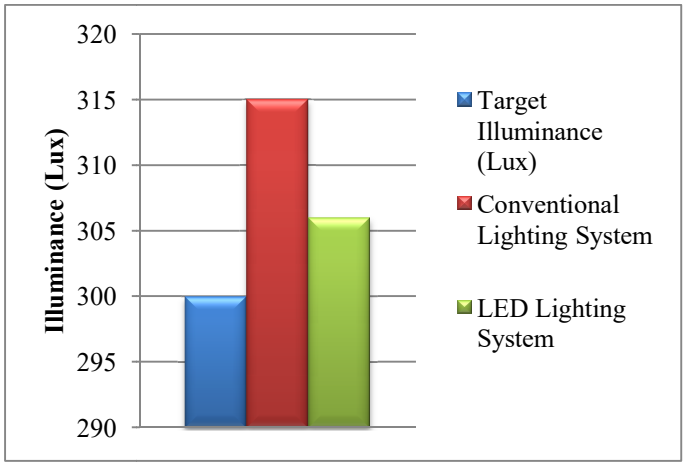


Fig. 9.171: Illuminance Comparison of Electrical UPS

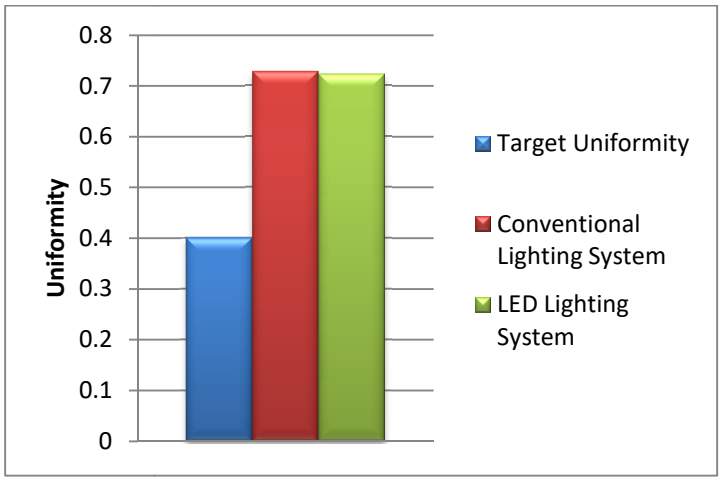


Fig. 9.172: Uniformity Comparison of Electrical UPS

In Fig. 9.171, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.172, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

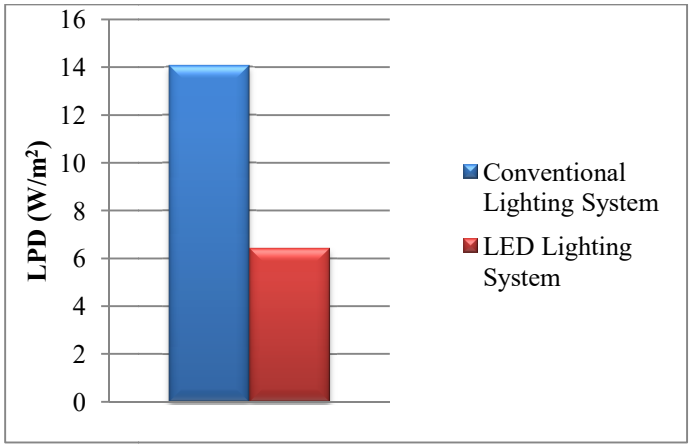


Fig. 9.173: LPD Comparison of Electrical UPS

In Fig. 9.173, LPD comparison is shown where LPD by using conventional luminaires is approx 2.18 times of using LED luminaires.

➢ **TER**

The Illuminance parameter comparison is shown in Table 9.101 and Power Consumption comparison

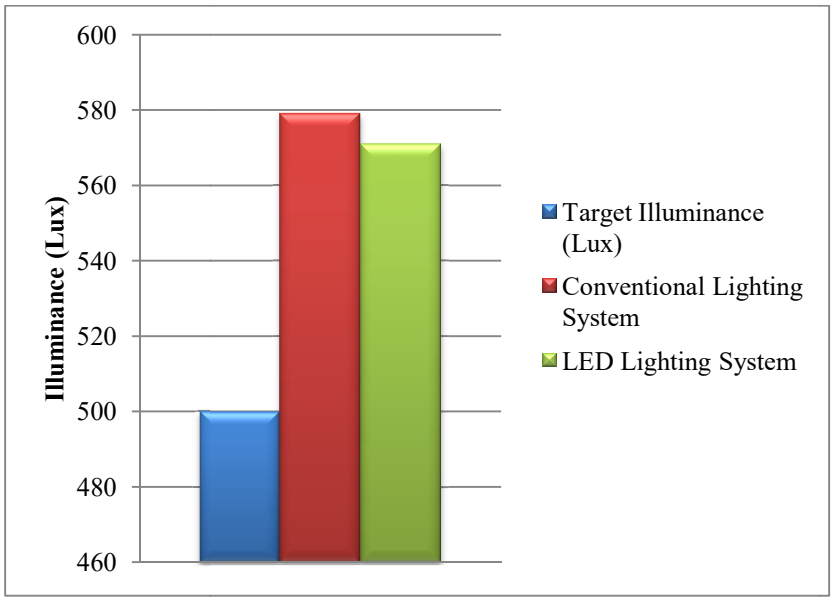


Fig. 9.174: Illuminance Comparison of TER

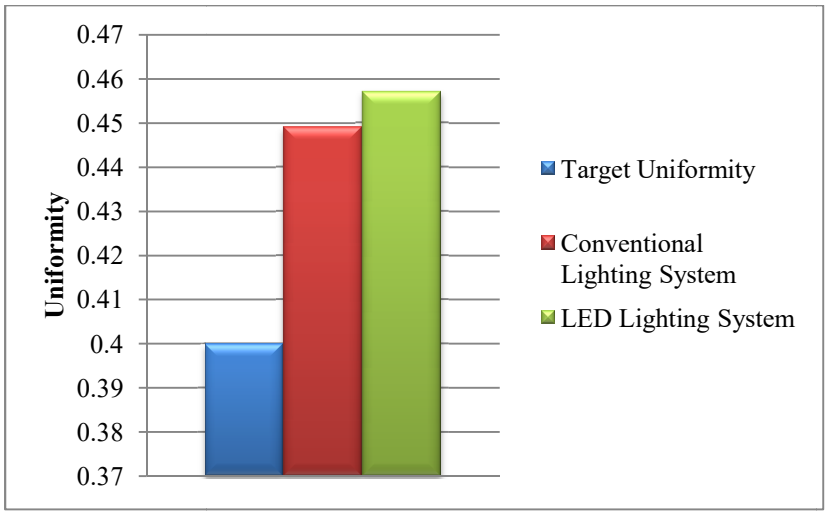


Fig. 9.175: Uniformity Comparison of TER

In Fig. 9.174, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.175, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

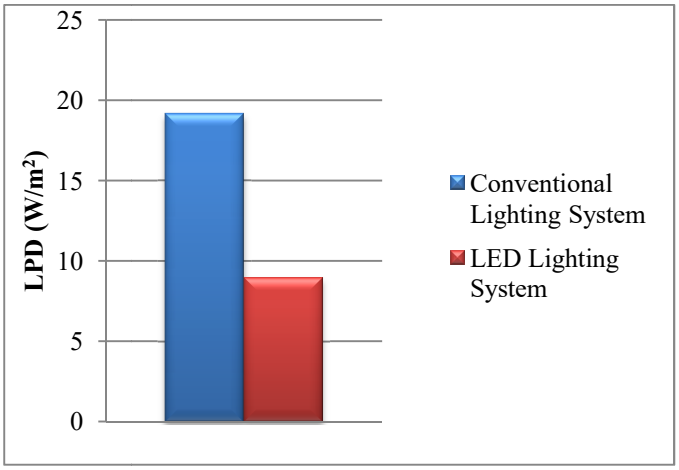


Fig. 9.176: LPD Comparison of TER

In Fig. 9.176, LPD comparison is shown where LPD by using conventional luminaires is approx 2.13 times of using LED luminaires.

- **UPS**

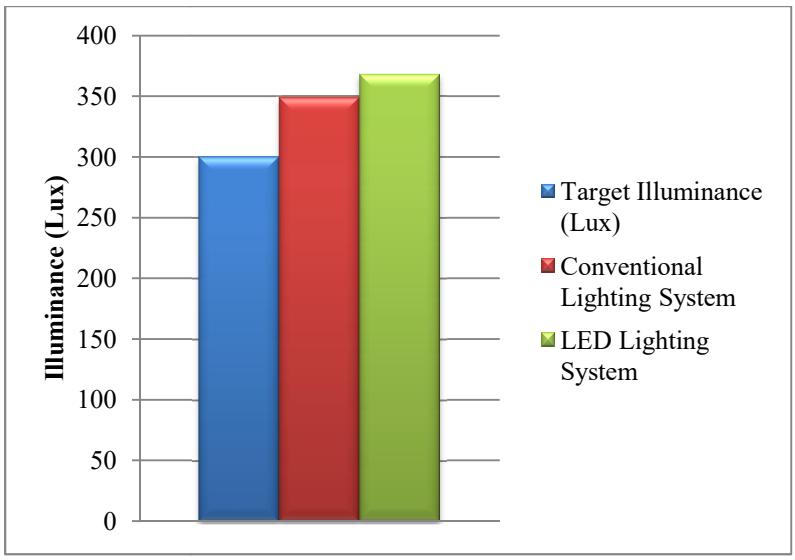


Fig. 9.177: Illuminance Comparison of UPS

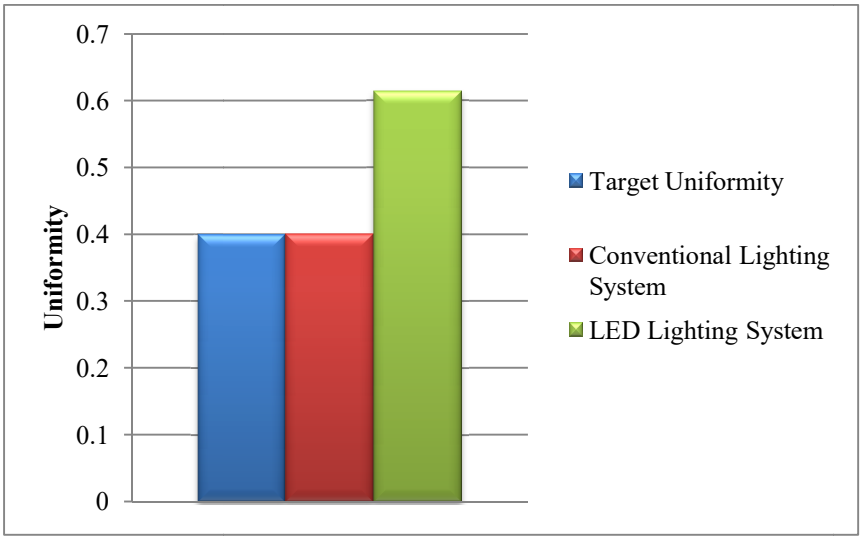


Fig. 9.178: Uniformity Comparison of UPS

In Fig. 9.177, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.178, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

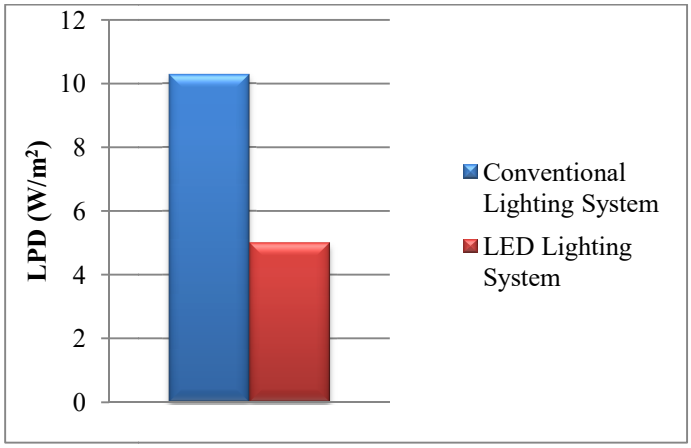


Fig. 9.179: LPD Comparison of UPS

In Fig. 9.179, LPD comparison is shown where LPD by using conventional luminaires is approx 2.06 times of using LED luminaires.

- **SER SIGNAL RELAY**

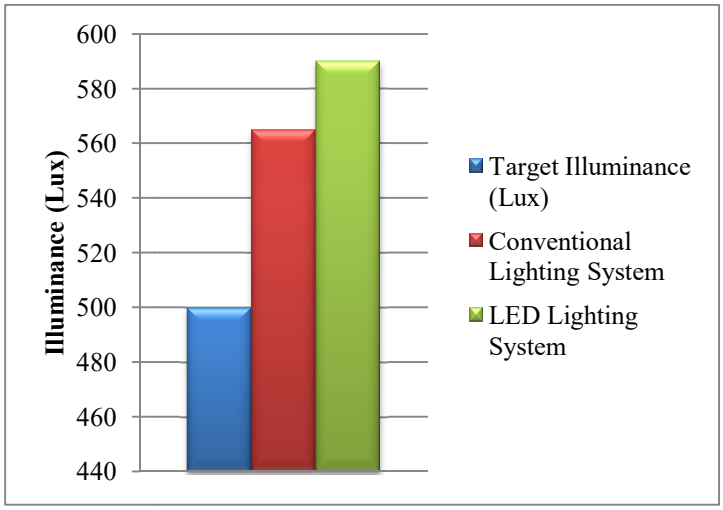


Fig. 9.180: Illuminance Comparison of SER SIGNAL RELAY

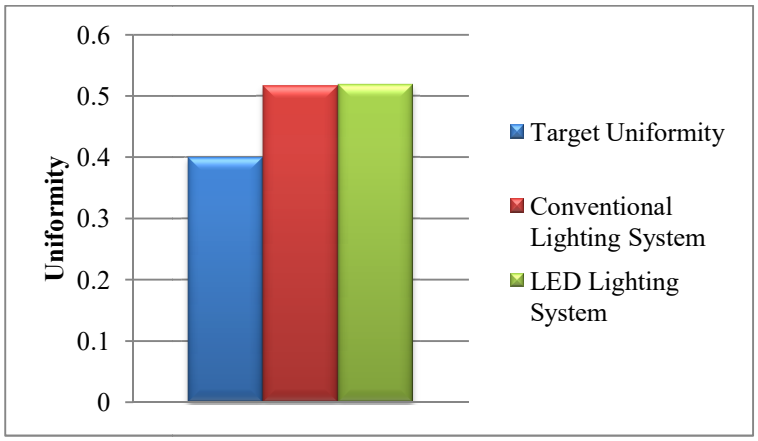


Fig. 9.181: Uniformity Comparison of SER SIGNAL RELAY

In Fig. 9.180, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.181, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

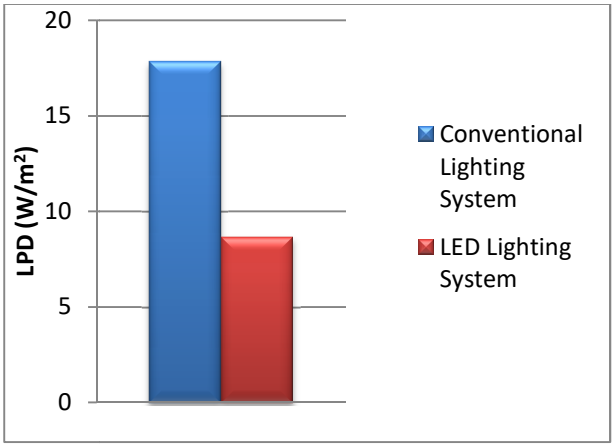


Fig. 9.182: LPD Comparison of SER SIGNAL RELAY

In Fig. 9.182, LPD comparison is shown where LPD by using conventional luminaires is approx 2.08 times of using LED luminaires.

➢ **TICKET OFFICE MACHINE 1**

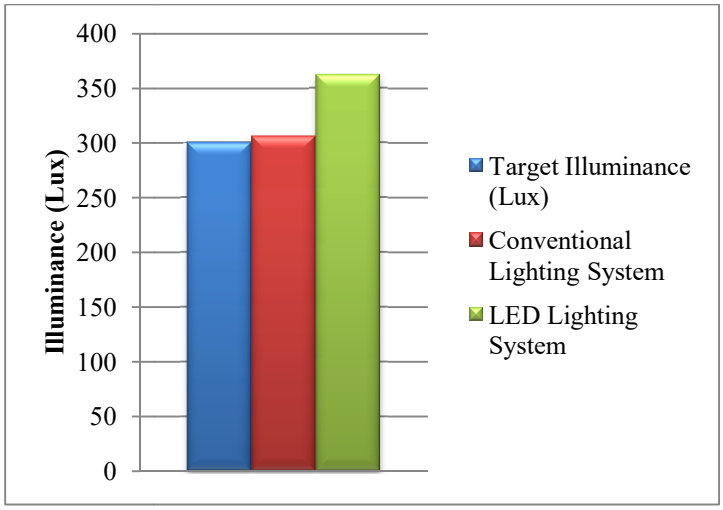


Fig. 9.183: Illuminance Comparison of TICKET OFFICE MACHINE 1

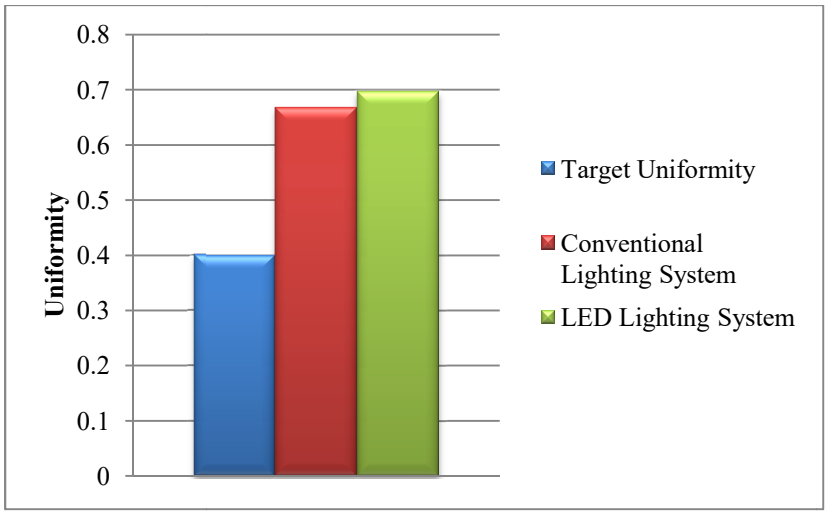


Fig. 9.184: Uniformity Comparison of TICKET OFFICE MACHINE 1

In Fig. 9.183, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.184, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

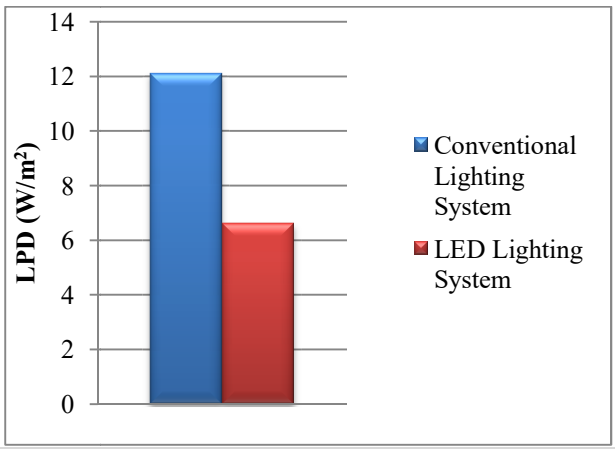


Fig. 9.185: LPD Comparison of TICKET OFFICE MACHINE 1

In Fig. 9.185, LPD comparison is shown where LPD by using conventional luminaires is approx 1.83 times of using LED luminaires.

- **TICKET OFFICE MACHINE 2**

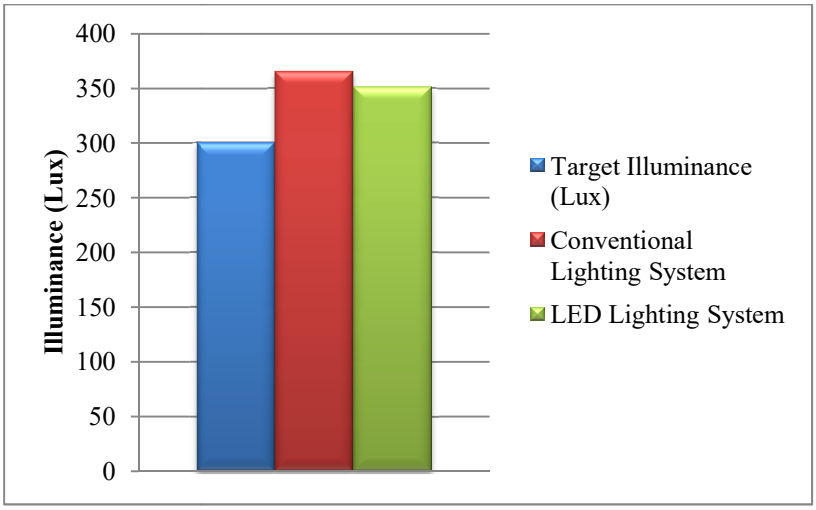


Fig. 9.186: Illuminance Comparison of TICKET OFFICE MACHINE 2

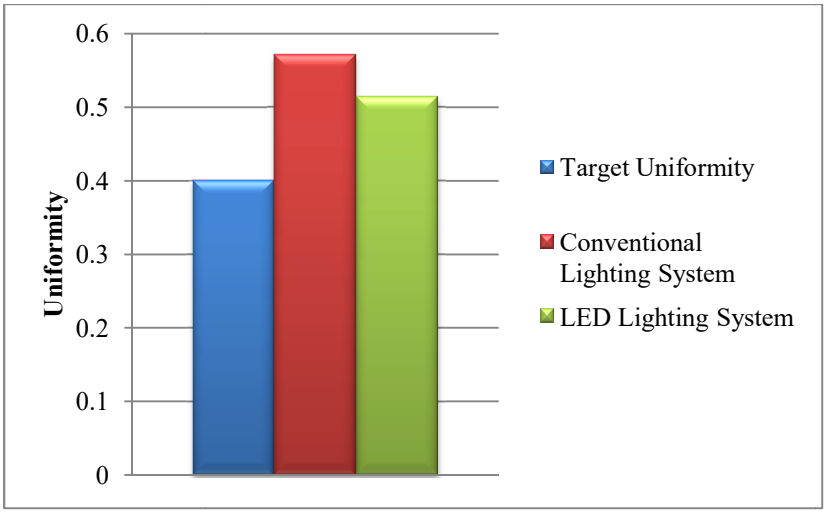


Fig. 9.187: Uniformity Comparison of TICKET OFFICE MACHINE 2

In Fig. 9.186, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.187, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

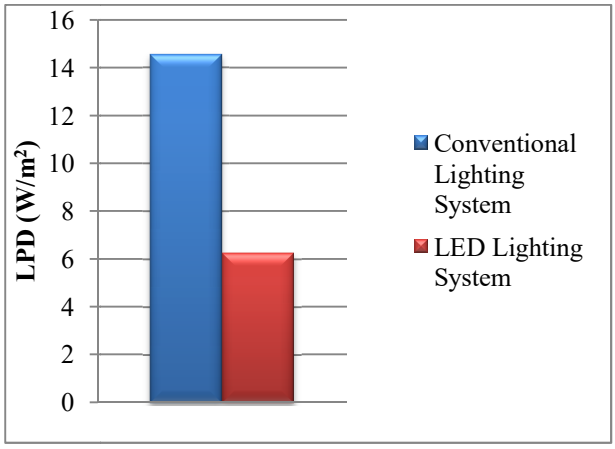


Fig. 9.188: LPD Comparison of TICKET OFFICE MACHINE 2

In Fig. 9.188, LPD comparison is shown where LPD by using conventional luminaires is approx 2.32 times of using LED luminaires.

- **AUDIT AND CASH**

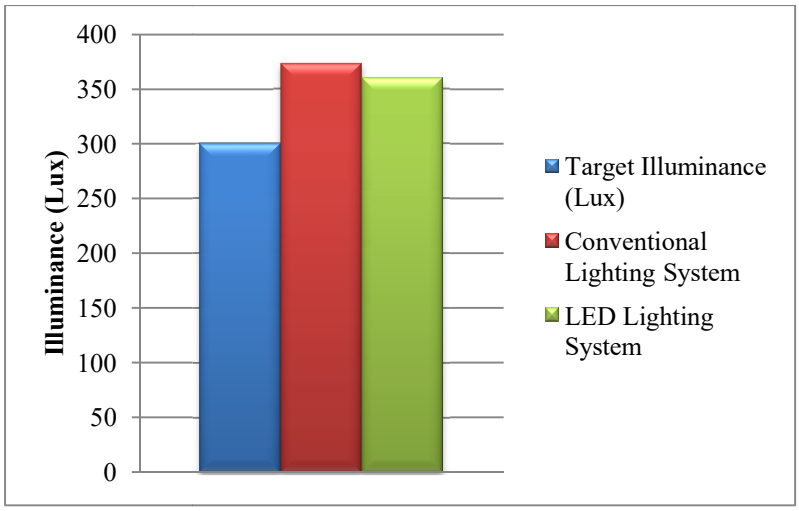


Fig. 9.189: Illuminance Comparison of AUDIT AND CASH

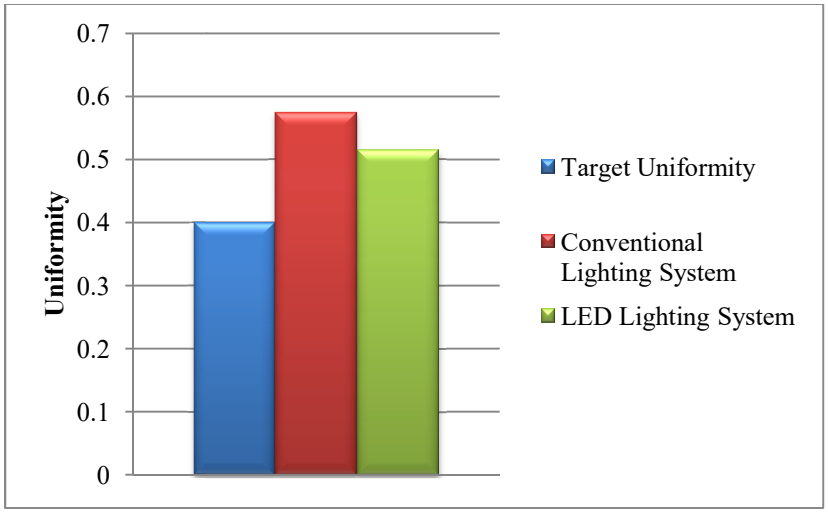


Fig. 9.190: Uniformity Comparison of AUDIT AND CASH

In Fig. 9.189, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.190, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

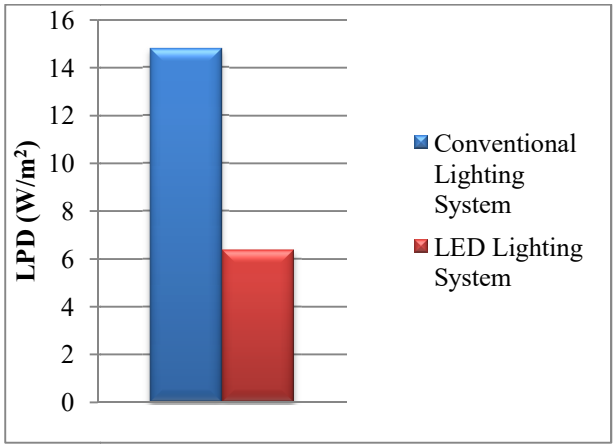


Fig. 9.191: LPD Comparison of AUDIT AND CASH

In Fig. 9.191, LPD comparison is shown where LPD by using conventional luminaires is approx 2.32 times of using LED luminaires.

- **ROOM BESIDE AUDIT AND CASH**

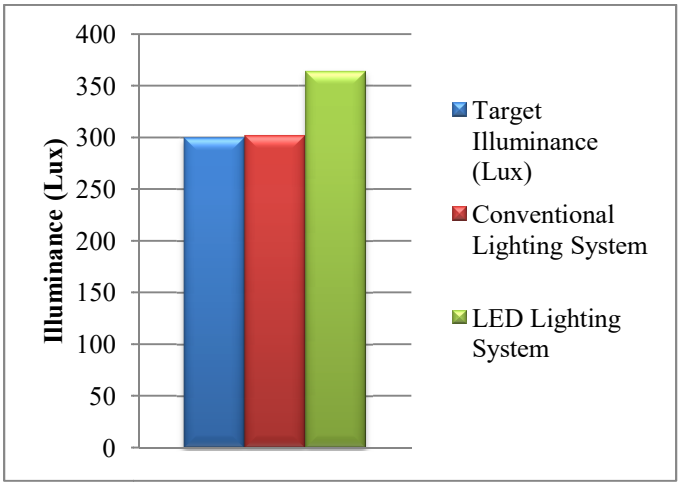


Fig. 9.192: Illuminance Comparison of ROOM BESIDE AUDIT AND CASH

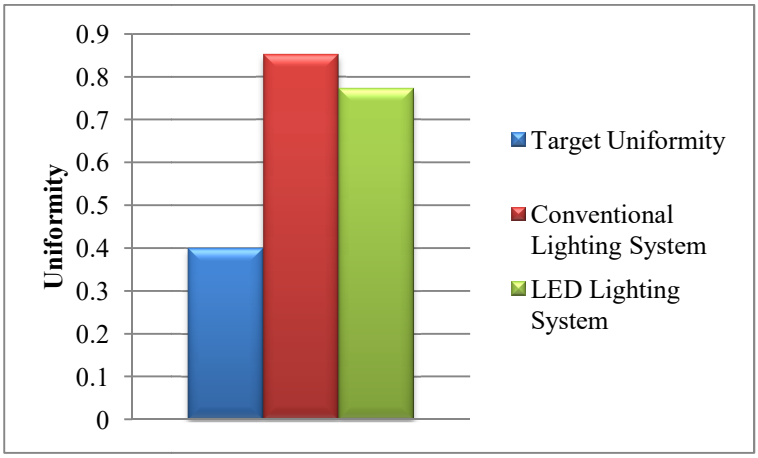


Fig. 9.193: Uniformity Comparison of ROOM BESIDE AUDIT AND CASH

In Fig. 9.192, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.193, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

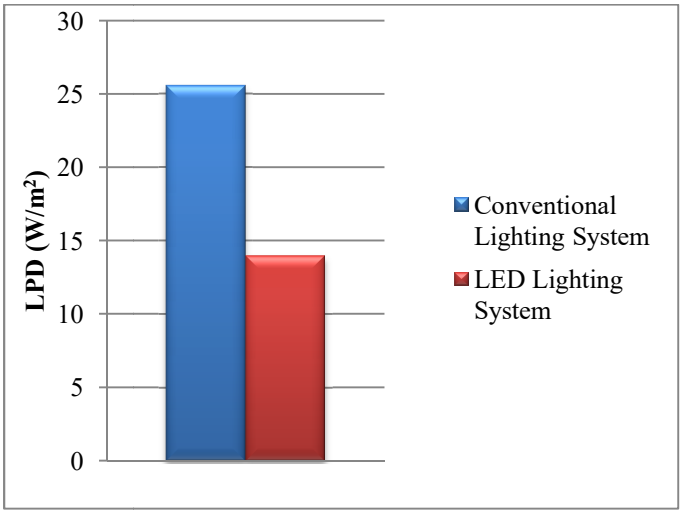


Fig. 9.194: LPD Comparison of ROOM BESIDE AUDIT AND CASH

In Fig. 9.194, LPD comparison is shown where LPD by using conventional luminaires is 82.90% higher than using LED luminaires.

- **SPARE ROOM**

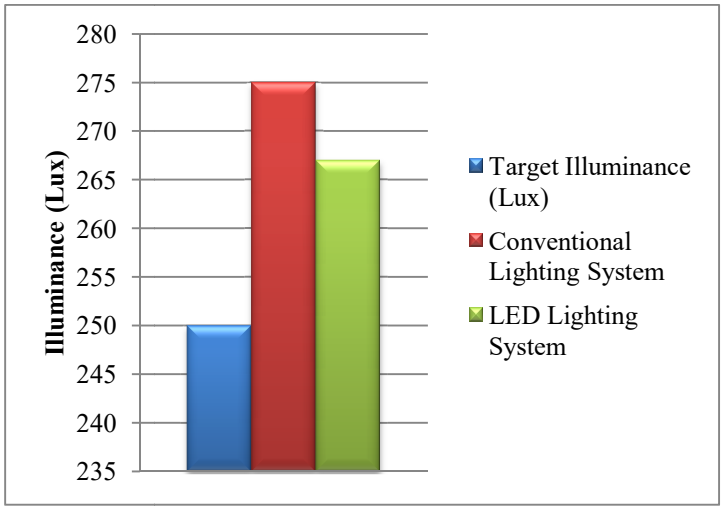


Fig. 9.195: Illuminance Comparison of SPARE ROOM

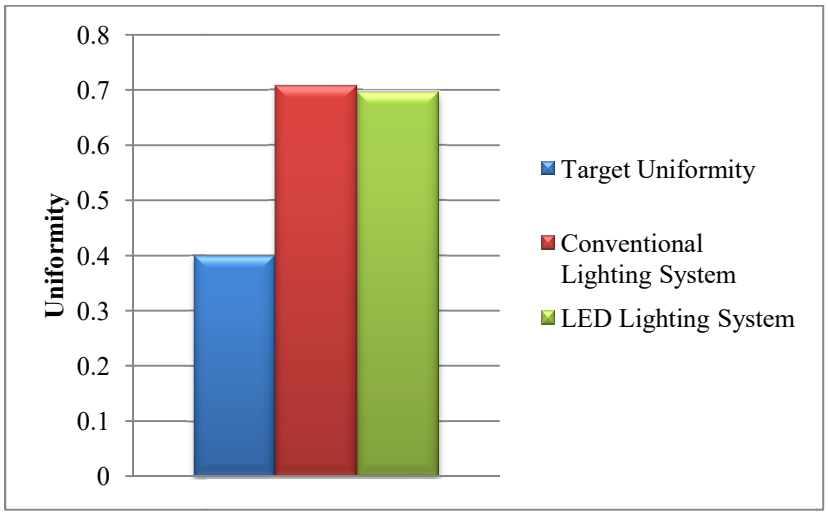


Fig. 9.196: Uniformity Comparison of SPARE ROOM

In Fig. 9.195, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.196, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

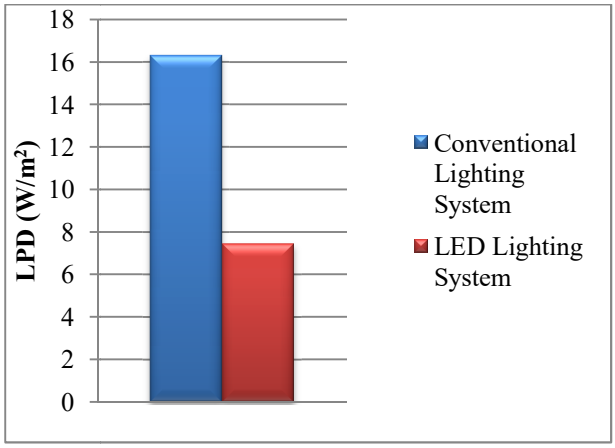


Fig. 9.197: LPD Comparison of SPARE ROOM

In Fig. 9.197, LPD comparison is shown where LPD by using conventional luminaires is 118.63% higher than using LED luminaires.

- **SUPERVISOR ROOM**

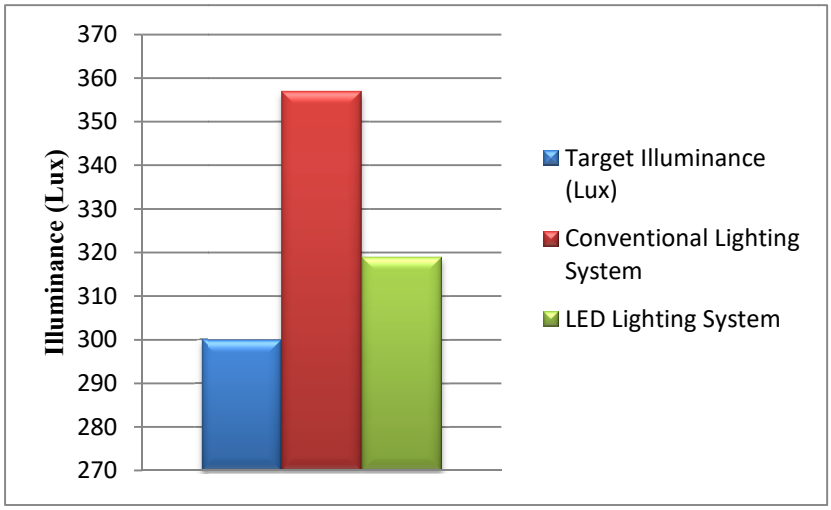


Fig. 9.198: Illuminance Comparison of SUPERVISOR ROOM

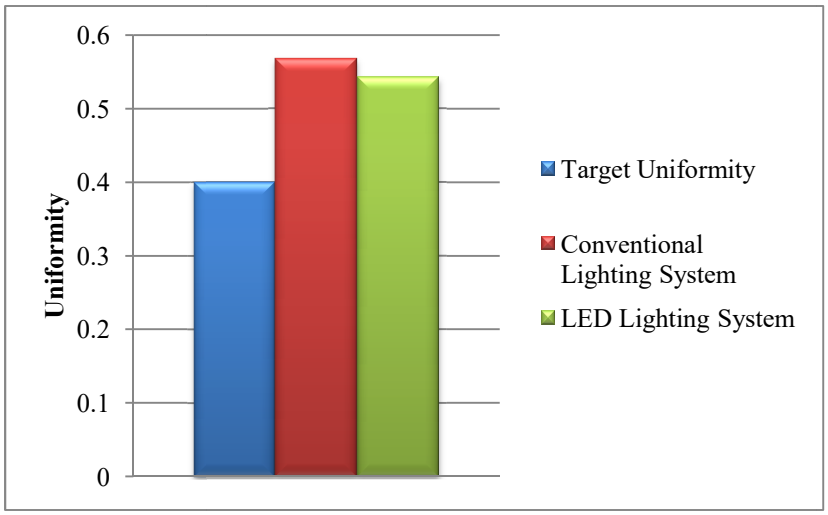


Fig. 9.199: Uniformity Comparison of SUPERVISOR ROOM

In Fig. 9.199, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.200, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

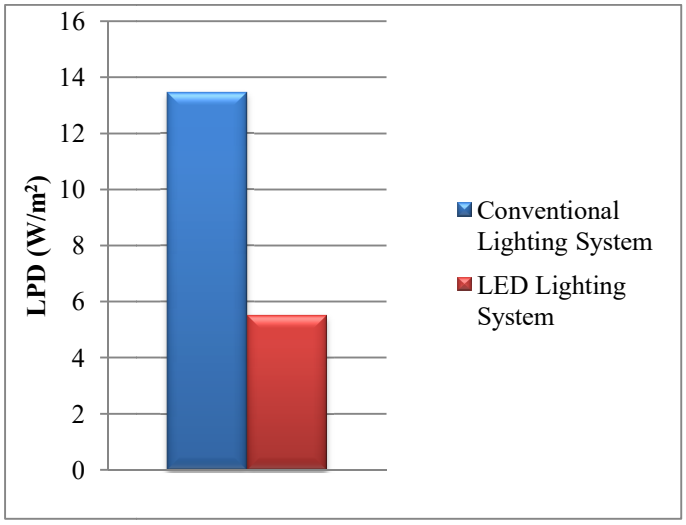


Fig. 9.200: LPD Comparison of SUPERVISOR ROOM

In Fig. 9.200, LPD comparison is shown where LPD by using conventional luminaires is approx 2.44 times of using LED luminaires.

- **STATION ENTRANCES 2**

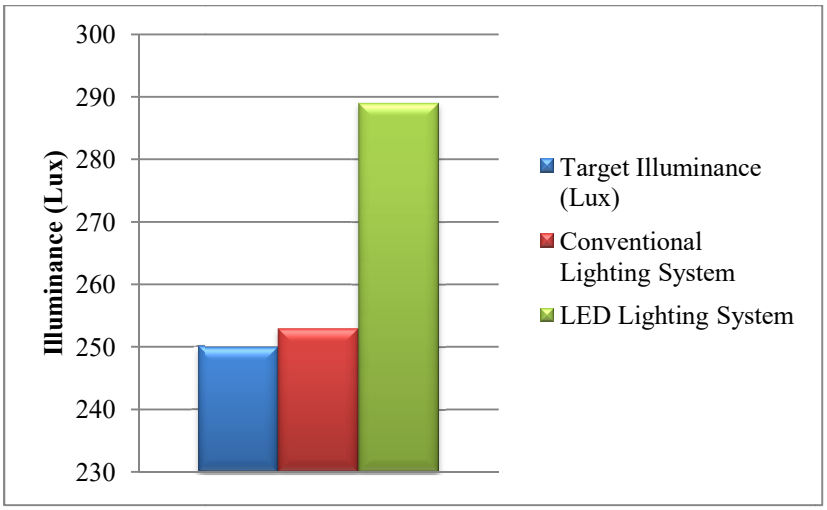


Fig. 9.201: Illuminance Comparison of STATION ENTRANCES 2

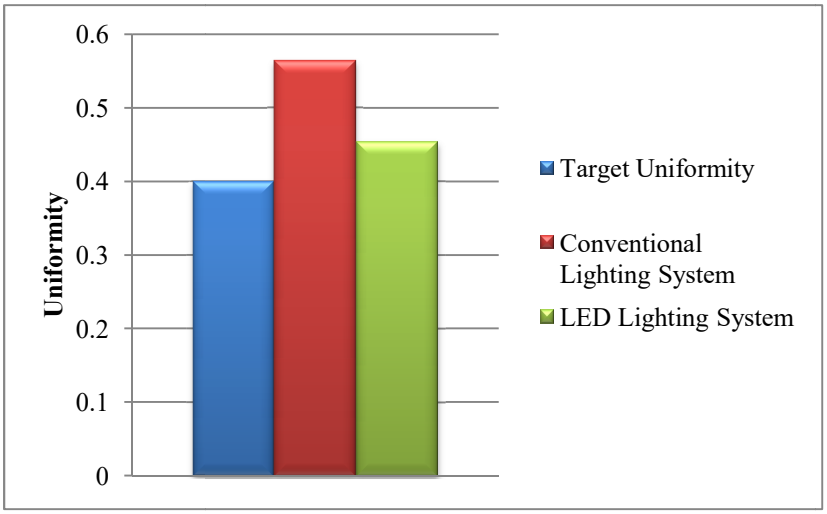


Fig. 9.202: Uniformity Comparison of STATION ENTRANCES 2

In Fig. 9.201, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.202, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

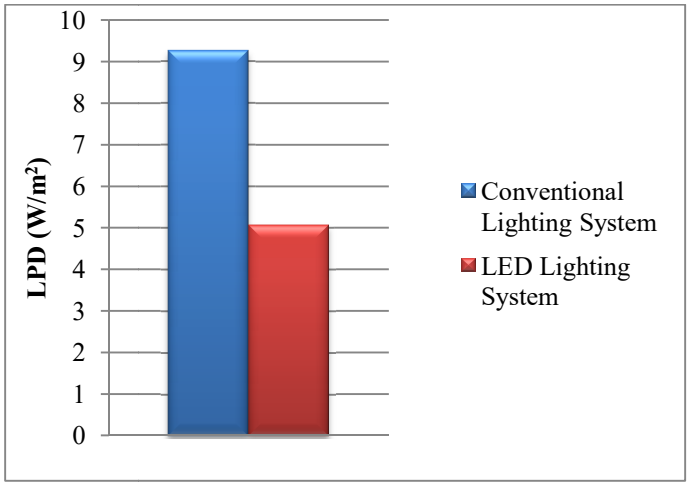


Fig. 9.203: LPD Comparison of STATION ENTRANCES 2

In Fig. 9.203, LPD comparison is shown where LPD by using conventional luminaires is approx 1.83 times of using LED luminaires.

- **STAFF MESS ROOM**

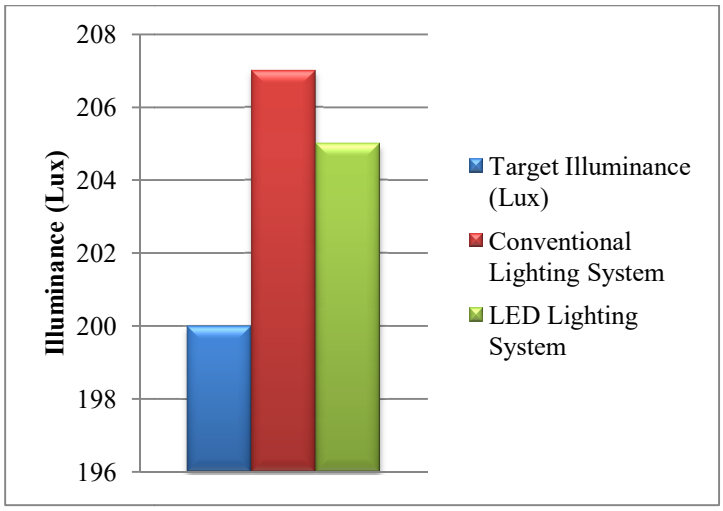


Fig. 9.204: Illuminance Comparison of STAFF MESS ROOM

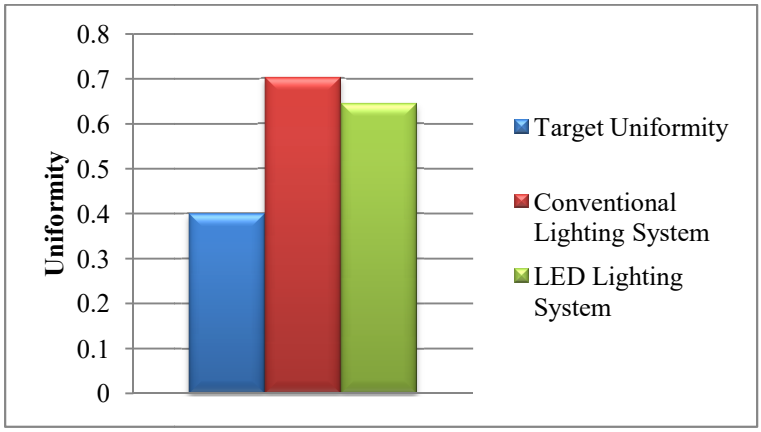


Fig. 9.205: Uniformity Comparison of STAFF MESS ROOM

In Fig. 9.204, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.205, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

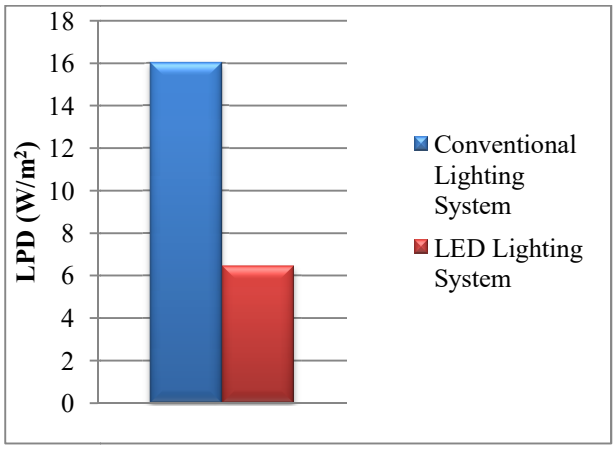


Fig. 9.206: LPD Comparison of STAFF MESS ROOM

In Fig. 9.206, LPD comparison is shown where LPD by using conventional luminaires is approx 2.48 times of using LED luminaires.

- **TOILET 1**

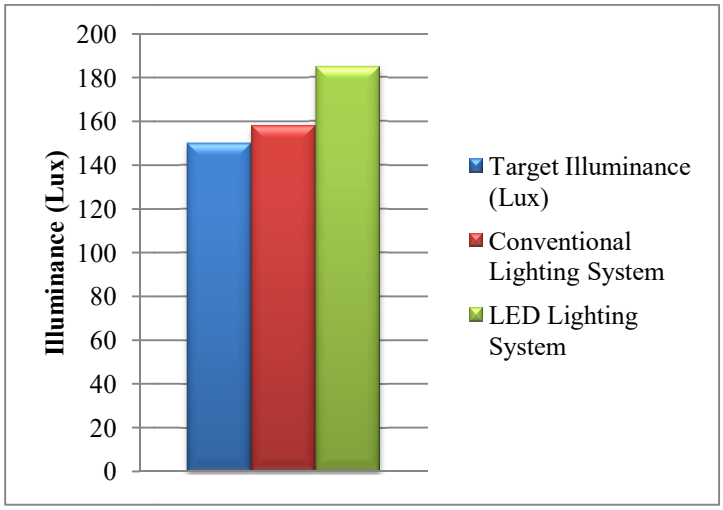


Fig. 9.207: Illuminance Comparison of TOILET 1

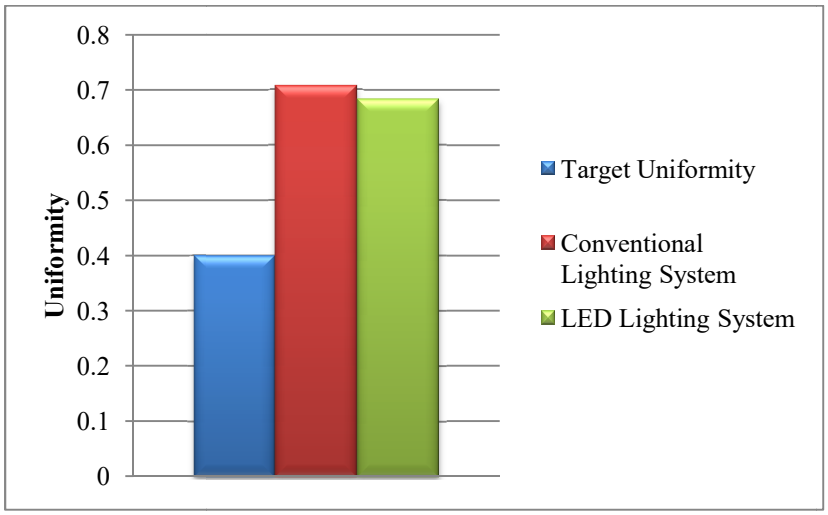


Fig. 9.208: Uniformity Comparison of TOILET 1

In Fig. 9.207, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.208, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

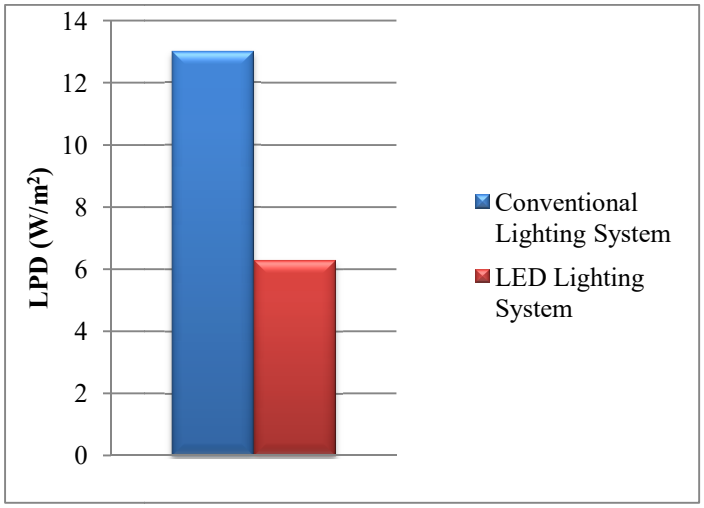


Fig. 9.209: LPD Comparison of TOILET 1

In Fig. 9.209, LPD comparison is shown where LPD by using conventional luminaires is approx 2.07 times of using LED luminaires.

- **TOILET 2**

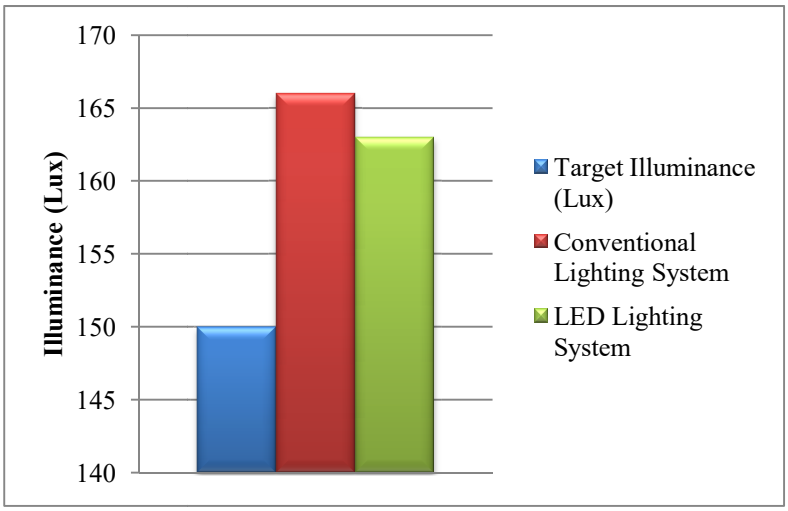


Fig. 9.210: Illuminance Comparison of TOILET 2

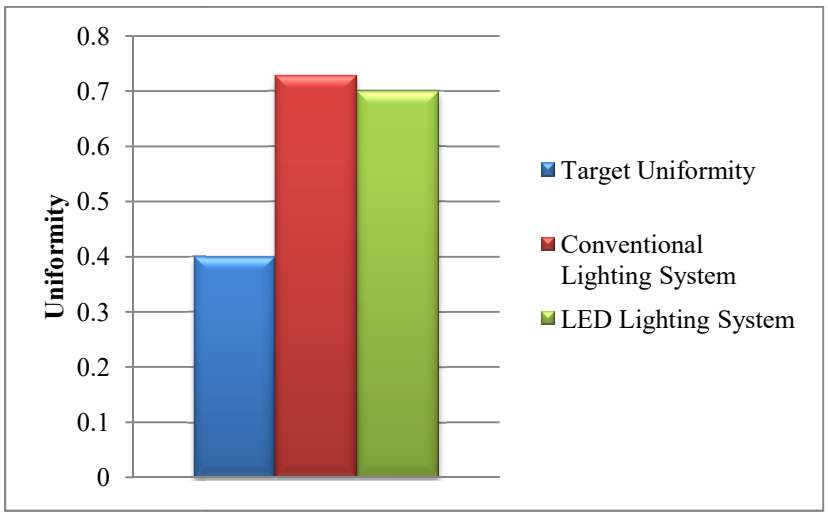


Fig. 9.211: Uniformity Comparison of TOILET 2

In Fig. 9.210, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.211, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

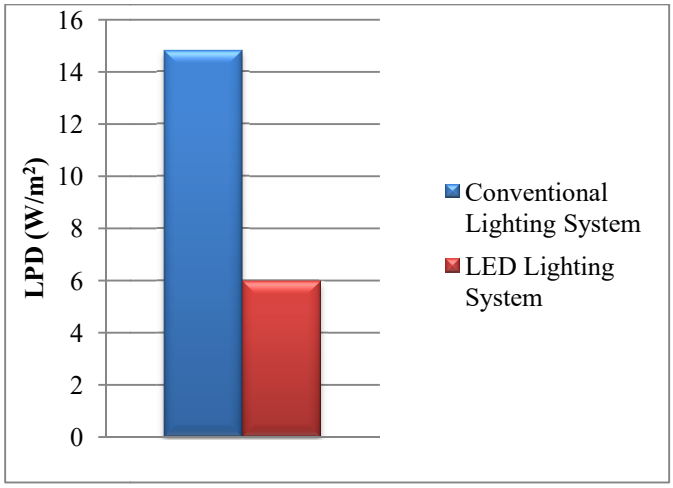


Fig. 9.212: LPD Comparison of TOILET 2

In Fig. 9.212, LPD comparison is shown where LPD by using conventional luminaires is approx 2.48 times of using LED luminaires.

- **TOILET 3**

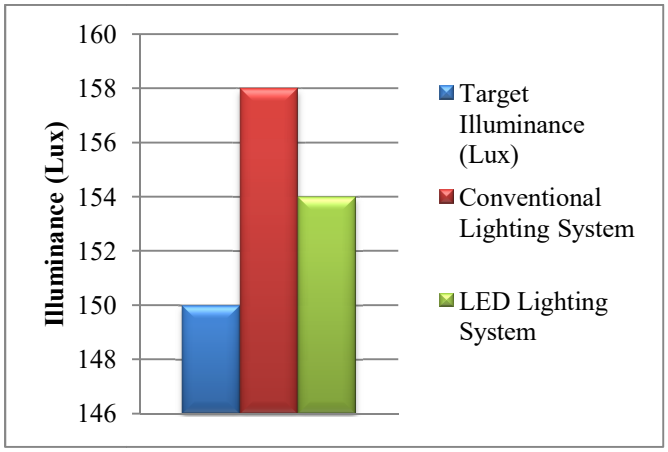


Fig. 9.213: Illuminance Comparison of TOILET 3

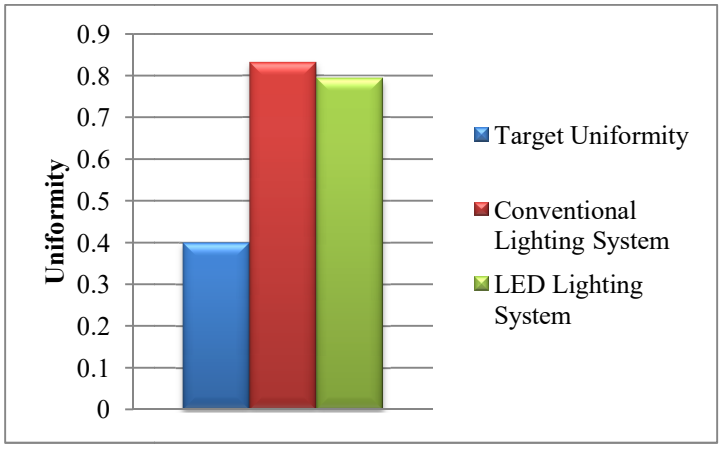


Fig. 9.214: Uniformity Comparison of TOILET 3

In Fig. 9.213, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.214, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

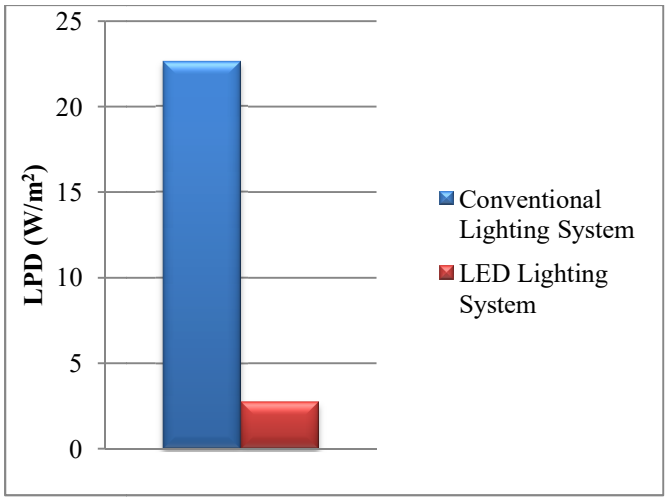


Fig. 9.215: LPD Comparison of TOILET 3

In Fig. 9.215, LPD comparison is shown where LPD by using conventional luminaires is approx 8.07 times of using LED luminaires.

- **STAFF MESS ROOM**

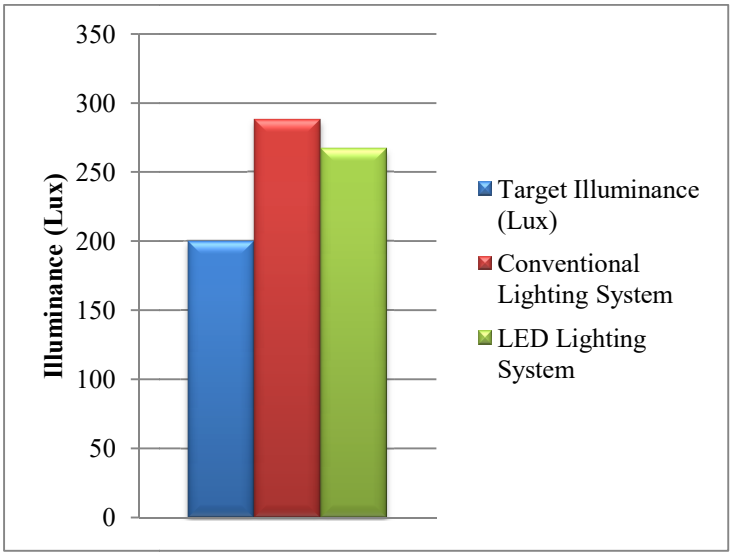


Fig. 9.216: Illuminance Comparison of STAFF MESS ROOM

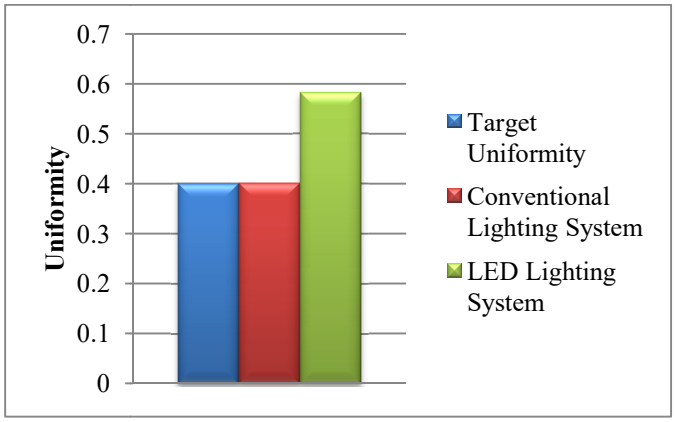


Fig. 9.217: Uniformity Comparison of STAFF MESS ROOM

In Fig. 9.216, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.217, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

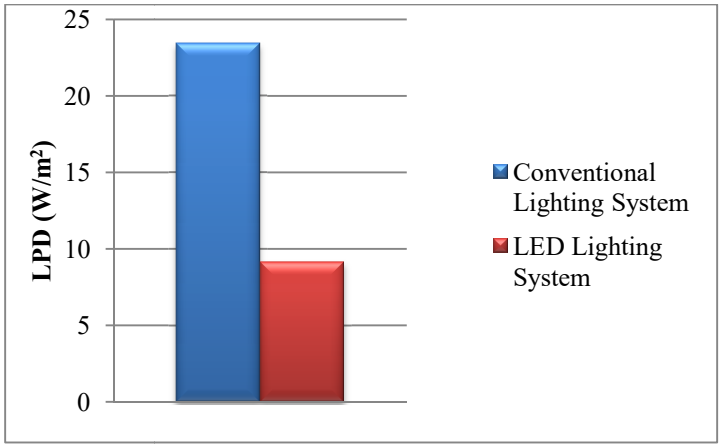


Fig. 9.218: LPD Comparison of STAFF MESS ROOM

In Fig. 9.218, LPD comparison is shown where LPD by using conventional luminaires is approx 2.56 times of using LED luminaires.

- **STATION CONTROL ROOM**

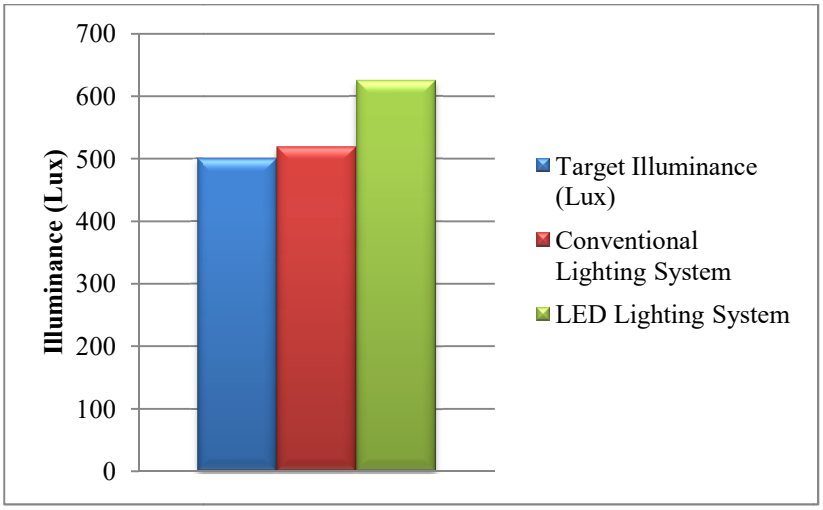


Fig. 9.219: Illuminance Comparison of STATION CONTROL ROOM

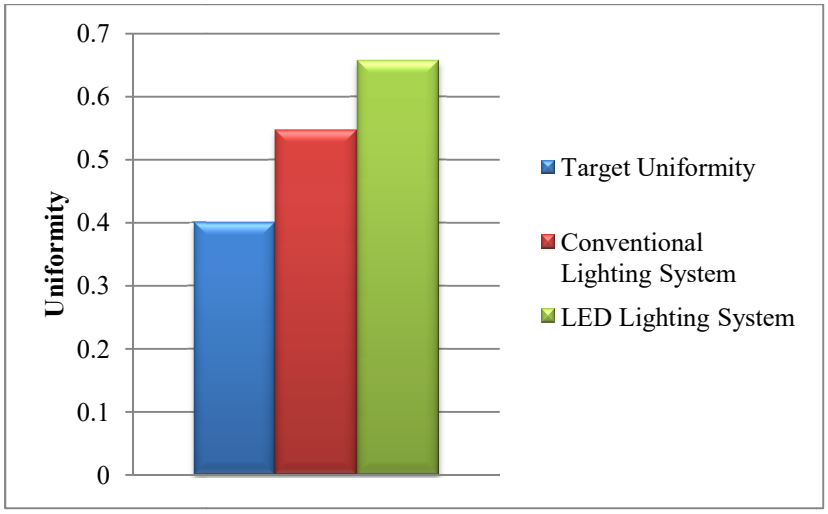


Fig. 9.220: Uniformity Comparison of STATION CONTROL ROOM

In Fig. 9.219, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.220, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

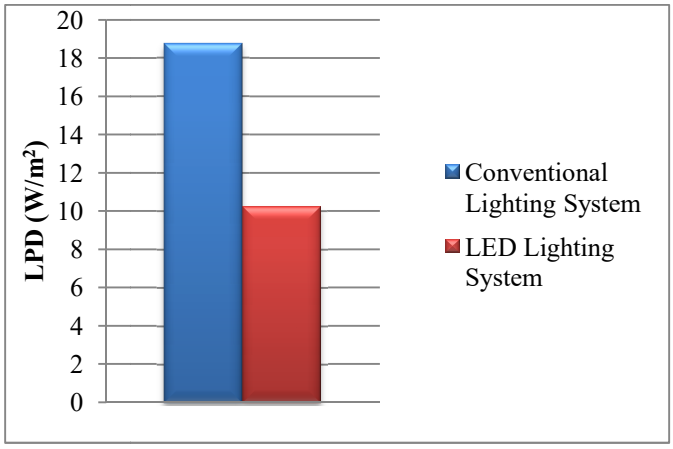


Fig. 9.221: LPD Comparison of STATION CONTROL ROOM

In Fig. 9.221, LPD comparison is shown where LPD by using conventional luminaires is approx 1.83 times of using LED luminaires.

- **SMR SIGNAL RELAY ROOM**

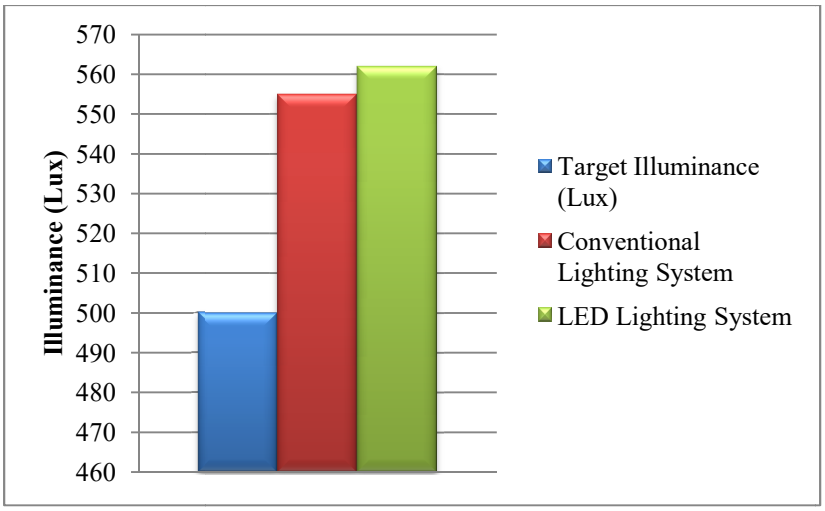


Fig. 9.222: Illuminance Comparison of SMR SIGNAL RELAY ROOM

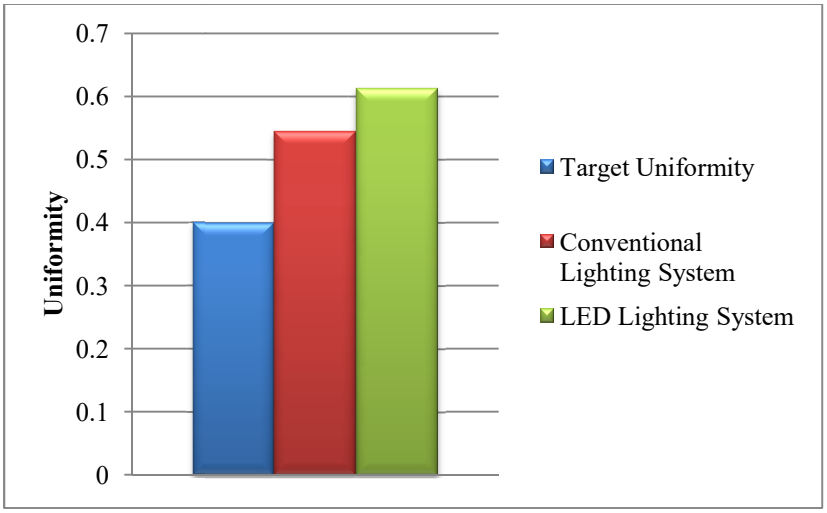


Fig. 9.223: Uniformity Comparison of SMR SIGNAL RELAY ROOM

In Fig. 9.222, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.223, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

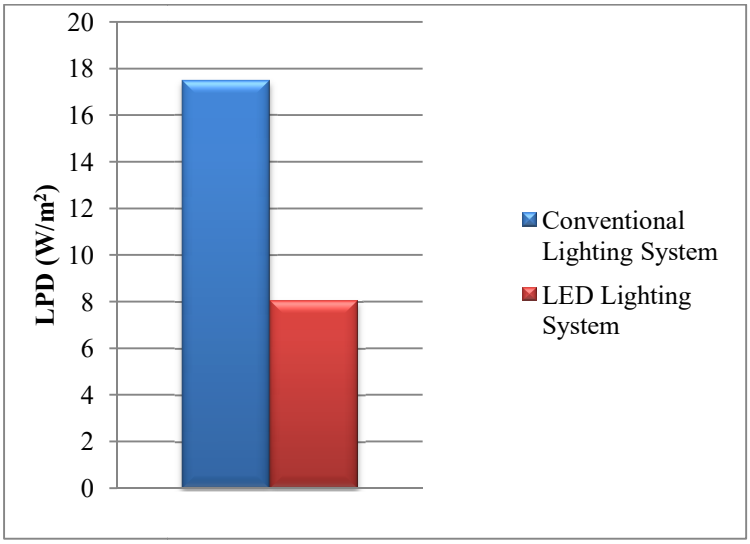


Fig. 9.224: LPD Comparison of SMR SIGNAL RELAY ROOM

In Fig. 9.224, LPD comparison is shown where LPD by using conventional luminaires is approx 2.16 times of using LED luminaires.

- **CORRIDOR NEAR TOILET**

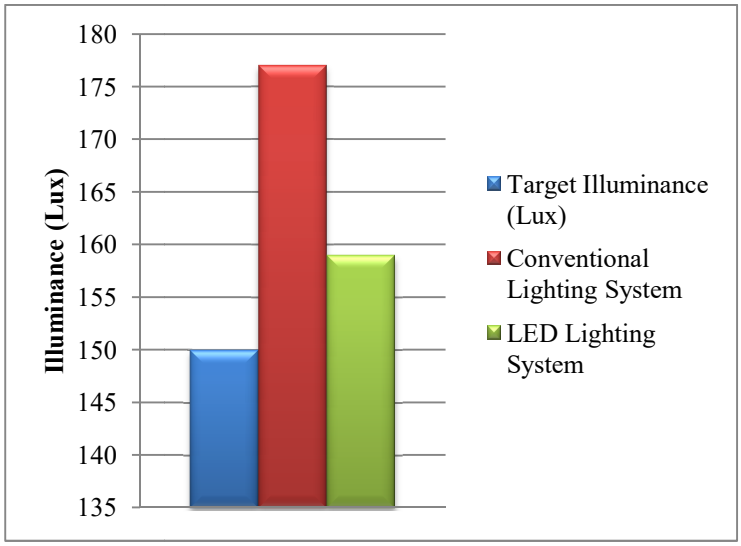


Fig. 9.225: Illuminance Comparison of CORRIDOR NEAR TOILET

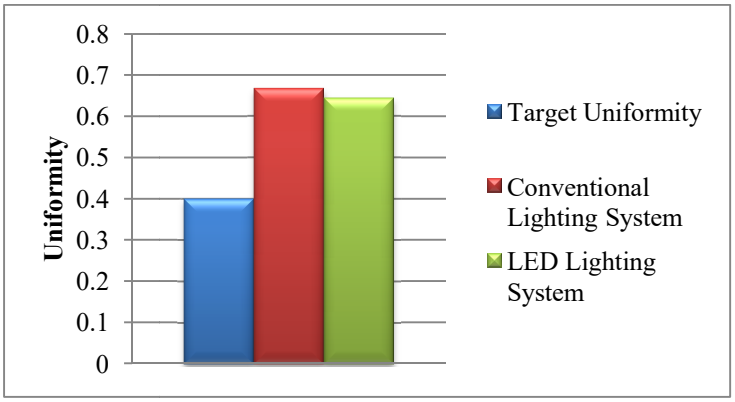


Fig. 9.226: Uniformity Comparison of CORRIDOR NEAR TOILET

In Fig. 9.225, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.226, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

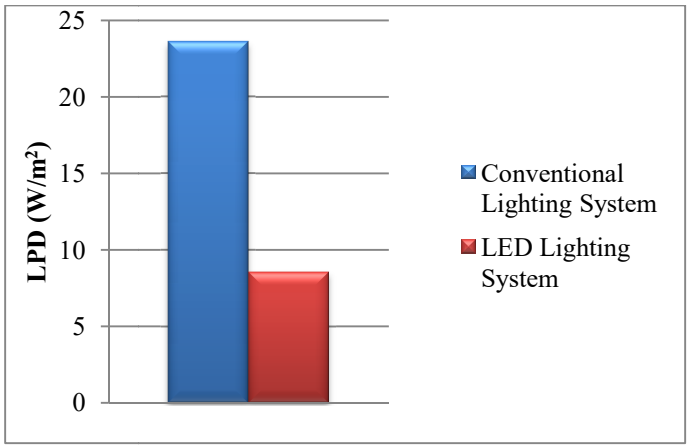


Fig. 9.227: LPD Comparison of CORRIDOR NEAR TOILET

In Fig. 9.227, LPD comparison is shown where LPD by using conventional luminaires is approx 2.76 times of using LED luminaires.

- **ENQUIRY ROOM**

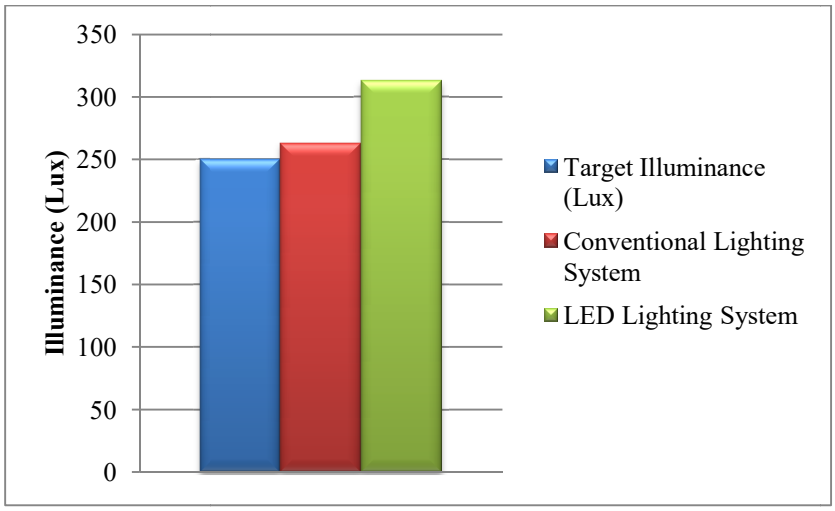


Fig. 9.228: Illuminance Comparison of ENQUIRY ROOM

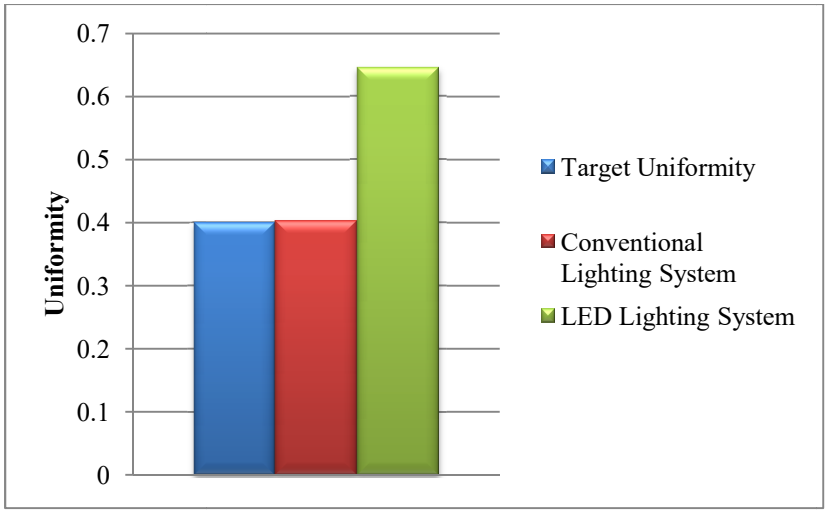


Fig. 9.229: Uniformity Comparison of ENQUIRY ROOM

In Fig. 9.228, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.229, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

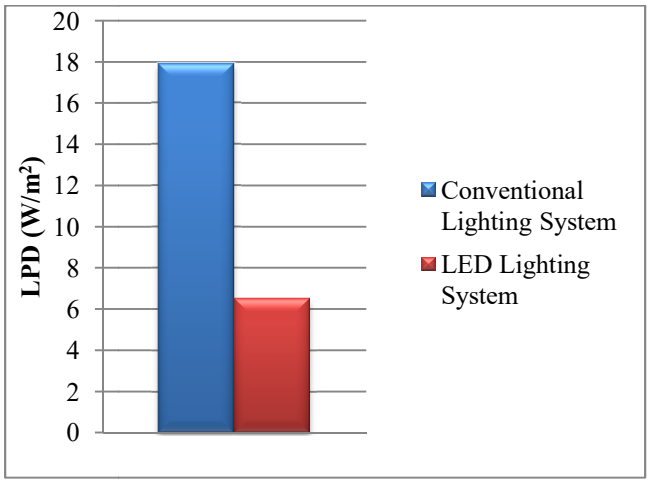


Fig. 9.230: LPD Comparison of ENQUIRY ROOM

In Fig. 9.230, LPD comparison is shown where LPD by using conventional luminaires is approx 2.74 times of using LED luminaires.

- **PASSAGE NEAR TOILET AREA**

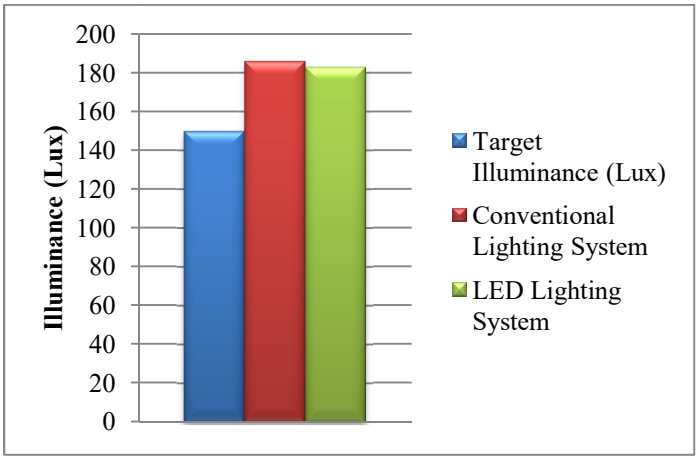


Fig. 9.231: Illuminance Comparison of PASSAGE NEAR TOILET AREA

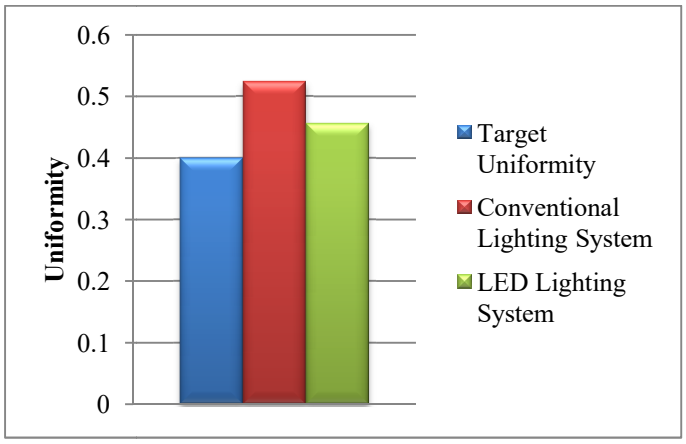


Fig. 9.232: Uniformity Comparison of PASSAGE NEAR TOILET AREA

In Fig. 9.231, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.232, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

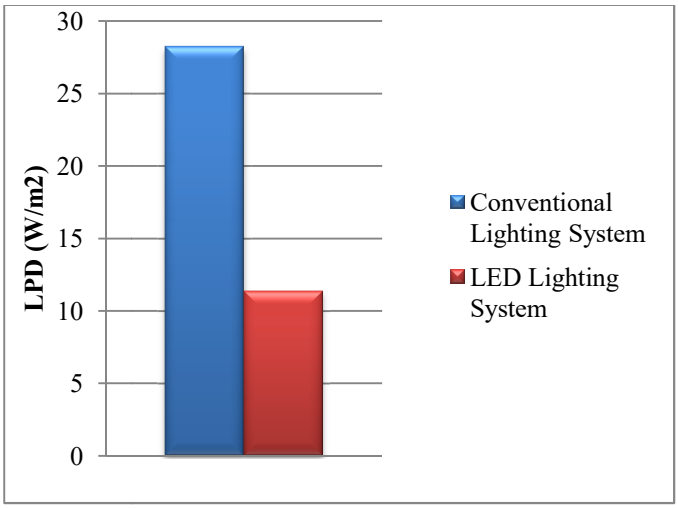


Fig. 9.233: LPD Comparison of PASSAGE NEAR TOILET AREA

In Fig. 9.233, LPD comparison is shown where LPD by using conventional luminaires is approx 2.48 times of using LED luminaires.

➢ STORE ROOM

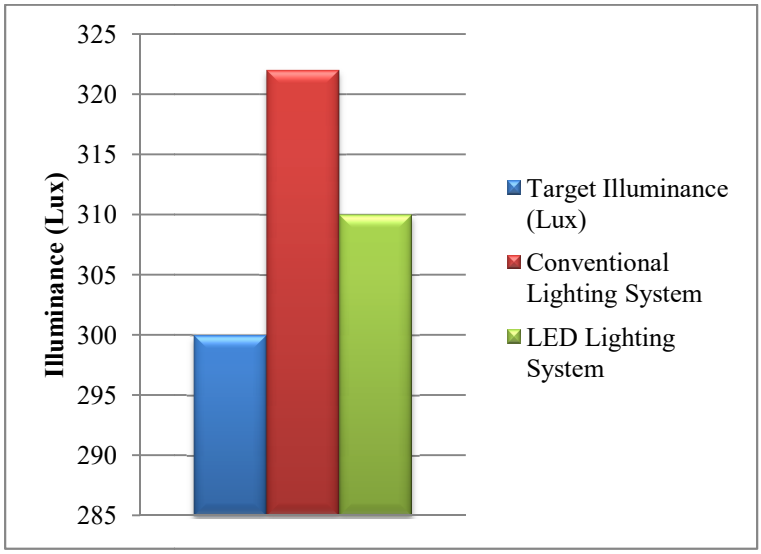


Fig. 9.234: Illuminance Comparison of STORE ROOM

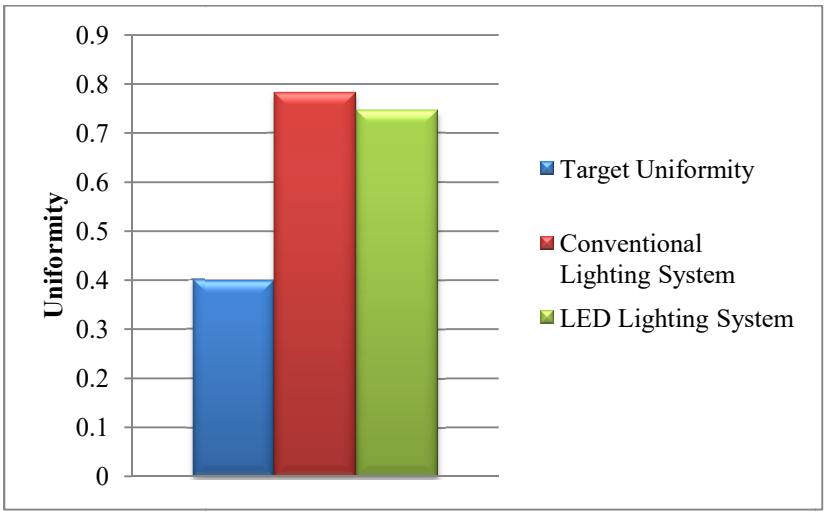


Fig. 9.235: Uniformity Comparison of STORE ROOM

In Fig. 9.234, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.235, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

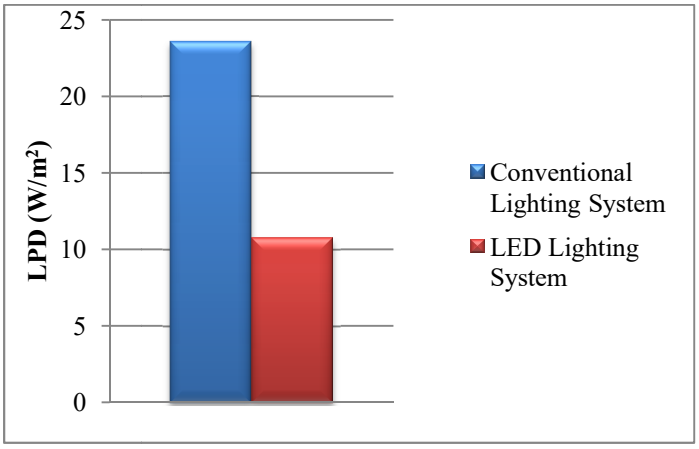


Fig. 9.236: LPD Comparison of STORE ROOM

In Fig. 9.236, LPD comparison is shown where LPD by using conventional luminaires is approx 2.19 times of using LED luminaires.

- **REFUSE STORE ROOM**

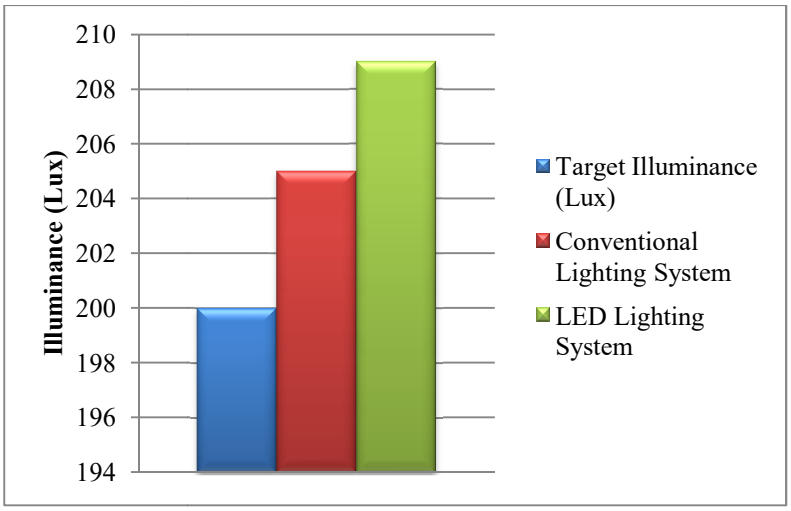


Fig. 9.237: Illuminance Comparison of REFUSE STORE ROOM

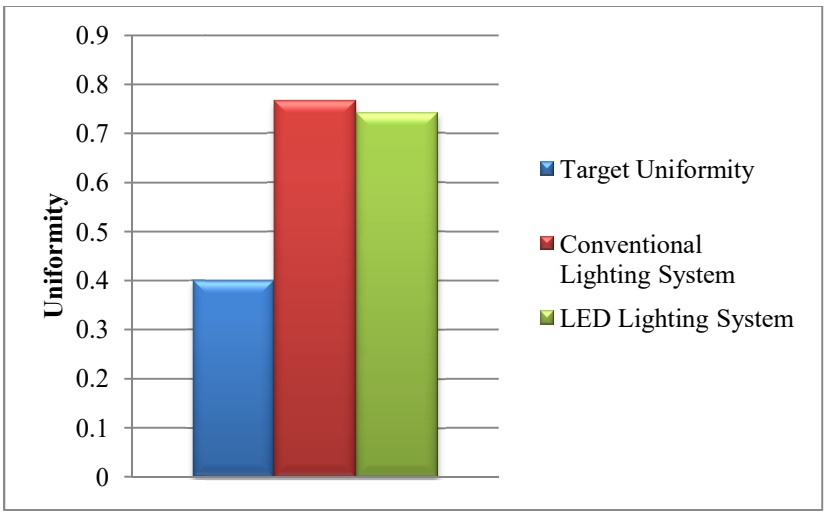


Fig. 9.238: Uniformity Comparison of REFUSE STORE ROOM

In Fig. 9.237, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.238, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

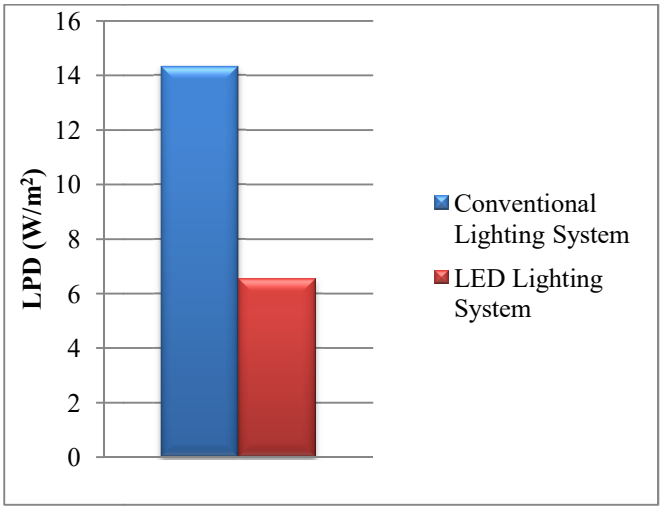


Fig. 9.239: LPD Comparison of REFUSE STORE ROOM

In Fig. 9.239, LPD comparison is shown where LPD by using conventional luminaires is approx 2.19 times of using LED luminaires.

➢ **ROOM BELOW ESCALATOR 1,2,3,4**

The Illuminance parameter comparison is shown in Table 9.145 and Power Consumption comparison is shown in Table 9.146.

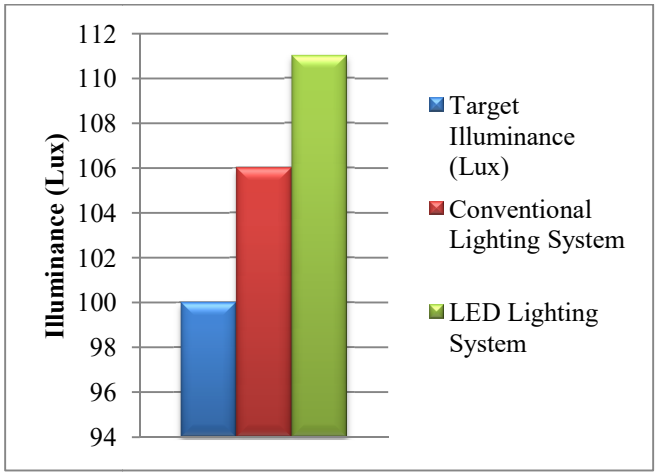


Fig. 9.240: Illuminance Comparison of ROOM BELOW ESCALATOR 1,2,3,4

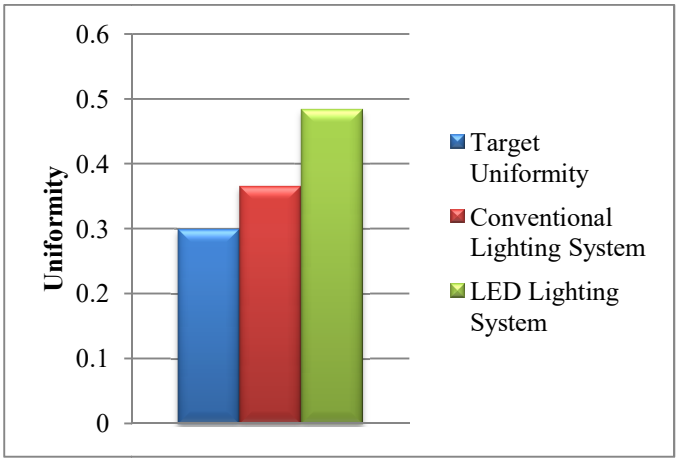


Fig. 9.241: Uniformity Comparison of ROOM BELOW ESCALATOR 1,2,3,4

In Fig. 9.240, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.241, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

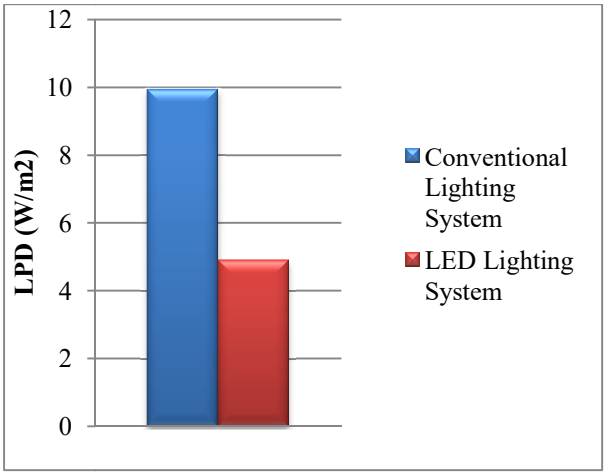


Fig. 9.242: LPD Comparison of ROOM BELOW ESCALATOR 1,2,3,4

In Fig. 9.242, LPD comparison is shown where LPD by using conventional luminaires is approx 2.02 times of using LED luminaires.

- **Area-wise Power Consumption**

The area-wise power consumption by using Conventional Luminaires and LED Luminaires are shown in Fig. 9.243 and Fig. 9.244 respectively. From both figure, Platform Area has maximum power consumption i.e. 47% by using conventional luminaires and 48% by using LED luminaires.

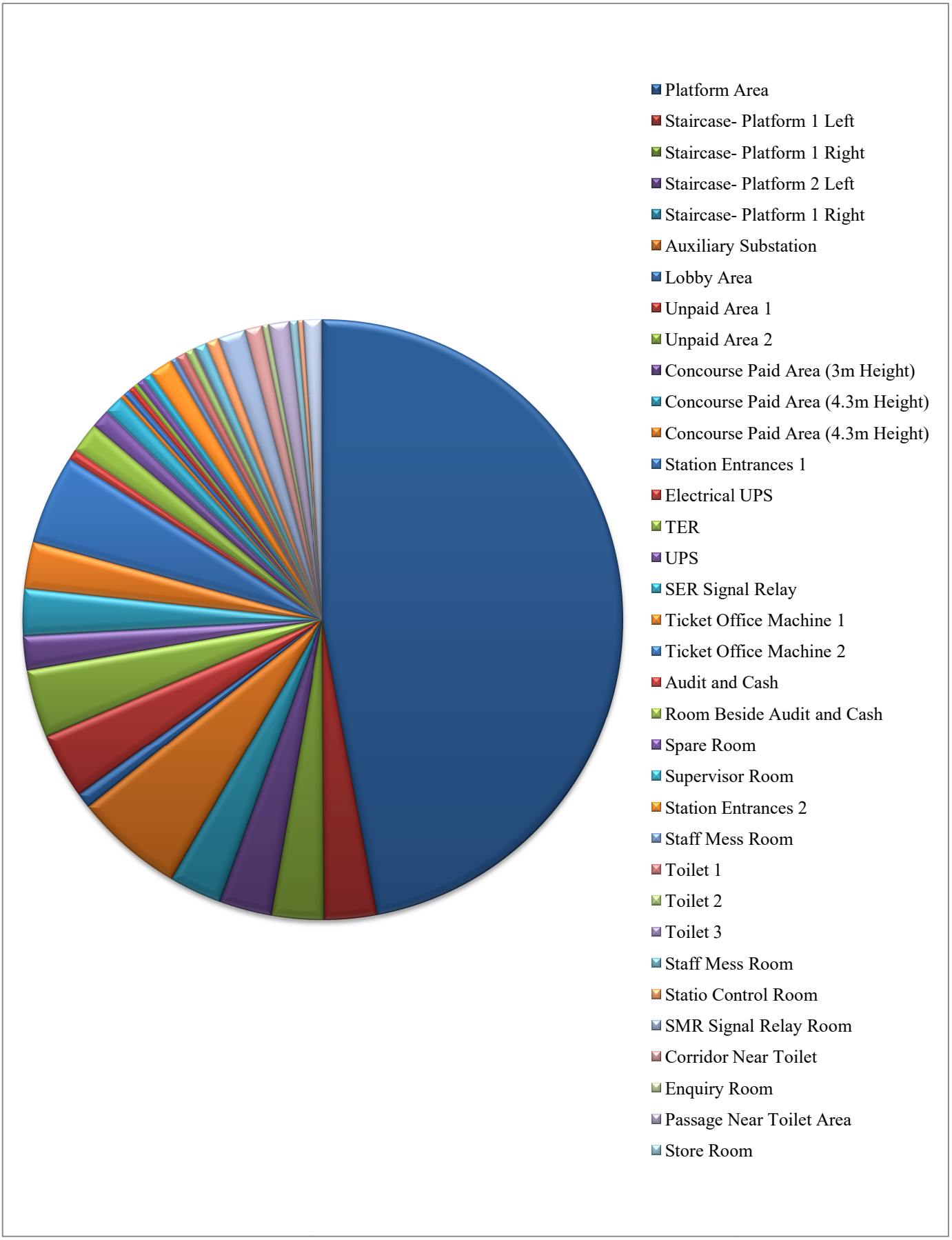


Fig. 9.243: Area-wise power consumption by using Conventional Luminaires

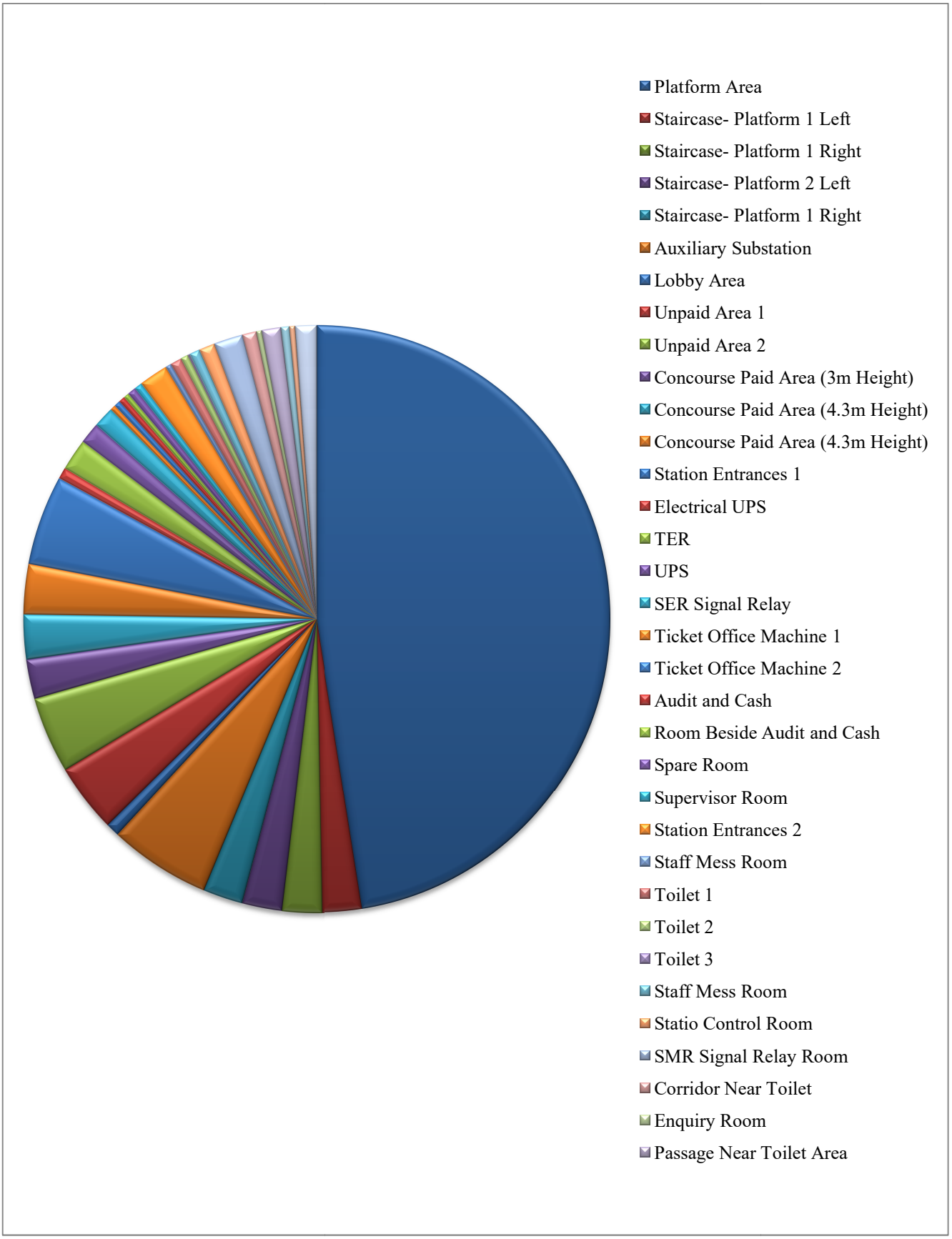


Fig. 9.244: Power Consumption by using LED Lumianire

9.5.2 LPD Evaluation of Metro Railway Station

Total Energy Usage in City Centre Metro with respect to LED Luminaire use: 24327.8 Watt
Total Ground Area: 6193.89 m^2
Total Lighting Power Density by Building Area Method: **3.93 W/ m^2**
According to Delhi Metro Rail Corporation Electrical and Design Wing (comparing values with ECBC 2016), LPD value should not exceed **7.5 W/ m^2**
Hence according to Building Area Method by using LED Luminaire, the LPD value is 52.4% less than standard LPD value. So, it can be stated that the designs with LED Luminiares are well feasible and also it can be said as an Energy Efficient Design.

9.5.3 Economic Comparison between Conventional and LED Solution of Case Study on Metro Railway Station

- **Cost Details of Conventional Luminaires used in this Project**

Sl. No.	Luminaire	Qty	Price Per Fixture [55]	Total Cost
1	Conventional Canopy Luminaire 1	116	3087.5	358150
2	Conventional Batten Type Luminiare 2	161	2055	330855
3	Conventional Clean-room Application Luminaire 1	20	3450	69000
4	Conventional Surface- Mounted Downlighter 1	133	875	116375
5	Conventional Batten Type Luminiare 3	80	1650	132000
6	Conventional 2x2 Luminaire 2	244	2255	550220

Total Cost of Conventional Luminaires: Rs. 1556600

- **Cost Details of LED Luminaires used in this Project**

Sl. No.	Luminaire	Qty	Price Per Fixture [56]	Total Cost
1	LED Batten 1	60	4800	288000
2	LED Canopy Luminaire 1	81	9850	797850
3	LED Tube Batten 2	178	2365	420970
4	LED Clean-room Application Luminaire 1	28	7200	201600
5	LED 2x2 Luminiare 2	209	3700	773300
6	LED Recessed Mounted Downlighter 1	2	700	1400
7	LED Surface-Mounted Downlighter 1	88	1000	88000

Total Cost of LED Luminaires: Rs. 2571120

- **Total Annual Operating Cost of LED Luminiare**

Sl. No.	Parameter	LED Luminaires						
		LED Batten 1	**LED Canopy Luminaire 1**	**LED Tube Batten 2**	**LED Clean-room Application Luminaire 1**	**LED 2x2 Luminiare 2**	**LED Recessed Mounted Downlighter 1**	**LED Surface-Mounted Downlighter 1**
1	**Power comsumption per luminaire in W**	36.6	71.6	40	39.7	34.2	12.4	12.4
2	**Total Quantity**	60	61	178	28	209	2	88
3	**Total Power Consumption in Watt**	2196	4367.6	7120	1111.6	7147.8	24.8	1091.2
4	**Usage of system per day in hours**	17	17	17	17	17	17	17
5	**Total working days/annum**	365	365	365	365	365	365	365
6	**Total power consumption per annum in W**	13626180	27100958	44179600	6897478	44352099	153884	6770896
7	**Total Energy consumption per annum in KWH**	13626.18	27100.958	44179.6	6897.478	44352.099	153.884	6770.896
8	**Electricity charges in Rs**	10	10	10	10	10	10	10
9	**Operating cost in Rs per annum**	136261.80	271009.58	441796.00	68974.78	443520.99	1538.84	67708.96
10	**Total Annual Operating Cost (Rs.)**	1430810.95						

- **Total Annual Operating Cost of Conventional Luminiare**

Sl. No.	Parameter	Conventional Luminaires					
		Conventional Canopy Luminaire 1	**Conventional Batten Type Luminiare 2**	**Conventional Clean-room Application Luminaire 1**	**Conventional Surface-Mounted Downlighter 1**	**Conventional Batten Type Luminiare 3**	**Conventional 2x2 Luminaire 2**
1	**Power comsumption per luminaire in W**	172	80	112.3	20.5	40	62.5
2	**Total Quantity**	116	161	20	133	80	244
3	**Total Power Consumption in Watt**	19952	12880	2246	2726.5	3200	15250
4	**Usage of system per day in hours**	17	17	17	17	17	17
5	**Total working days/annum**	365	365	365	365	365	365
6	**Total power consumption per annum in W**	123802160	79920400	13936430	16917932.5	19856000	94626250
7	**Total Energy consumption per annum in KWH**	123802.16	79920.4	13936.43	16917.9325	19856	94626.25
8	**Electricity charges in Rs**	10	10	10	10	10	10
9	**Operating cost in Rs per annum**	1238021.6	799204	139364.3	169179.325	198560	946262.5
10	**Total Annual Operating Cost (Rs.)**	3490591.725					

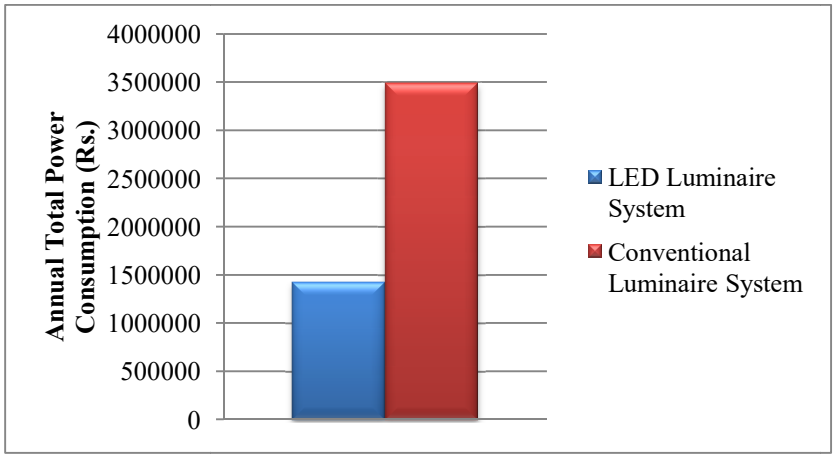


Fig. 9.245: Annual Total Power Consumption (Rs.) Cost Comparison between two simulations

Fig. 9.245 shows the annual operating cost comparison where by using conventional lumnaires, annual operating cost is 2.44 times of using LED luminaires.

- **Annual Lamp Replacement and Maintenance Cost**

Sl. No.		Conventional Canopy Luminaire 1	Conventional Batten Type Luminiare 2	Conventional Clean-room Application Luminaire 1	Conventional Surface-Mounted Downlighter 1	Conventional Batten Type Luminiare 3	Conventional 2x2 Luminaire 2
	Lamp Type	**150 W Metal Halide Lamp**	**2 nos 36W FTL**	**3 nos 36W CFL**	**18 W CFL**	**36 W FTL**	**4 nos. 14 W T5**
1	**Average Lamp Life**	10000	15000	6000	18000	15000	18000
2	**Number of lamps to be replaced per annum**	696	133	62	46	33	336
3	**Price per Lamp** [55]	660	60	180	140	60	83
4	**Cost of lamp replacement (Rs)**	459360	7980	11160	6440	1980	27888
5	**Average cost of maintenance Rs. 25 per luminaire (conventional) per year**	2900	4025	500	3325	2000	6100
9	**Total Cost of replacement and maintenance (Rs)**	533658					

➢ **Payback Period Calcultaion**

Sl. No.	Annual Power & Maintenance Cost (Rs)	LED Luminaire	Conventional Luminaire
1	Luminaire Power Consumption Cost	1430810.95	3490591.725
2	Annual Lamp Replacement Cost and Maintenance Cost	NA	533658
	Comparison		
1	Present worth	2571120	1556600
2	Annual Running Cost	1430811	4024250
	Payback Time		
0	Total Cost of operation at start	2571120	1556600
1	Total Cost of operation after 1st year	4001931	5580850
2	Total Cost of operation after 2nd year	5432742	9605099
3	Total Cost of operation after 3rd year	6863553	13629349
4	Total Cost of operation after 4th year	8294364	17653599

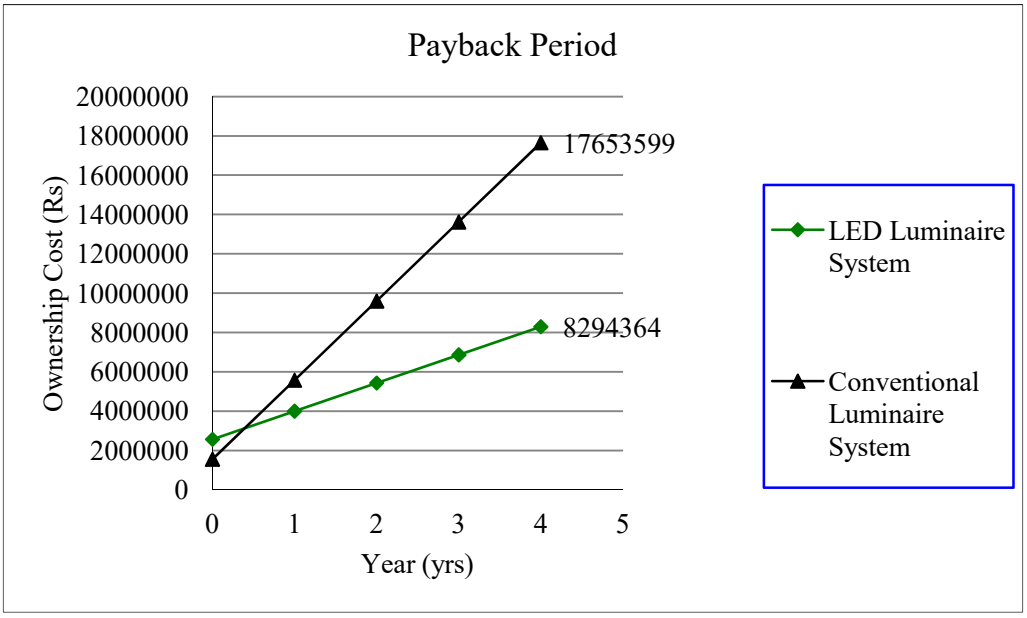


Fig. 9.246: Ownership Cost v/s Year

From Fig. 9.246, it is observed that, the intersection of two lines is at approxmimately 6 months.

So, by Break Even Method, Payback period is approx 6 months.

9.6 Result Analysis and Cost Analysis of Case Study on Office Building

9.6.1 Result Analysis of Case Study on Office Building

The average illuminance, uniformity and Power Consumption within that area is the primary comparison parameter.

➢ **Corridor**

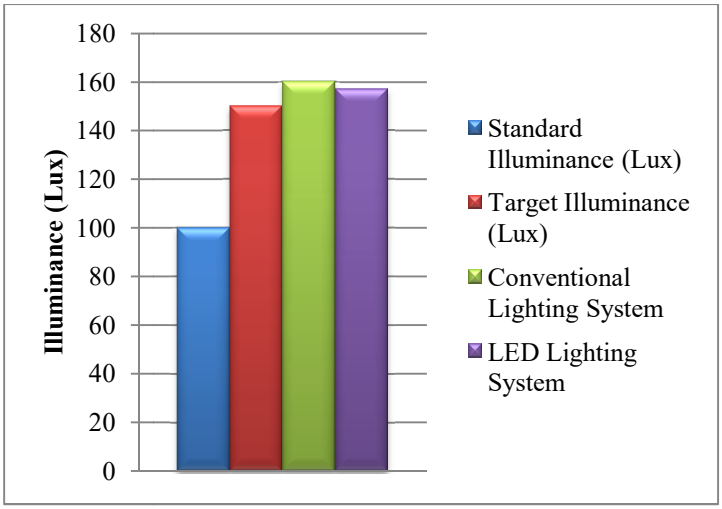


Fig. 9.247: Illuminance Comparison of Corridor

In Fig. 9.247, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

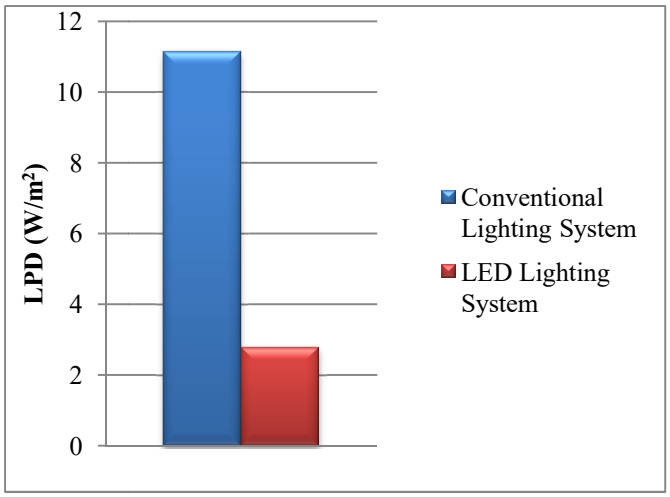


Fig. 9.248: LPD Comparison of Corridor

In Fig. 9.248, LPD comparison is shown where LPD by using conventional luminaires is approx 3.98 times of than using LED luminaires.

➢ **Corridor 1**

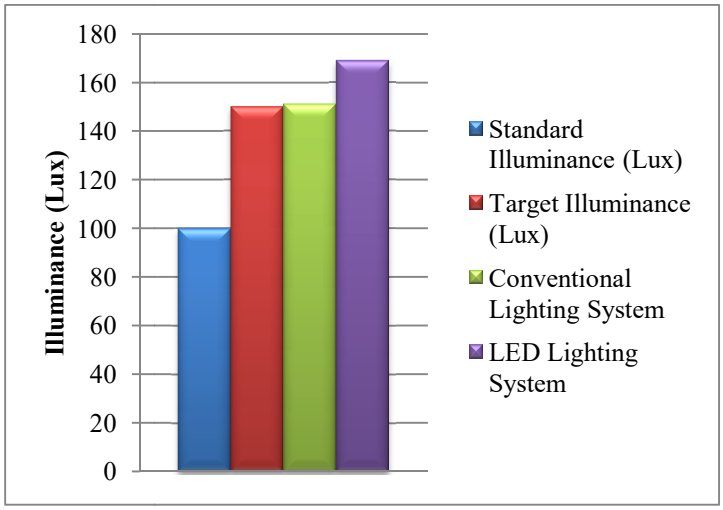


Fig. 9.249: Illuminance Comparison of Corridor 1

In Fig. 9.249, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

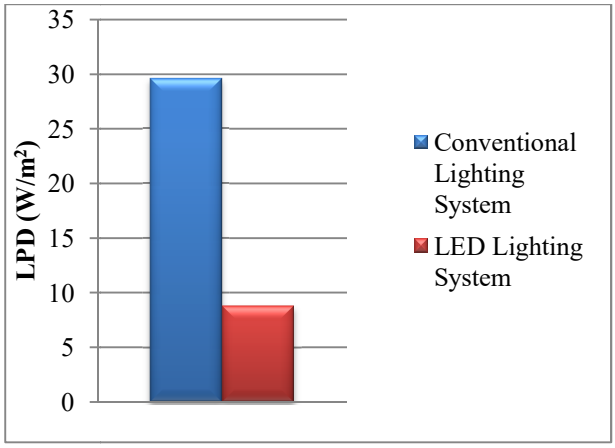


Fig. 9.250: LPD Comparison of Corridor 1

In Fig. 9.250, LPD comparison is shown where LPD by using conventional luminaires is approx 3.36 times of than using LED luminaires.

- **Director's Office**

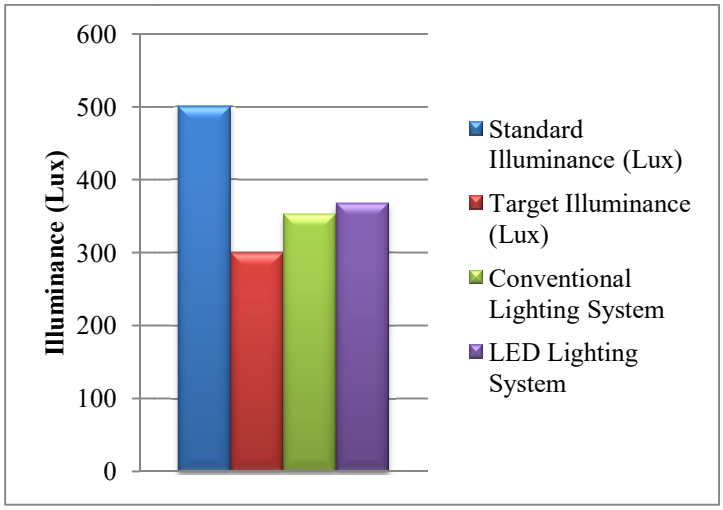


Fig. 9.251: Illuminance Comparison of Director's Office

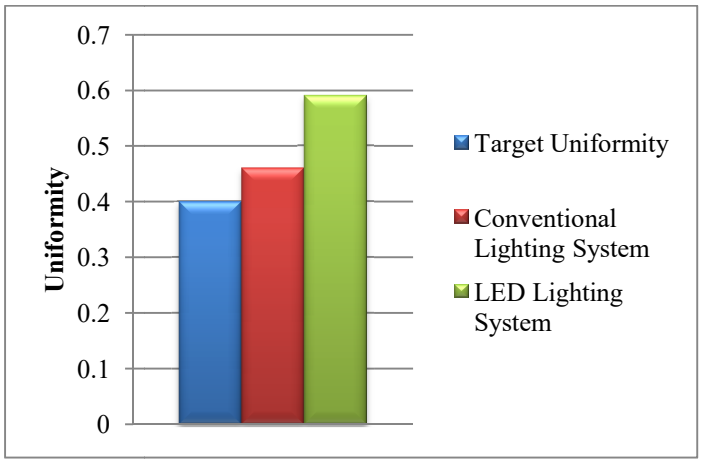


Fig. 9.252: Uniformity Comparison of Director's Office

In Fig. 9.251, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.252, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

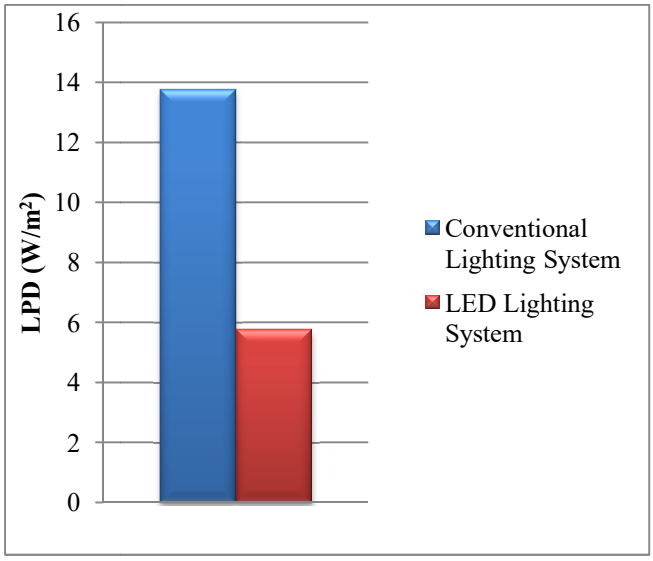


Fig. 9.253: LPD Comparison of Director's Office

In Fig. 9.253, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of than using LED luminaires.

- **Electric Room**

The Illuminance parameter comparison is shown in Table 9.153 and Power Consumption comparison

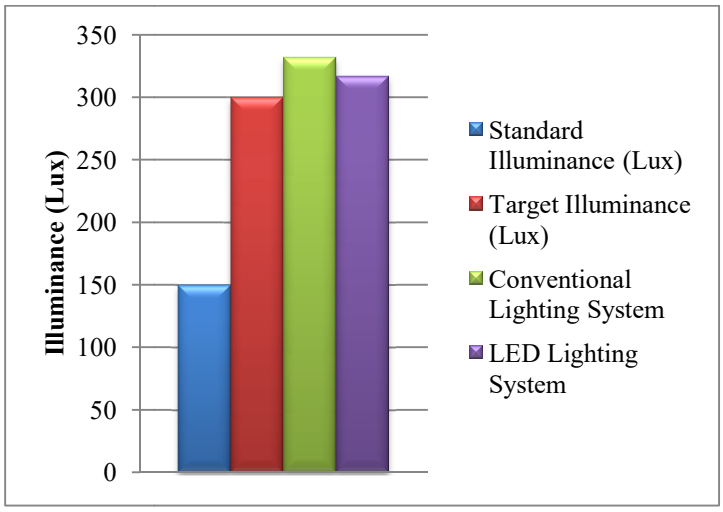


Fig. 9.254: Illuminance Comparison of Electric Room

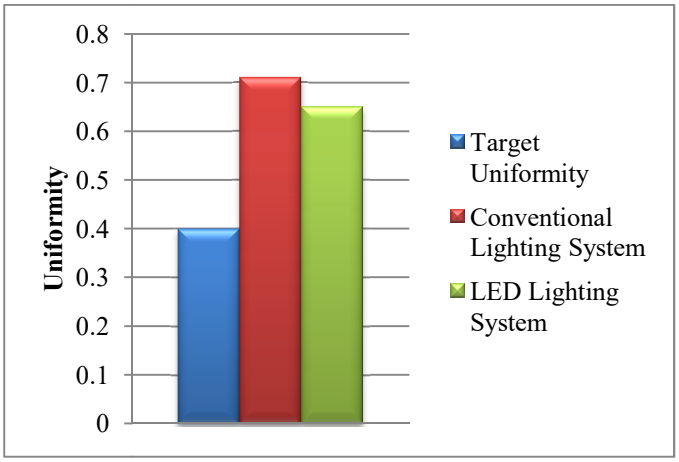


Fig. 9.255: Uniformity Comparison of Electric Room

In Fig. 9.254, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.255, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

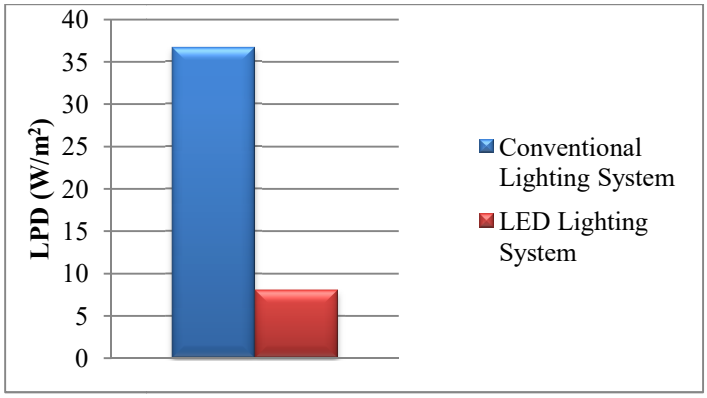


Fig. 9.256: LPD Comparison of Electric Room

In Fig. 9.256, LPD comparison is shown where LPD by using conventional luminaires is approx 4.57 times of than using LED luminaires.

- **Entrance**

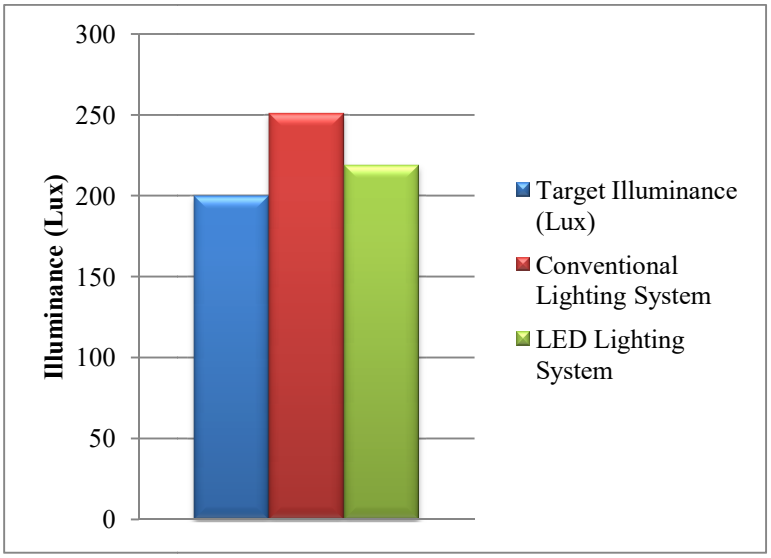


Fig. 9.257: Illuminance Comparison of Entrance

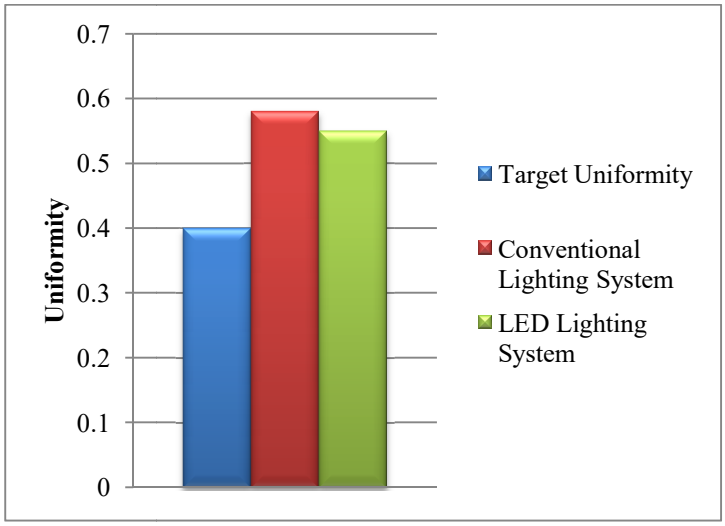


Fig. 9.258: Uniformity Comparison of Entrance

In Fig. 9.257, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.258, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

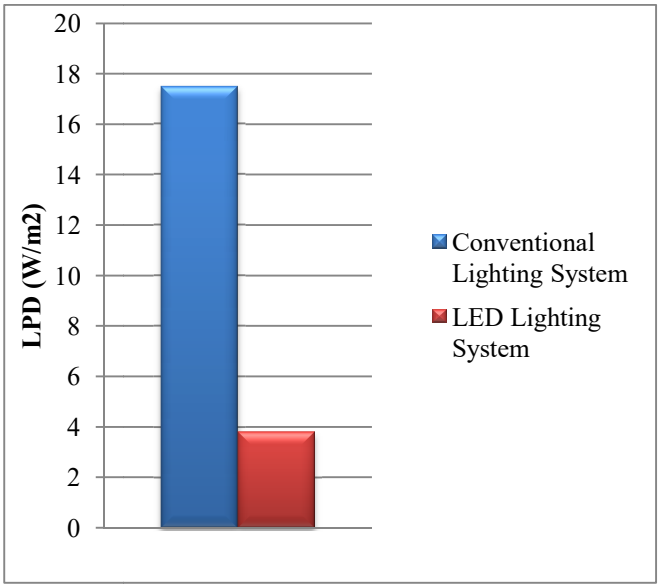


Fig. 9.259: LPD Comparison of Entrance

In Fig. 9.259, LPD comparison is shown where LPD by using conventional luminaires is approx 4.58 times of using LED luminaires.

- **Existing IT Room 1**

The Illuminance parameter comparison is shown in Table 9.157 and Power Consumption comparison

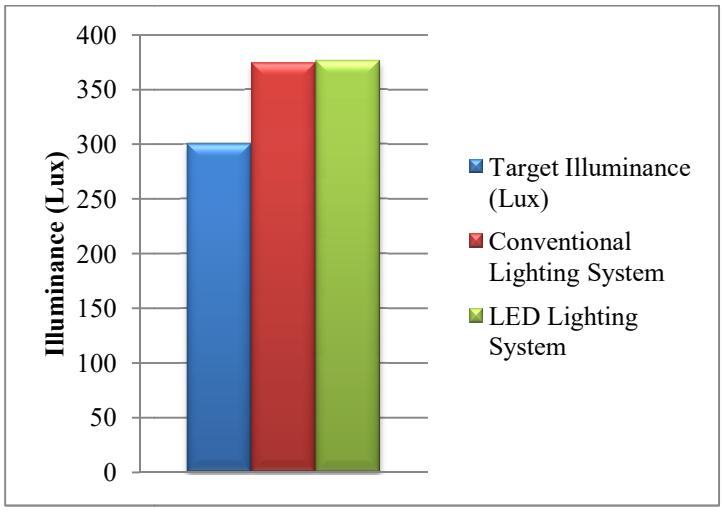


Fig. 9.260: Illuminance Comparison of Existing IT Room 1

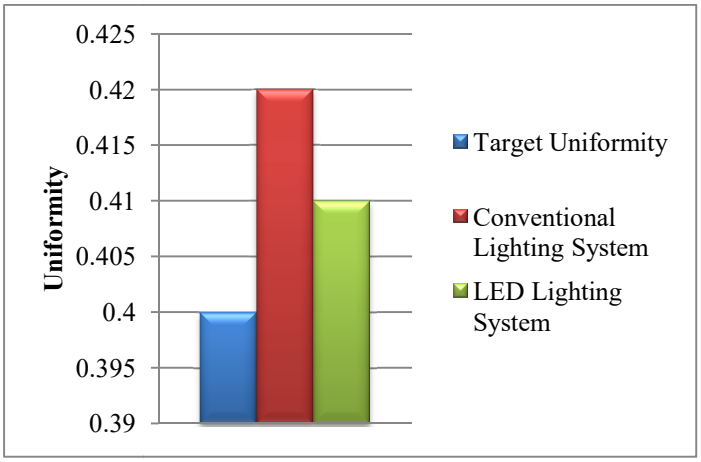


Fig. 9.261: Uniformity Comparison of Existing IT Room 1

In Fig. 9.260, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.261, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

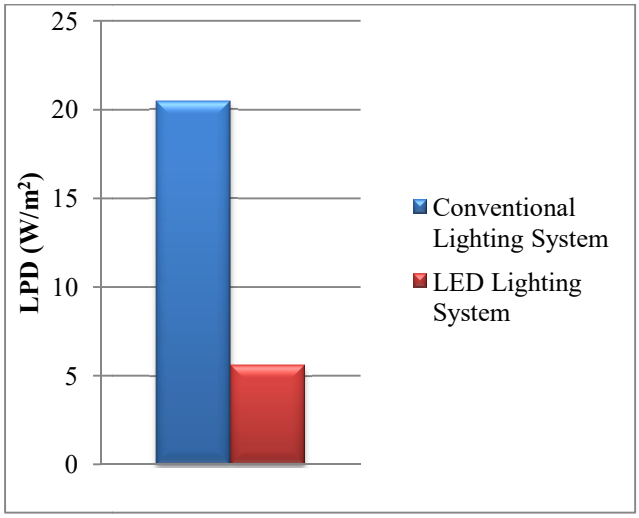


Fig. 9.262: LPD Comparison of Existing IT Room 1

In Fig. 9.262, LPD comparison is shown where LPD by using conventional luminaires is approx 3.64 times of using LED luminaires.

- **Existing IT Room**

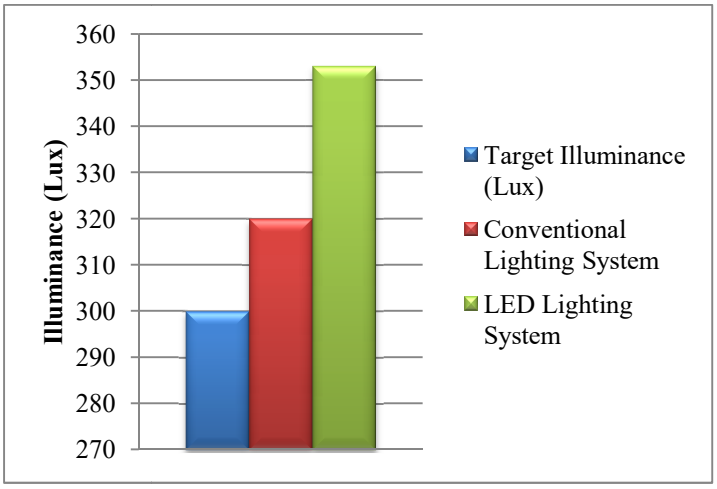


Fig. 9.263: Illuminance Comparison of Existing IT Room

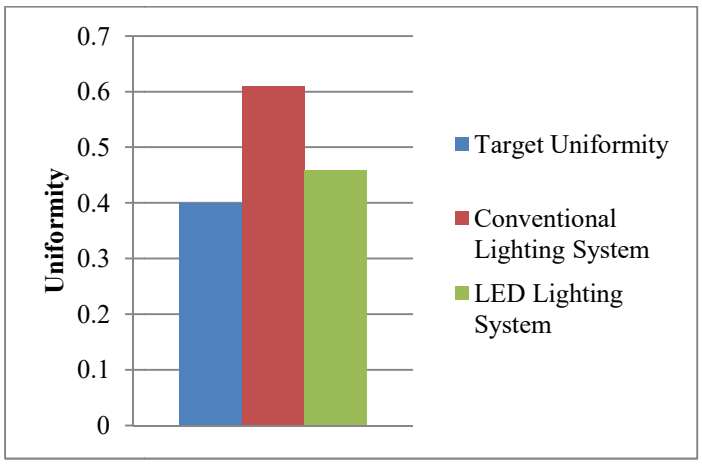


Fig. 9.264: Uniformity Comparison of Existing IT Room

In Fig. 9.263, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.264, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

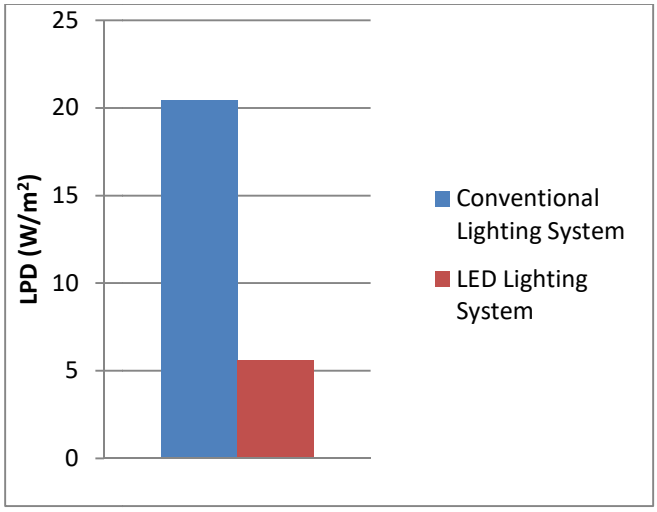


Fig. 9.265: LPD Comparison of Existing IT Room

In Fig. 9.265, LPD comparison is shown where LPD by using conventional luminaires is approx 4.12 times of using LED luminaires.

- **Head of Section**

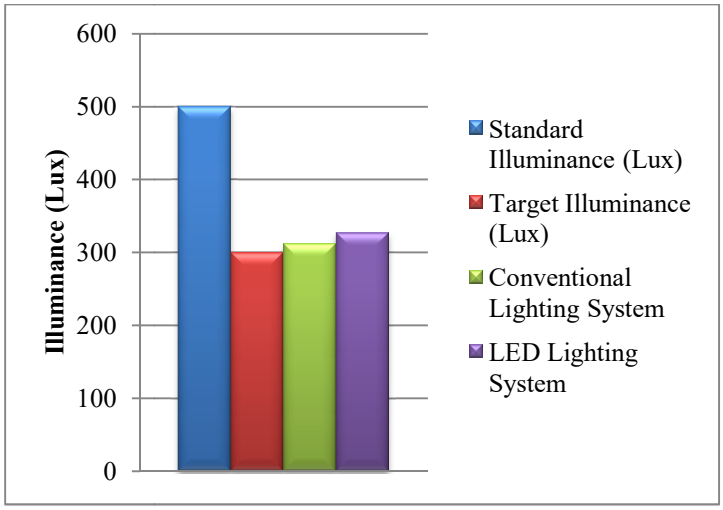


Fig. 9.266: Illuminance Comparison of Head of Section

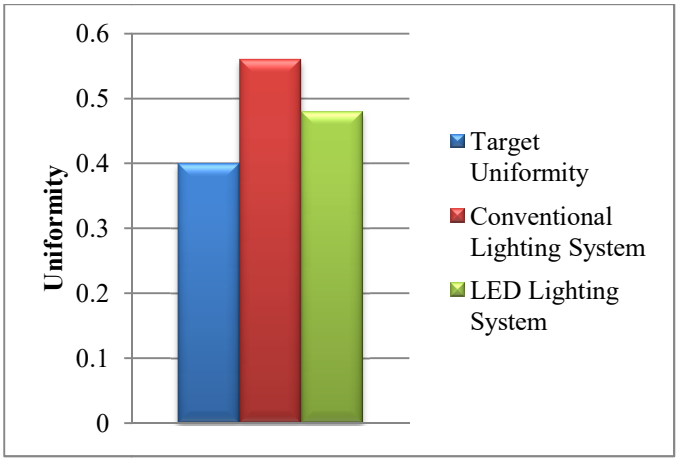


Fig. 9.267: Uniformity Comparison of Head of Section

In Fig. 9.266, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.267, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

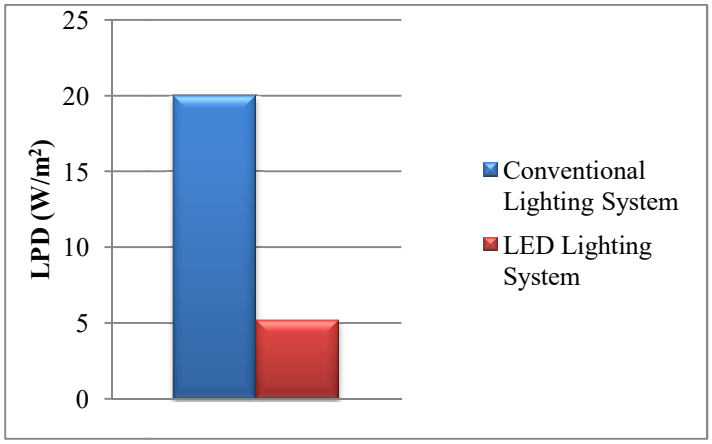


Fig. 9.268: LPD Comparison of Head of Section

In Fig. 9.268, LPD comparison is shown where LPD by using conventional luminaires is 3.84 times of using LED luminaires.

- **Officer's Room**

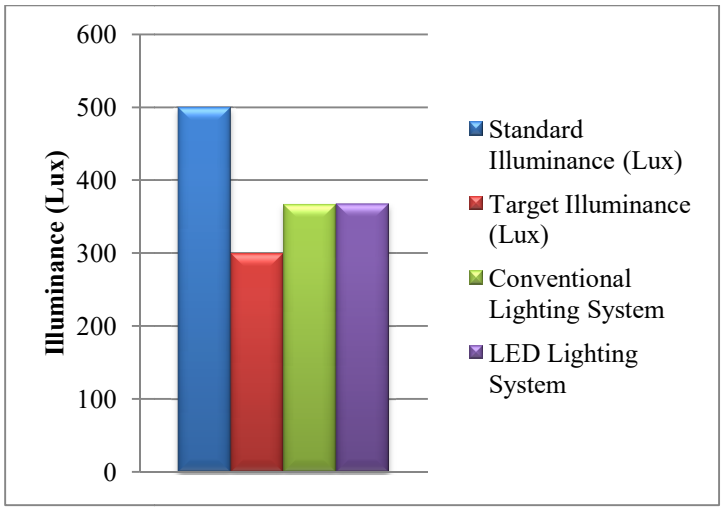


Fig. 9.269: Illuminance Comparison of Officer's Room

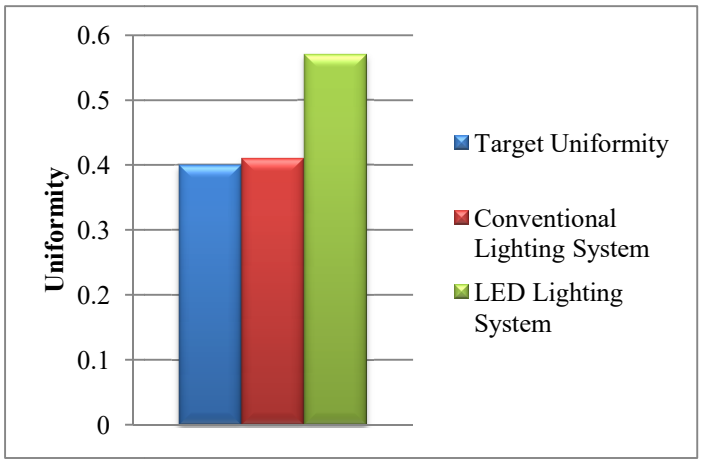


Fig. 9.270: Uniformity Comparison of Officer's Room

In Fig. 9.269, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved

in both cases. In Fig. 9.270, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

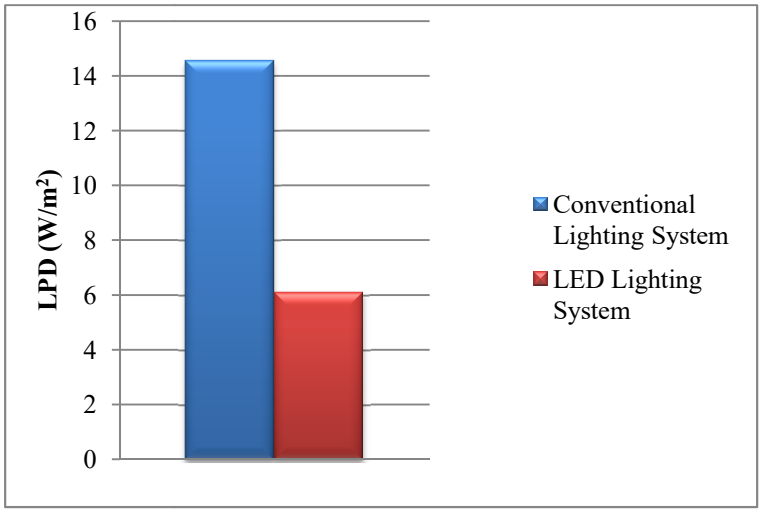


Fig. 9.271: LPD Comparison of Officer's Room

In Fig. 9.271, LPD comparison is shown where LPD by using conventional luminaires is 2.38 times of using LED luminaires.

➢ **Pantry 1**

The Illuminance parameter comparison is shown in Table 9.165 and Power Consumption comparison is shown in Table 9.166.

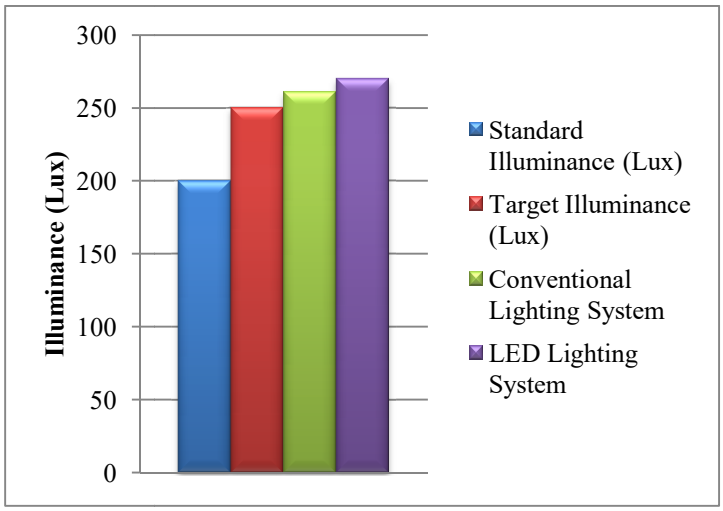


Fig. 9.272: Illuminance Comparison of Pantry 1

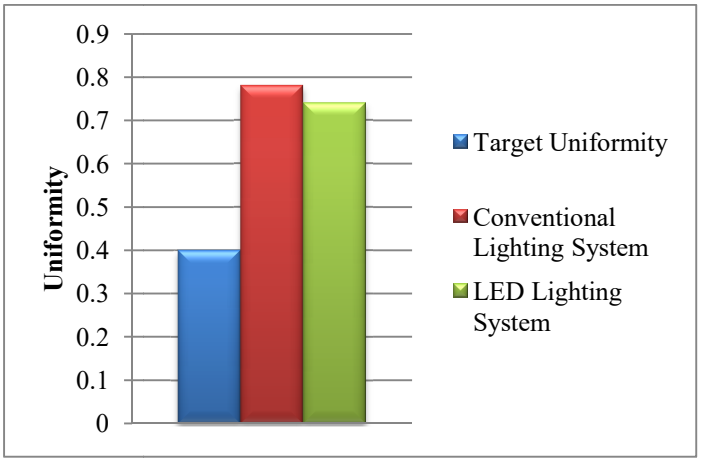


Fig. 9.273: Uniformity Comparison of Pantry 1

In Fig. 9.272, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.273, the uniformity comparison is shown where uniformity achieved by using Conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

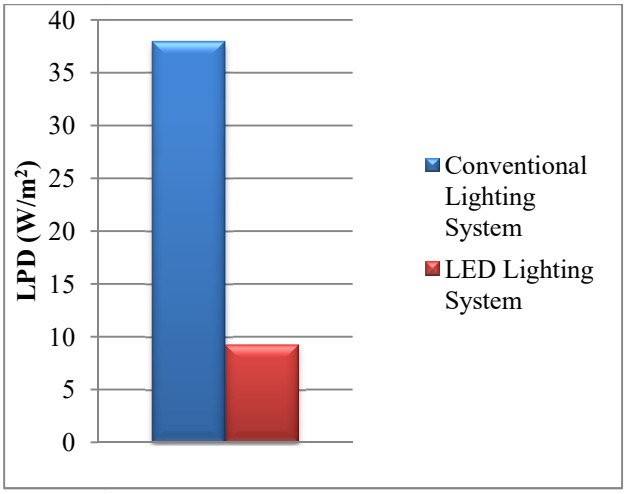


Fig. 9.274: LPD Comparison of Pantry 1

In Fig. 9.274, LPD comparison is shown where LPD by using conventional luminaires is approx 4.08 times of using LED luminaires.

- **Pantry 2**

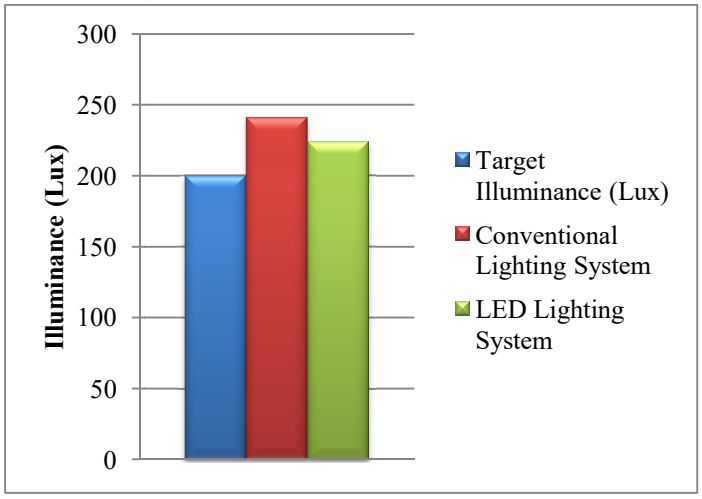


Fig. 9.275: Illuminance Comparison of Pantry 2

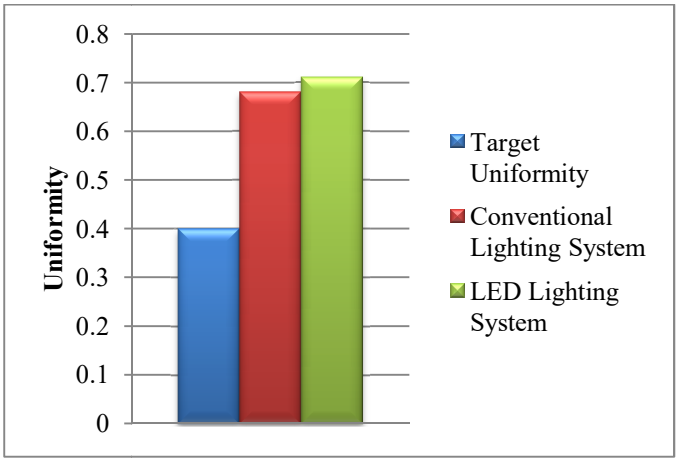


Fig. 9.276: Uniformity Comparison of Pantry 2

In Fig. 9.275, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than LED the luminaires. Also target illuminance is achieved in both cases. In Fig. 9.276, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

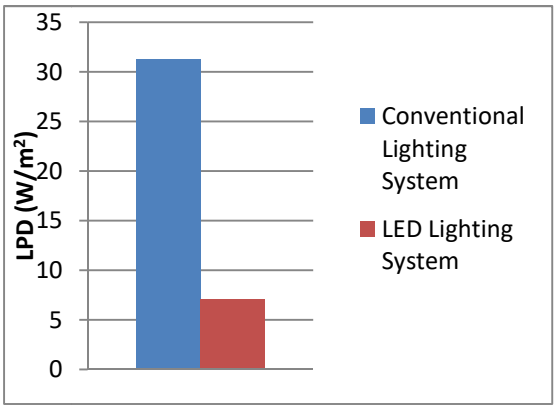


Fig. 9.277: LPD Comparison of Pantry 2

In Fig. 9.277, LPD comparison is shown where LPD by using conventional luminaires is approx 4.39 times of using LED luminaires.

➢ **Pantry**

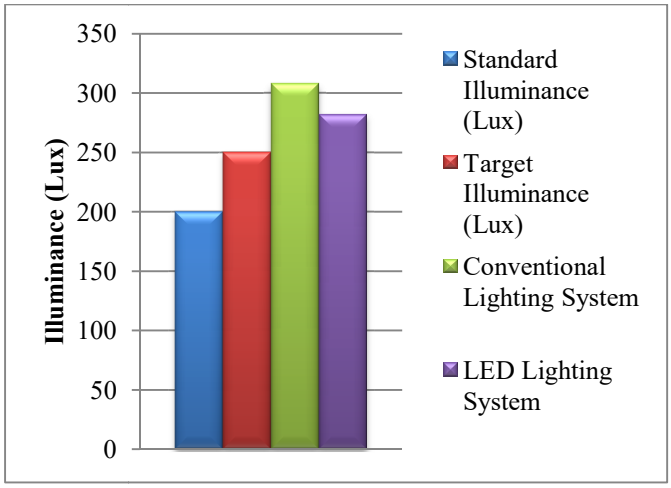


Fig. 9.278: Illuminance Comparison of Pantry

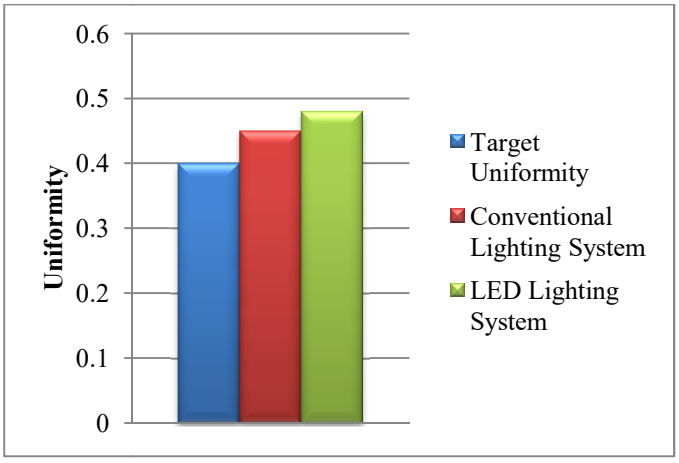


Fig. 9.279: Uniformity Comparison of Pantry

In Fig. 9.278, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than LED the luminaires. Also target illuminance is achieved in both cases. In Fig. 9.279, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

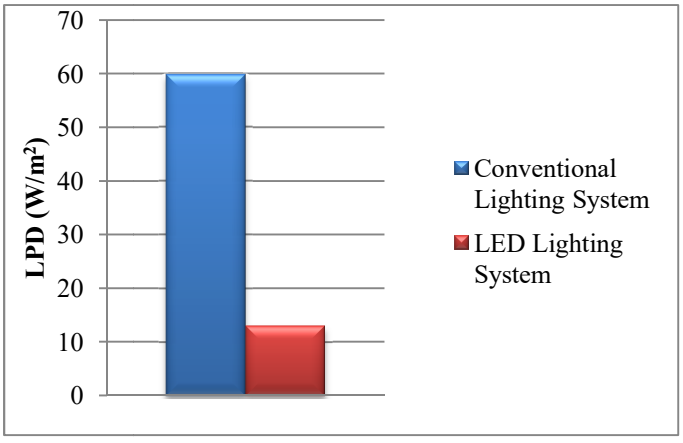


Fig. 9.280: LPD Comparison of Pantry

In Fig. 9.280, LPD comparison is shown where LPD by using conventional luminaires is 356.80% higher than using LED luminaires.

- **Photocopier Room**

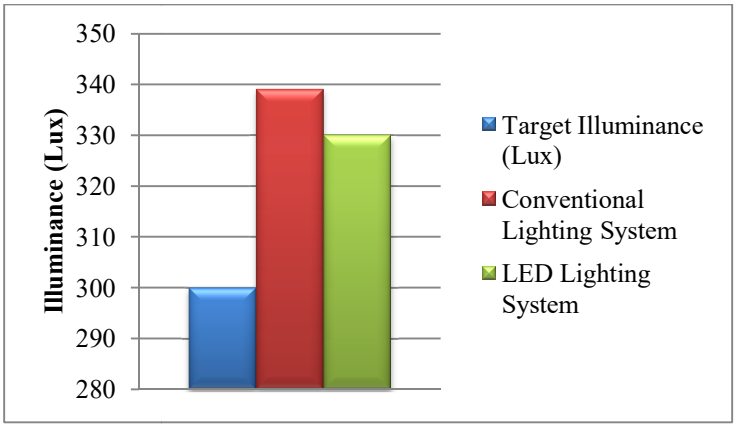


Fig. 9.281: Illuminance Comparison of Photocopier Room

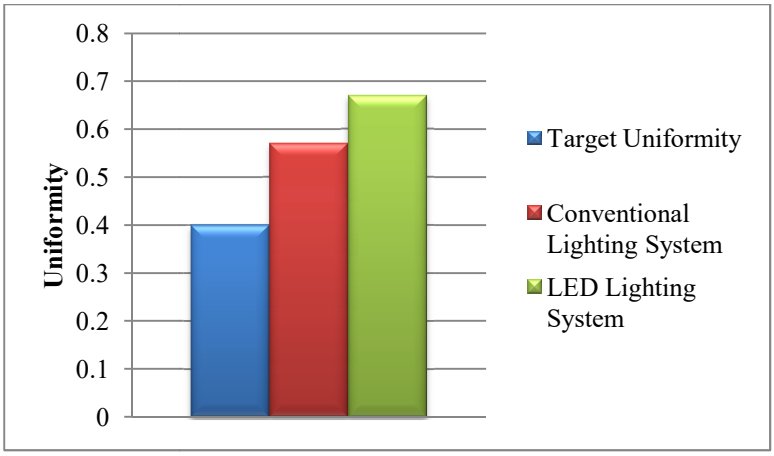


Fig. 9.282: Uniformity Comparison of Photocopier Room

In Fig. 9.281, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than LED the luminaires. Also target illuminance is achieved in both cases. In Fig. 9.282, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

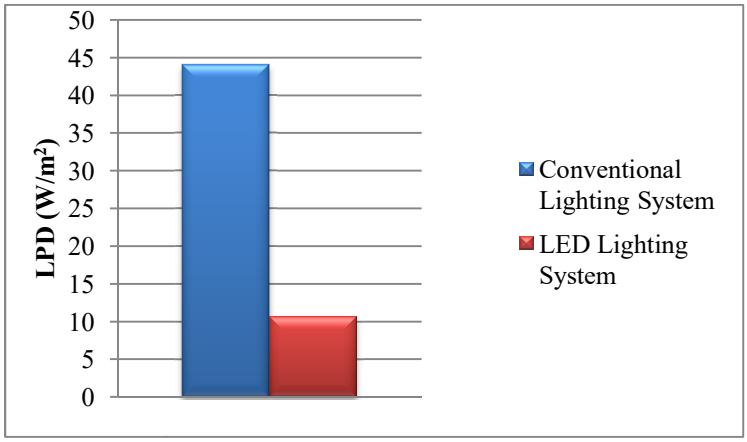


Fig. 9.283: LPD Comparison of Photocopier Room

In Fig. 9.283, LPD comparison is shown where LPD by using conventional luminaires is approx 4.11 times of using LED luminaires.

- **Reception Area**

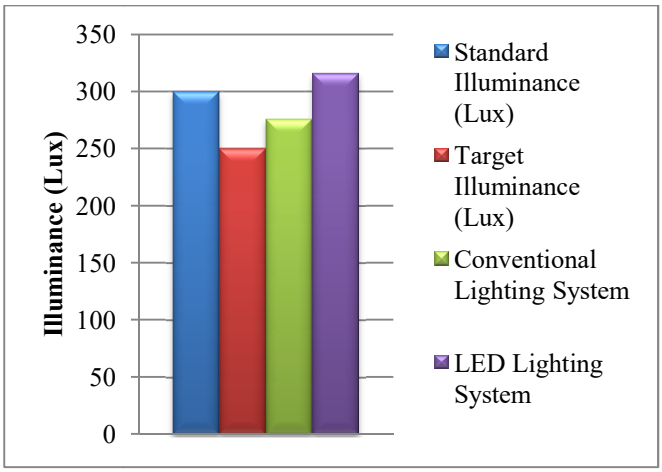


Fig. 9.284: Illuminance Comparison of Reception Area

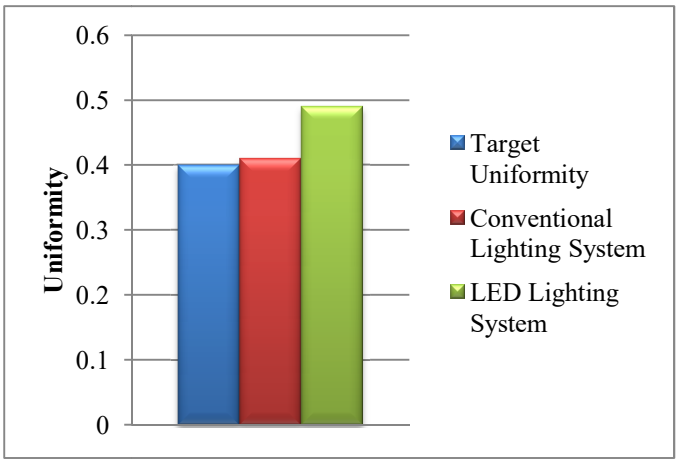


Fig. 9.285: Uniformity Comparison of Reception Area

In Fig. 9.284, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than conventional the luminaires. Also target illuminance is achieved in both cases. In Fig. 9.285, the uniformity comparison is shown where uniformity achieved by using

LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

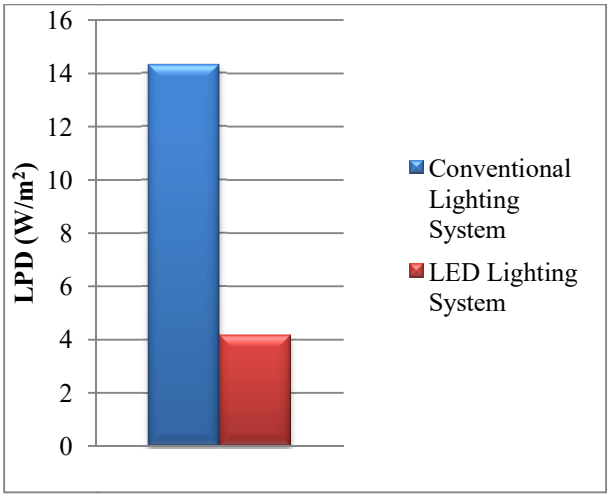


Fig. 9.286: LPD Comparison of Reception Area

In Fig. 9.286, LPD comparison is shown where LPD by using conventional luminaires is approx 3.43 times of using LED luminaires.

- **Secretary SE01**

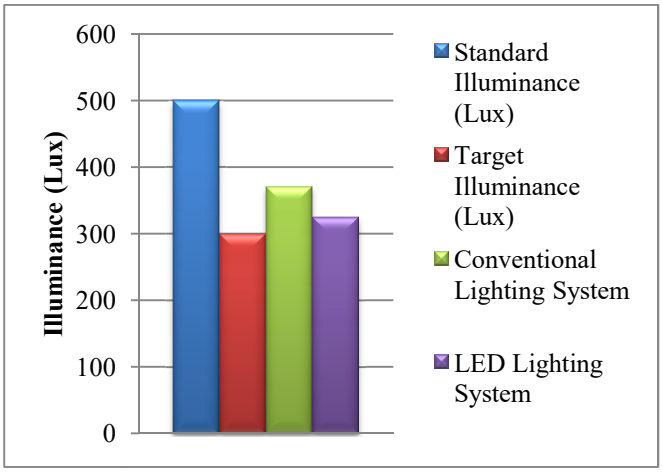


Fig. 9.287: Illuminance Comparison of Secretary SE01

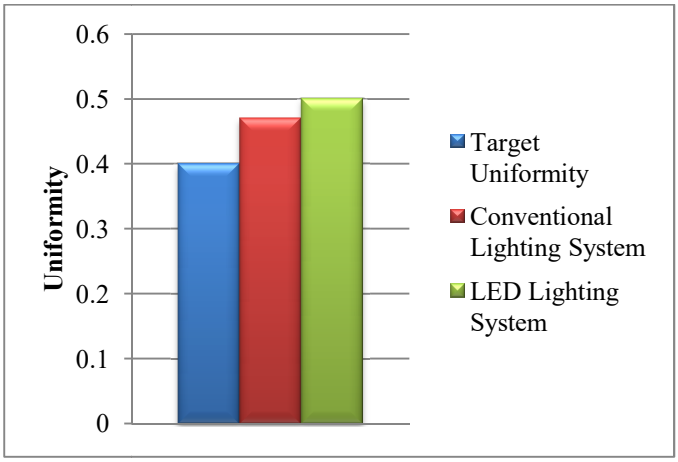


Fig. 9.288: Uniformity Comparison of Secretary SE01

In Fig. 9.287, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.288, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

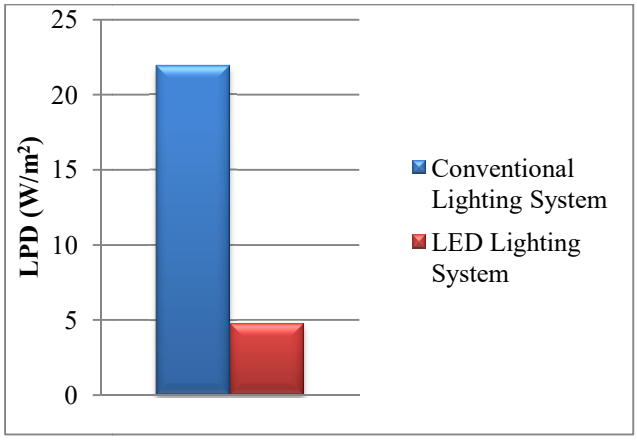


Fig. 9.289: LPD Comparison of Secretary SE01

In Fig. 9.289, LPD comparison is shown where LPD by using conventional luminaires is approx 4.57 times of using LED luminaires.

- **Security Check and Exit Lobby**

The Illuminance parameter comparison is shown in Table 9.177 and Power Consumption comparison

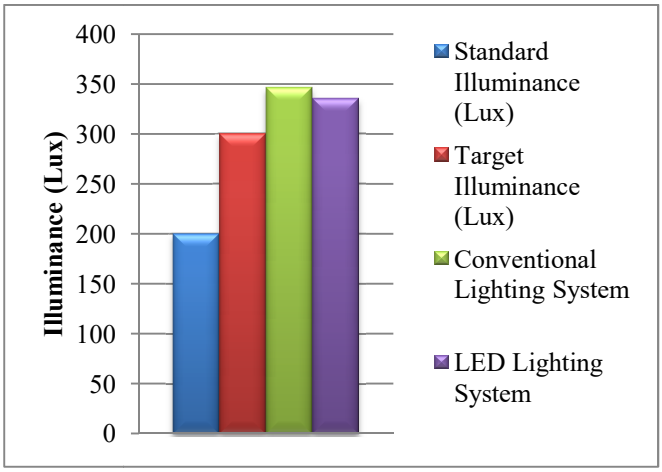


Fig. 9.290: Illuminance Comparison of Security Check and Exit Lobby

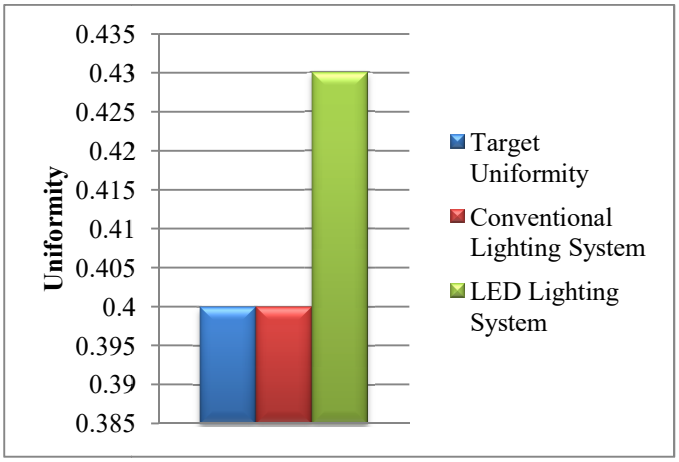


Fig. 9.291: Uniformity Comparison of Security Check and Exit Lobby

In Fig. 9.290, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.291, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

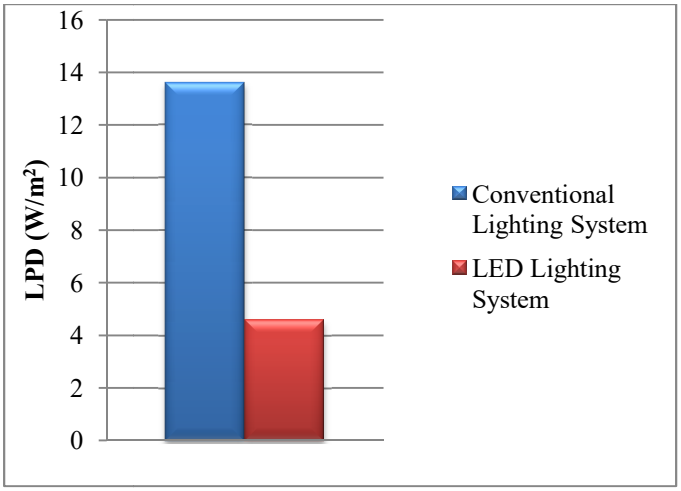


Fig. 9.292: LPD Comparison of Security Check and Exit Lobby

In Fig. 9.292, LPD comparison is shown where LPD by using conventional luminaires is approx 2.95 times of using LED luminaires.

- **Services**

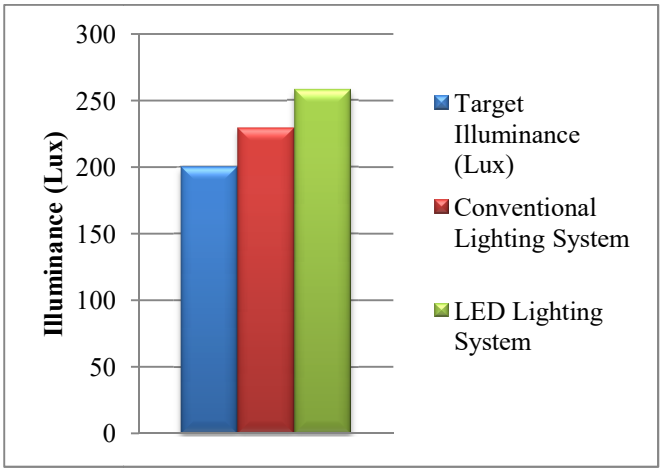


Fig. 9.293: Illuminance Comparison of Services

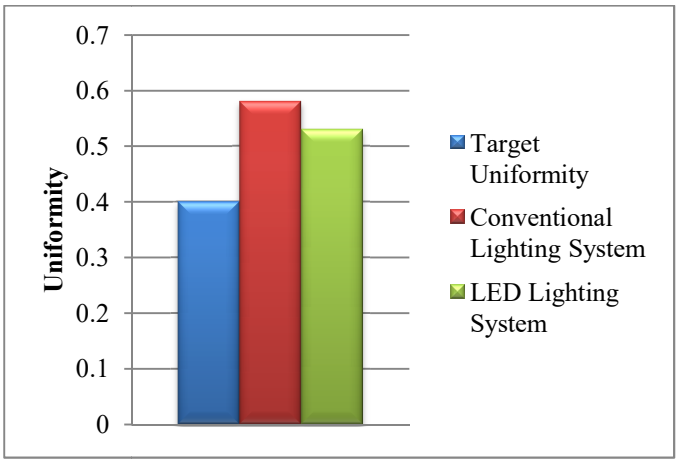


Fig. 9.294: Uniformity Comparison of Services

In Fig. 9.293, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.294, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

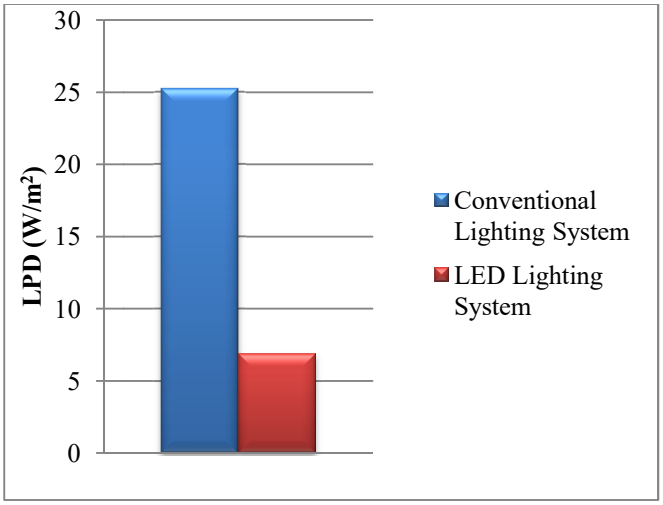


Fig. 9.295: LPD Comparison of Services

In Fig. 9.295, LPD comparison is shown where LPD by using conventional luminaires is approx 3.66 times of using LED luminaires.

- **ST 01**

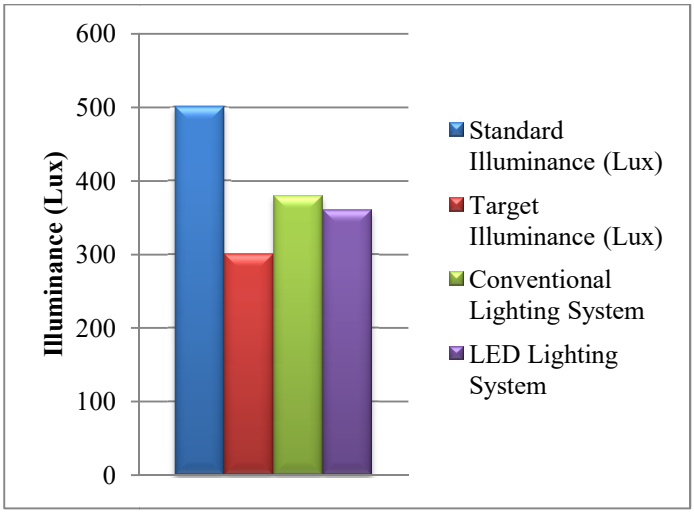


Fig. 9.296: Illuminance Comparison of ST 01

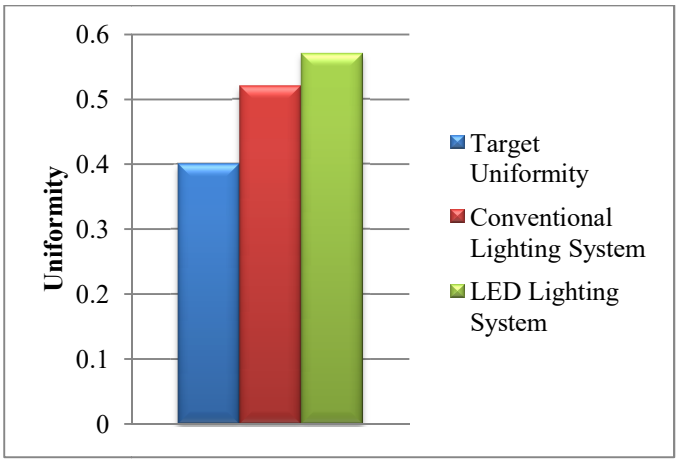


Fig. 9.297: Uniformity Comparison of ST 01

In Fig. 9.296, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.297, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

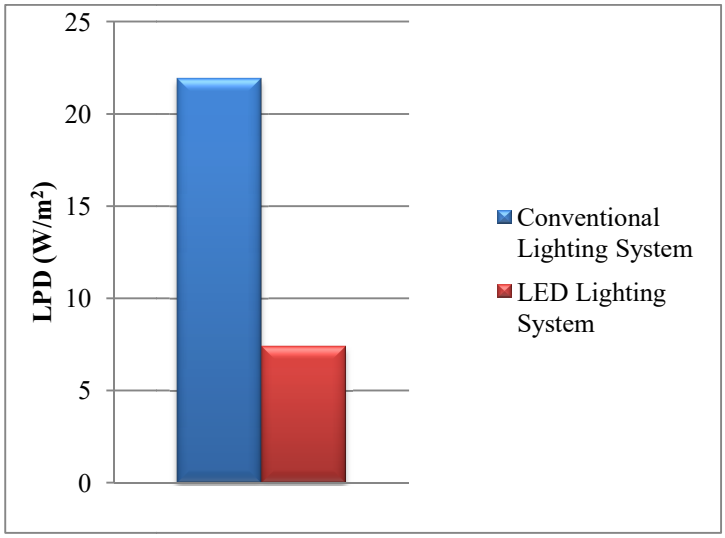


Fig. 9.298: LPD Comparison of ST 01

In Fig. 9.289, LPD comparison is shown where LPD by using conventional luminaires is approx 2.96 times of using LED luminaires.

➢ **ST 07**

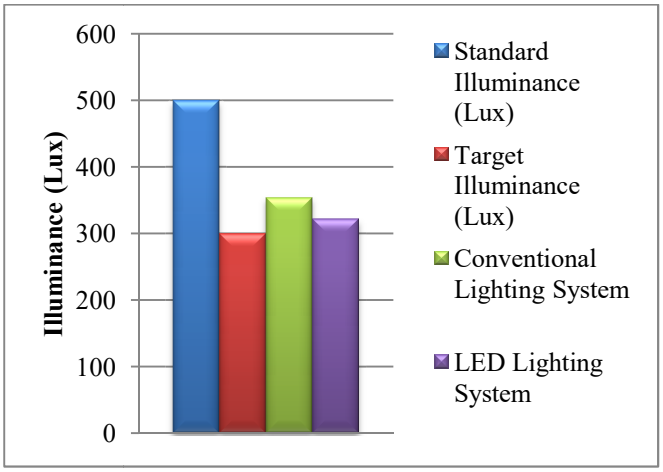


Fig. 9.299: Illuminance Comparison of ST 07

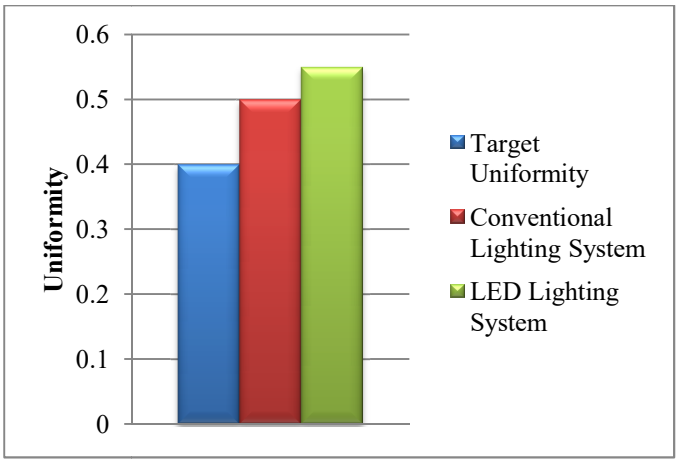


Fig. 9.300: Uniformity Comparison of ST 07

In Fig. 9.299, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.300, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

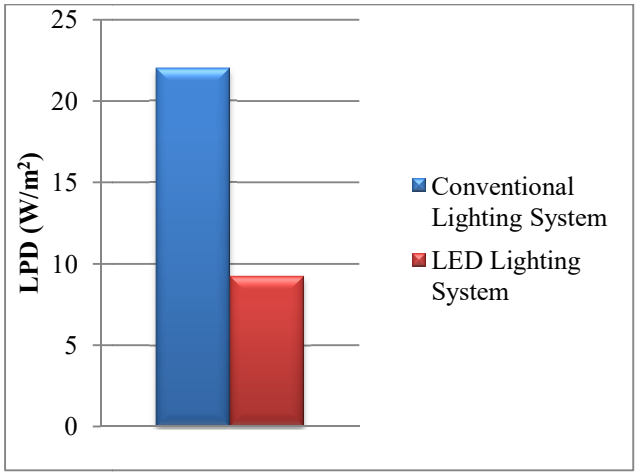


Fig. 9.300: LPD Comparison of ST 07

In Fig. 9.300, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

- **ST 08**

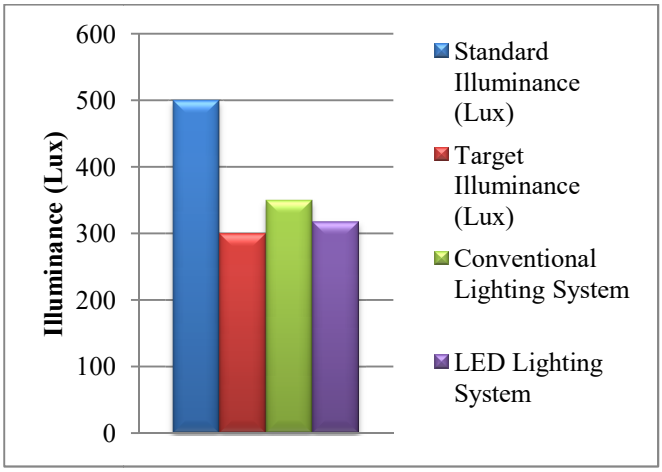


Fig. 9.301: Illuminance Comparison of ST 08

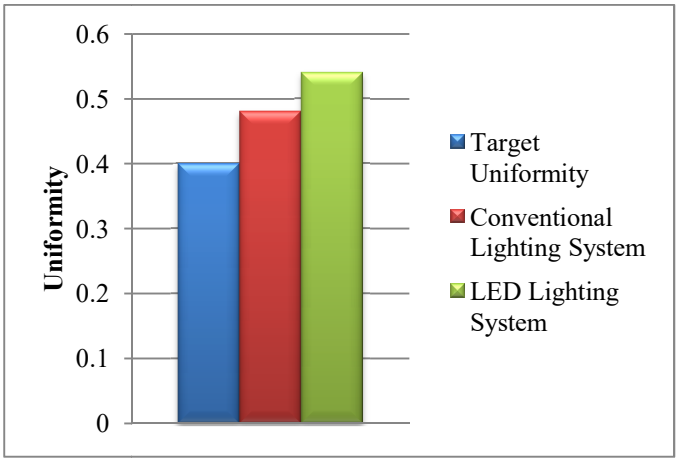


Fig. 9.302: Uniformity Comparison of ST 08

In Fig. 9.301, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.302, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

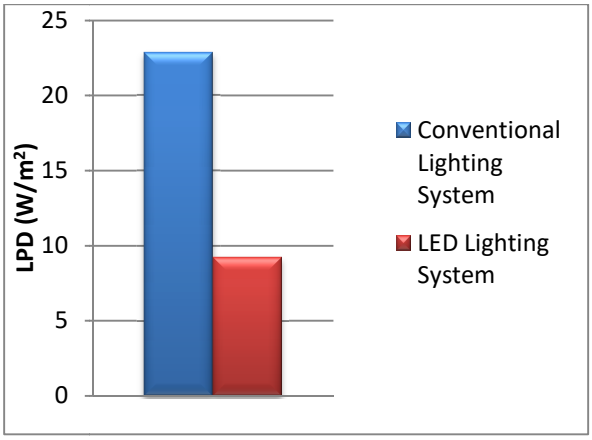


Fig. 9.303: LPD Comparison of ST 08

In Fig. 9.303, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

- **ST 09**

The Illuminance parameter comparison is shown in Table 9.187 and Power Consumption comparison

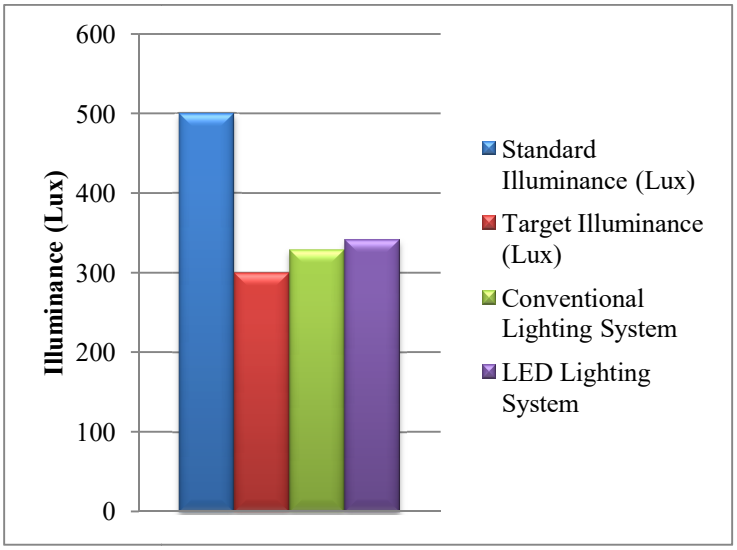


Fig. 9.304: Illuminance Comparison of ST 09

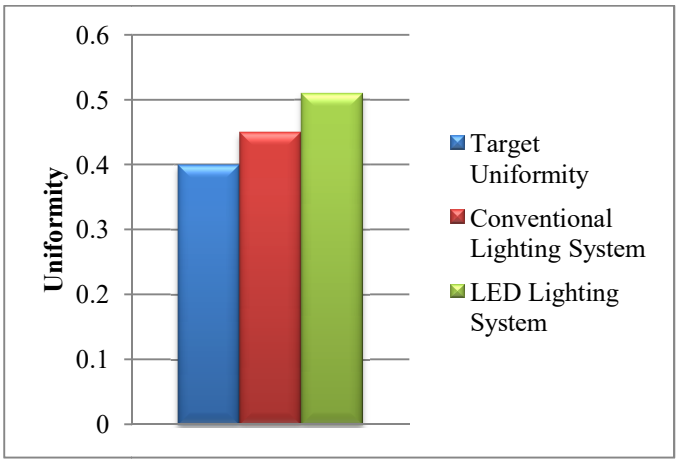


Fig. 9.305: Uniformity Comparison of ST 09

In Fig. 9.304, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.305, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

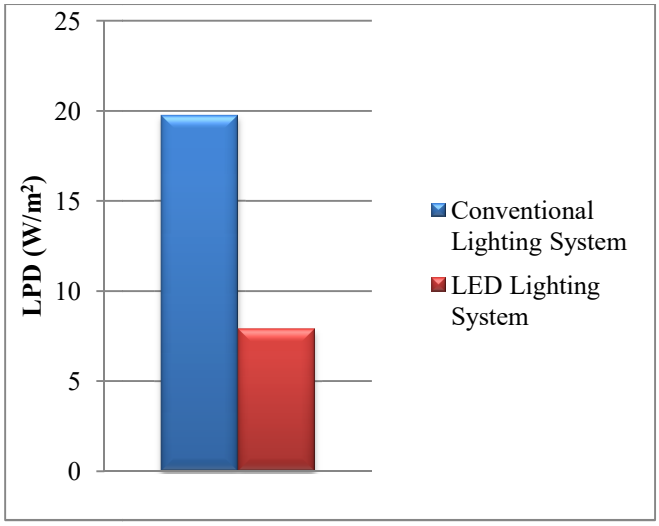


Fig. 9.306: LPD Comparison of ST 09

In Fig. 9.306, LPD comparison is shown where LPD by using conventional luminaires is approx 2.48 times of using LED luminaires.

- **ST 10**

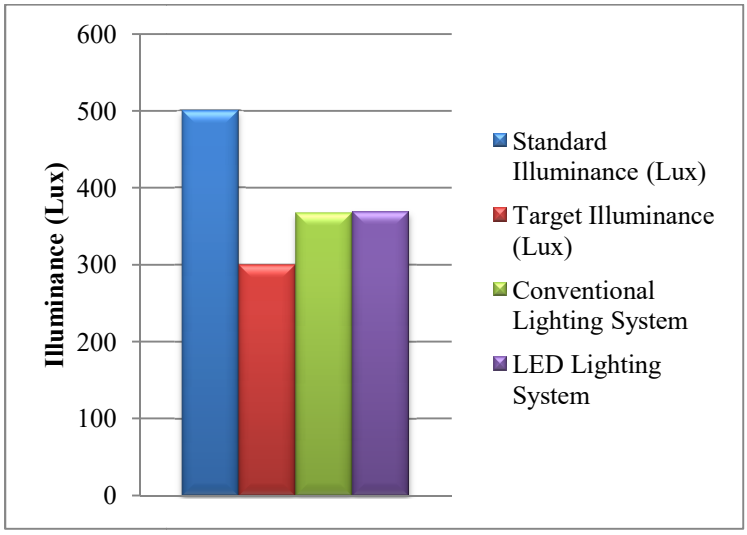


Fig. 9.307: Illuminance Comparison of ST 10

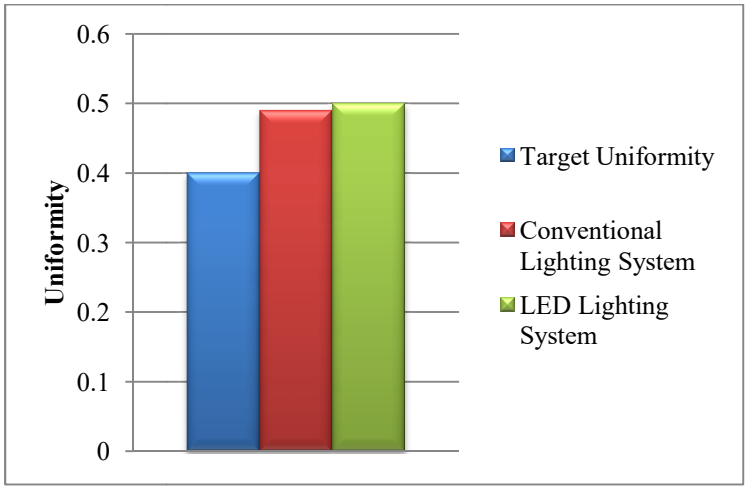


Fig. 9.308: Uniformity Comparison of ST 10

In Fig. 9.307, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.308, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

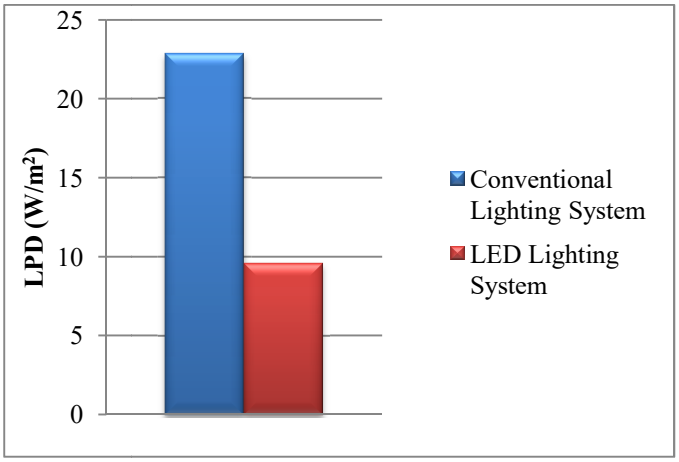


Fig. 9.309: LPD Comparison of ST 10

In Fig. 9.309, LPD comparison is shown where LPD by using conventional luminaires is approx 3.56 times of using LED luminaires.

- **ST 11**

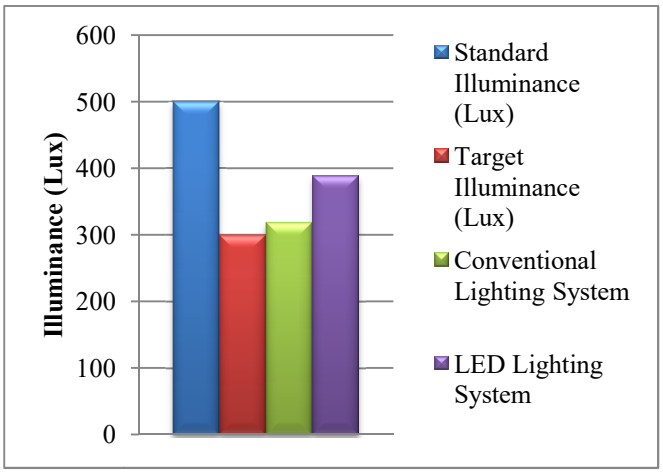


Fig. 9.310: Illuminance Comparison of ST 11

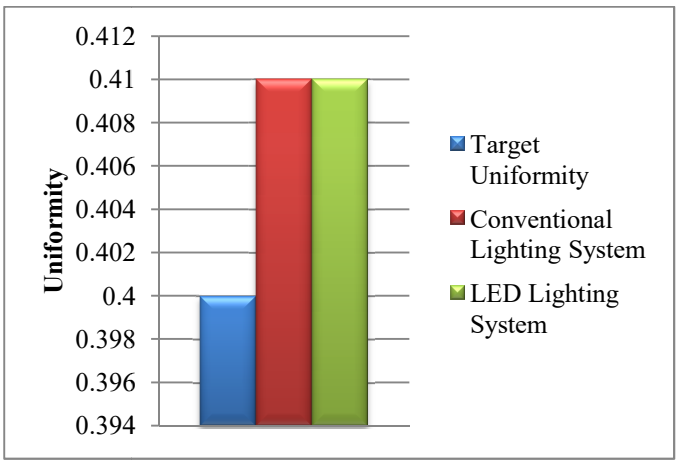


Fig. 9.311: Uniformity Comparison of ST 11

In Fig. 9.310, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.311, the uniformity comparison is shown where uniformity achieved by using

LED luminaires is same as the conventional luminaires. Also target illuminance is achieved in both cases.

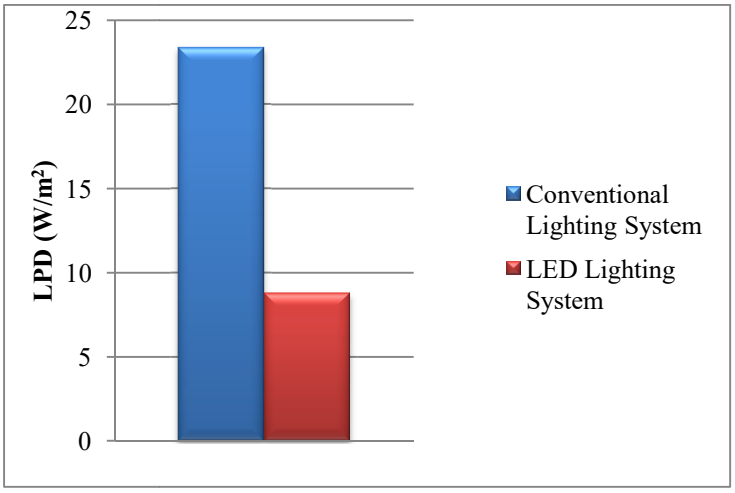


Fig. 9.312: LPD Comparison of ST 11

In Fig. 9.312, LPD comparison is shown where LPD by using conventional luminaires is approx 2.66 times of using LED luminaires.

- **ST 12**

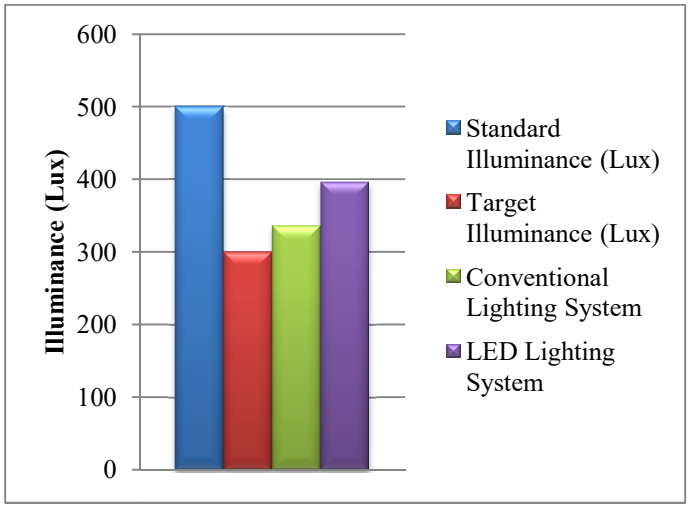


Fig. 9.313: Illuminance Comparison of ST 12

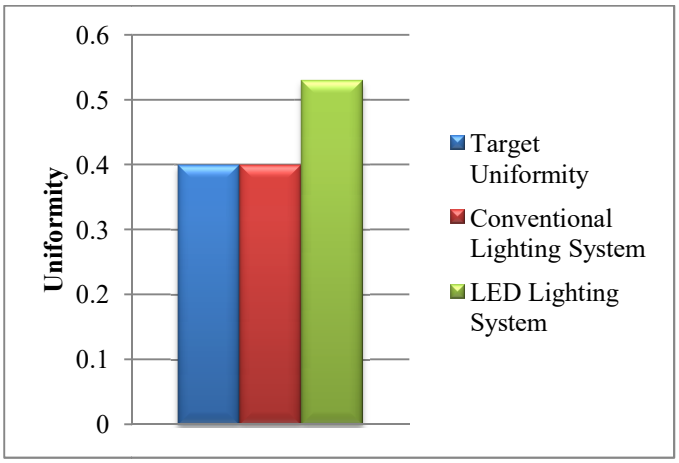


Fig. 9.314: Uniformity Comparison of ST 12

In Fig. 9.313, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.314, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

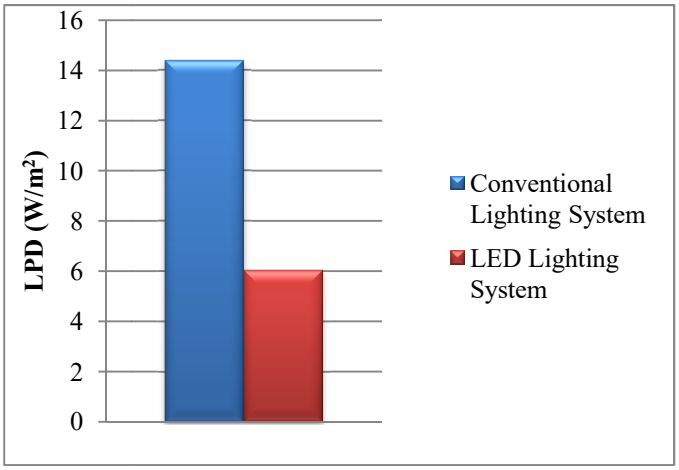


Fig. 9.315: LPD Comparison of ST 12

In Fig. 9.315, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

- **ST 15**

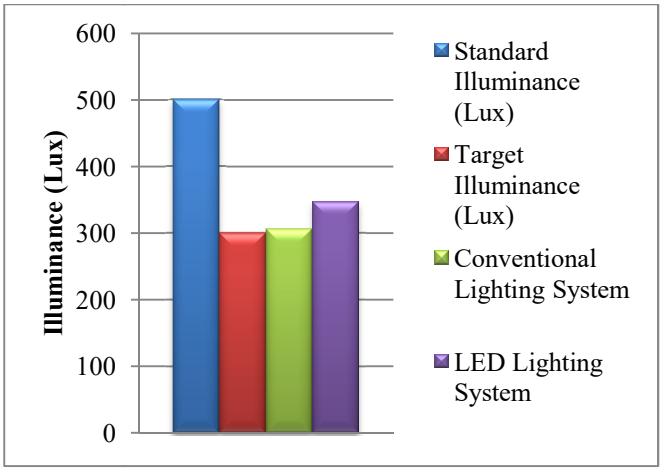


Fig. 9.316: Illuminance Comparison of ST 15

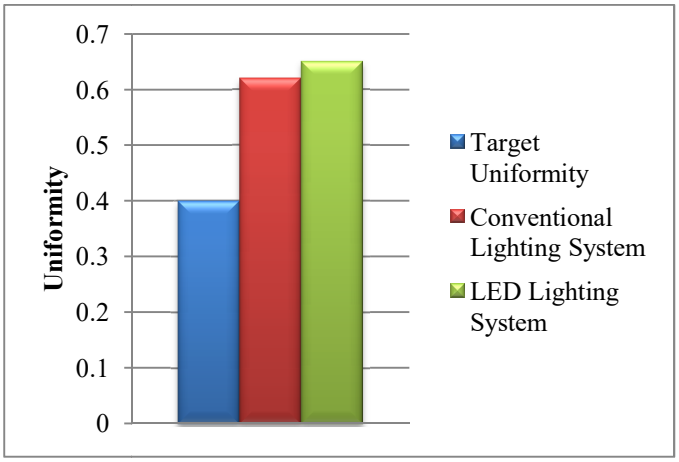


Fig. 9.317: Uniformity Comparison of ST 15

In Fig. 9.316, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.317, the uniformity comparison is shown where uniformity achieved by using LED luminaires is same as the conventional luminaires. Also target illuminance is achieved in both cases.

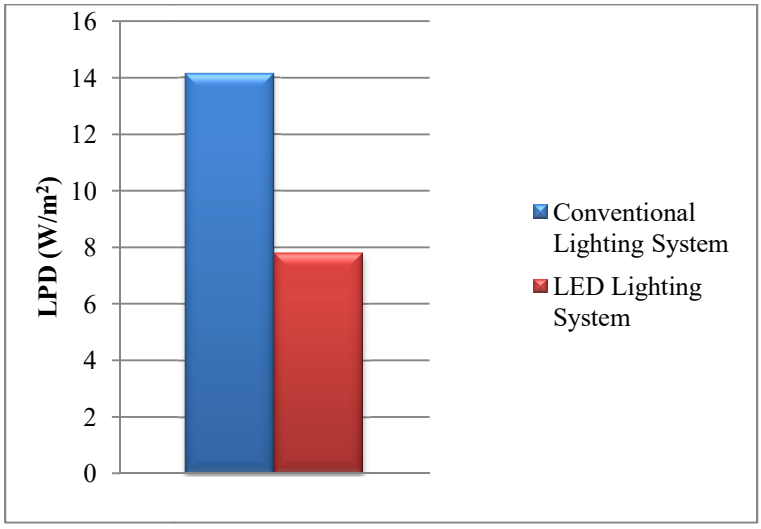


Fig. 9.318: LPD Comparison of ST 15

In Fig. 9.318, LPD comparison is shown where LPD by using conventional luminaires is approx 1.81 times of using LED luminaires.

- **ST 16**

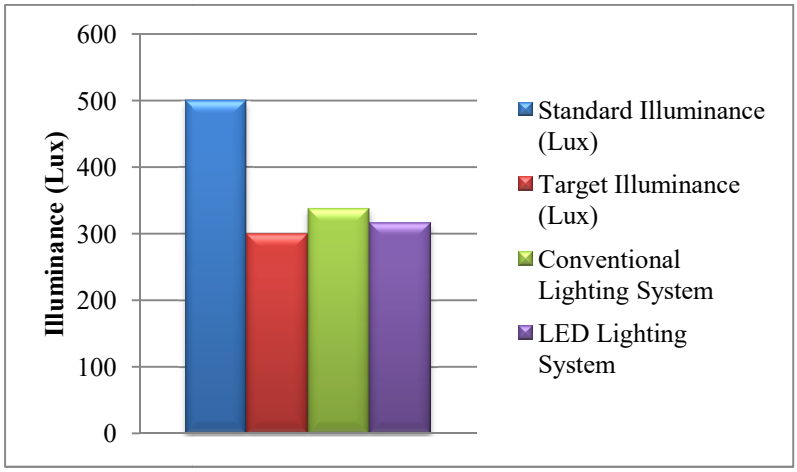


Fig. 9.319: Illuminance Comparison of ST 16

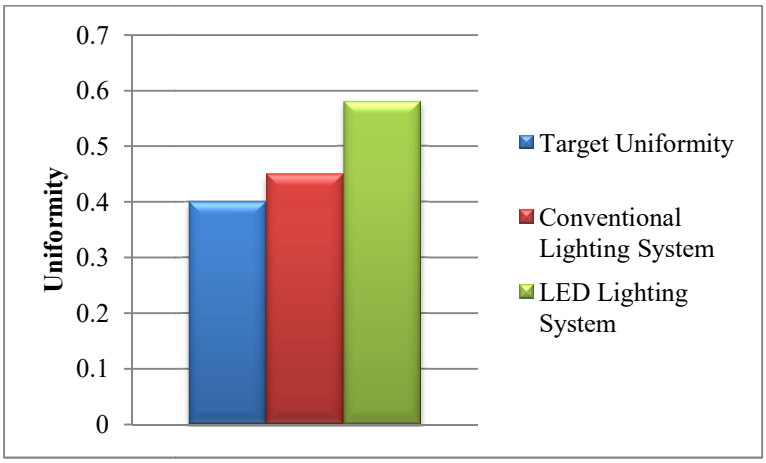


Fig. 9.320: Uniformity Comparison of ST 16

In Fig. 9.319, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases. In Fig. 9.320, the uniformity comparison is shown where uniformity achieved by using LED luminaires is same as the conventional luminaires. Also target illuminance is achieved in both cases.

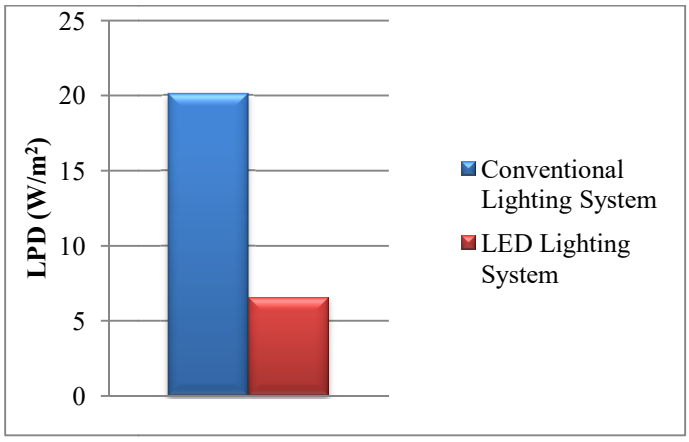


Fig. 9.321: LPD Comparison of ST 16

In Fig. 9.321, LPD comparison is shown where LPD by using conventional luminaires is approx 3.08 times of using LED luminaires.

➢ **ST 17**

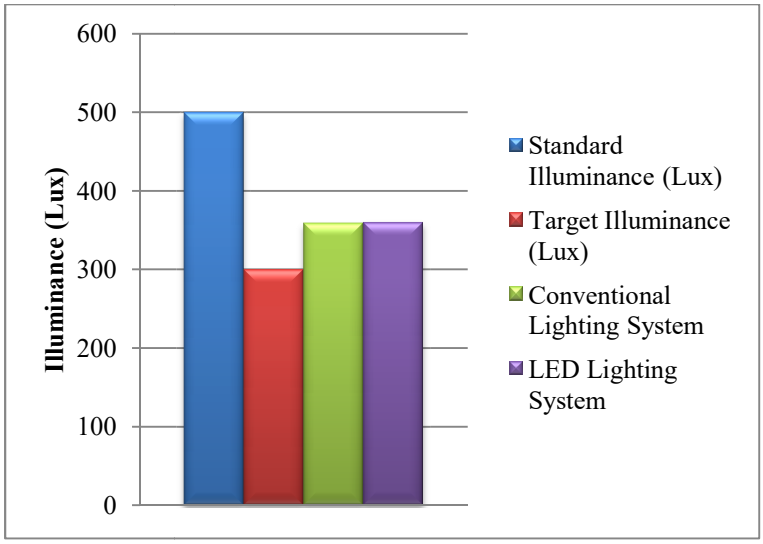


Fig. 9.322: Illuminance Comparison of ST 17

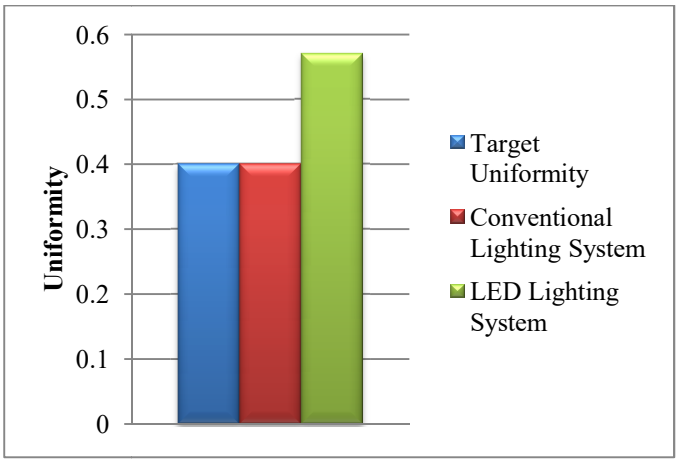


Fig. 9.323: Uniformity Comparison of ST 17

In Fig. 9.322, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.323, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

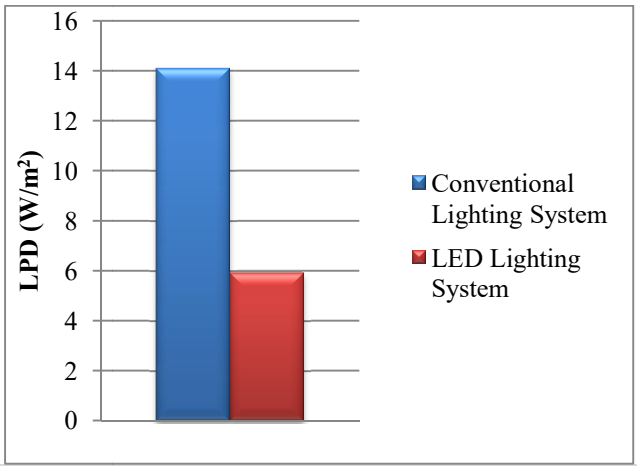


Fig. 9.324: LPD Comparison of ST 17

In Fig. 9.324, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

- **ST 18**

The Illuminance parameter comparison is shown in Table 9.201 and Power Consumption comparison

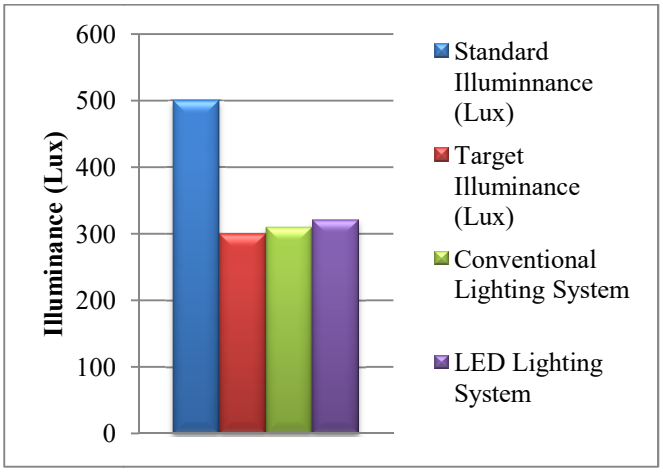


Fig. 9.325: Illuminance Comparison of ST 18

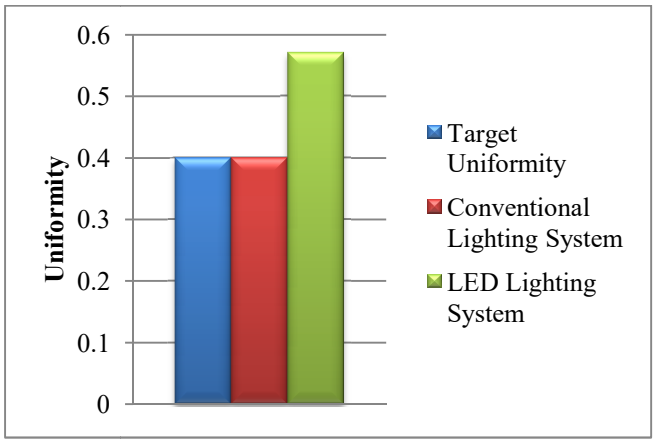


Fig. 9.326: Uniformity Comparison of ST 18

In Fig. 9.325, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.326, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

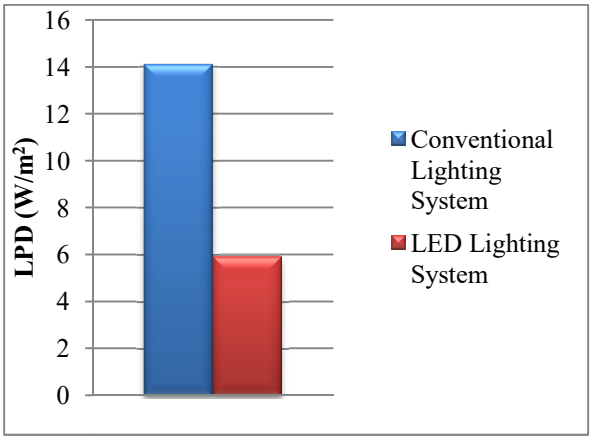


Fig. 9.327: LPD Comparison of ST 18

In Fig. 9.327, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

➢ **ST 19**

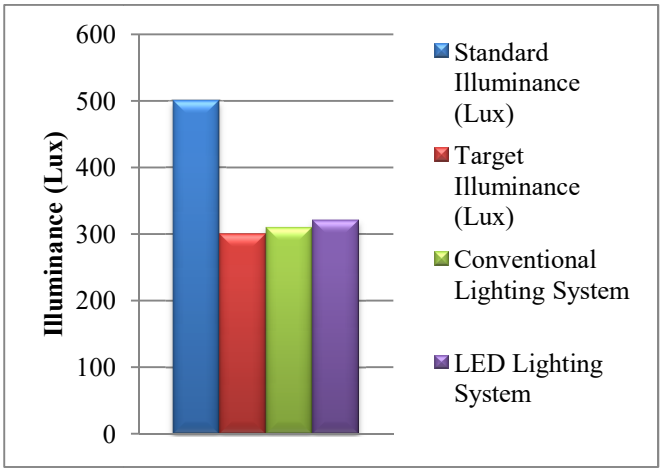


Fig. 9.328: Illuminance Comparison of ST 19

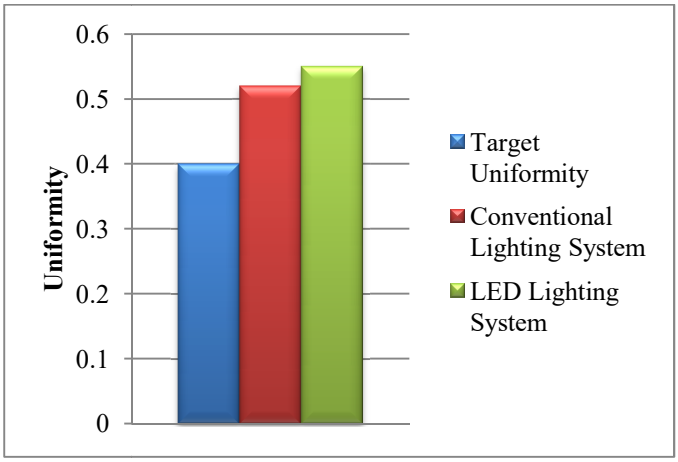


Fig. 9.329: Uniformity Comparison of ST 19

In Fig. 9.328, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.329, the uniformity comparison is shown where uniformity achieved by using

LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

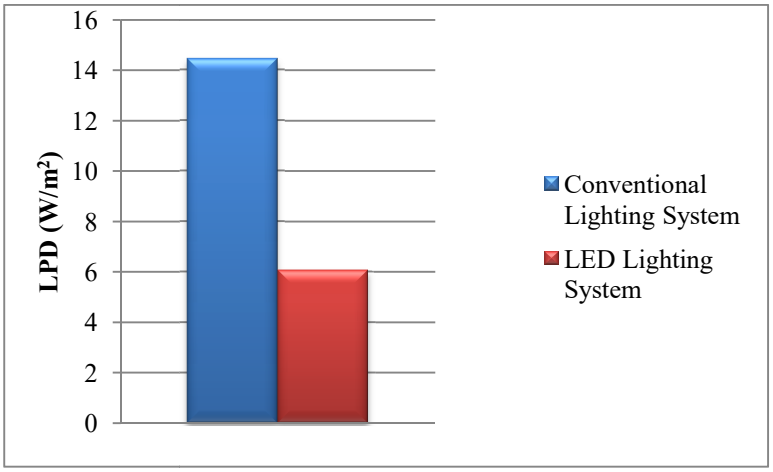


Fig. 9.330: LPD Comparison of ST 19

In Fig. 9.330, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

- **ST 20**

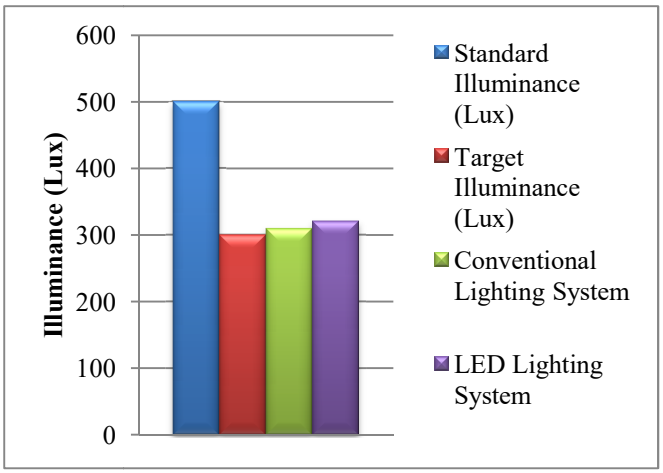


Fig. 9.331: Illuminance Comparison of ST 20

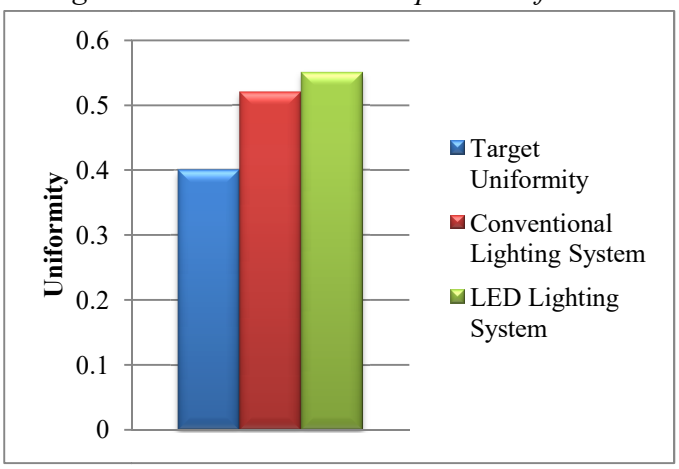


Fig. 9.332: Uniformity Comparison of ST 20

In Fig. 9.331, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.332, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

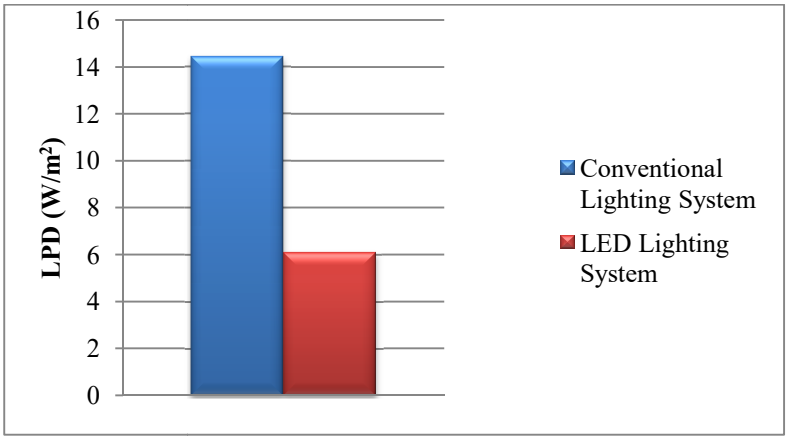


Fig. 9.333: LPD Comparison of ST 20

In Fig. 9.333, LPD comparison is shown where LPD by using conventional luminaires is approx 2.38 times of using LED luminaires.

- **ST 21**

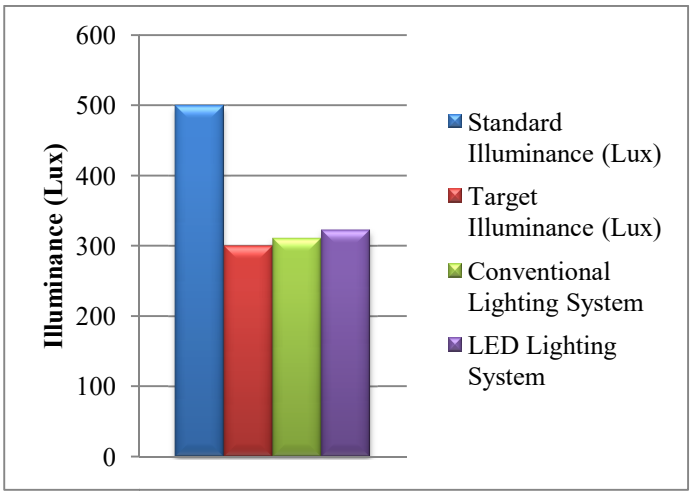


Fig. 9.334: Illuminance Comparison of ST 21

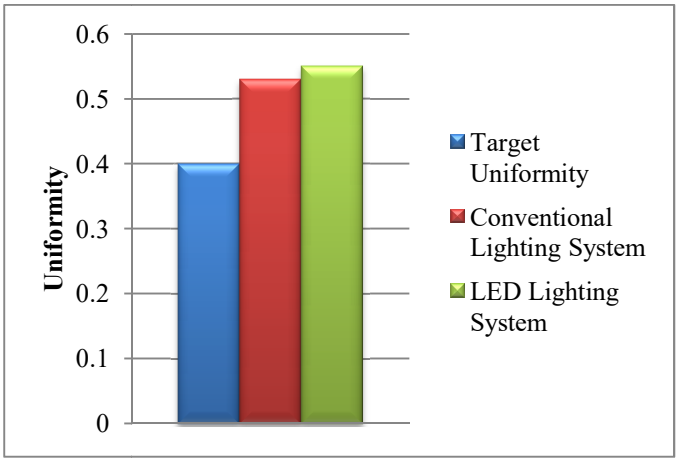


Fig. 9.335: Uniformity Comparison of ST 21

In Fig. 9.334, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.335, the uniformity comparison is shown where uniformity achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

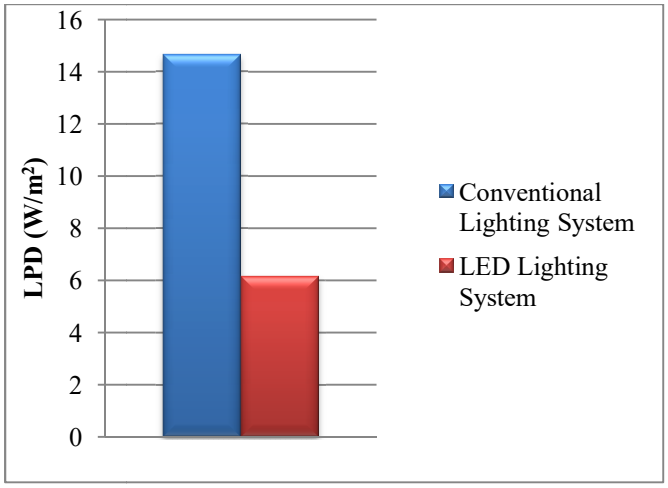


Fig. 9.336: LPD Comparison of ST 21

In Fig. 9.336, LPD comparison is shown where LPD by using conventional luminaires is 2.38 times of using LED luminaires.

- **ST 22**

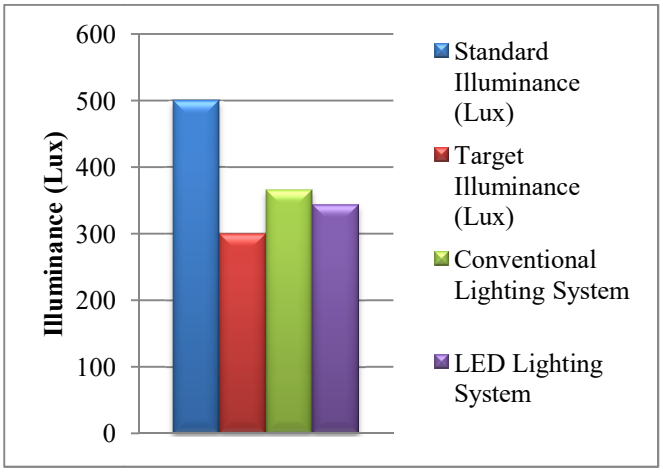


Fig. 9.337: Illuminance Comparison of ST 22

In Fig. 9.337, the average illuminance comparison is shown where average illuminance achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

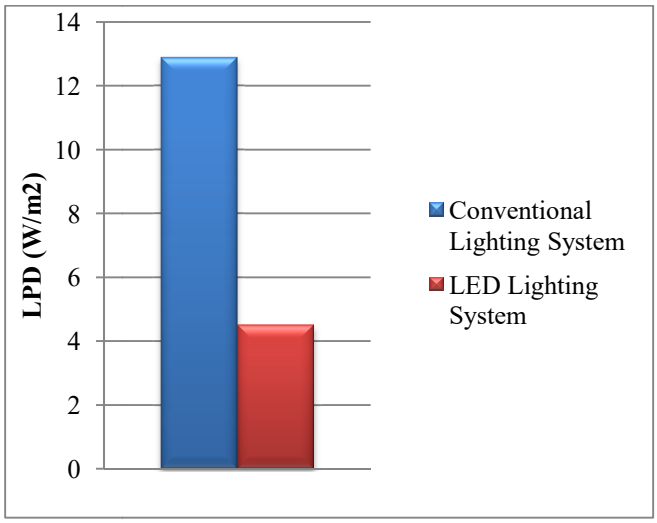


Fig. 9.338: LPD Comparison of ST 22

In Fig. 9.338, LPD comparison is shown where LPD by using conventional luminaires is approx 2.85 times of using LED luminaires.

- **STORE**

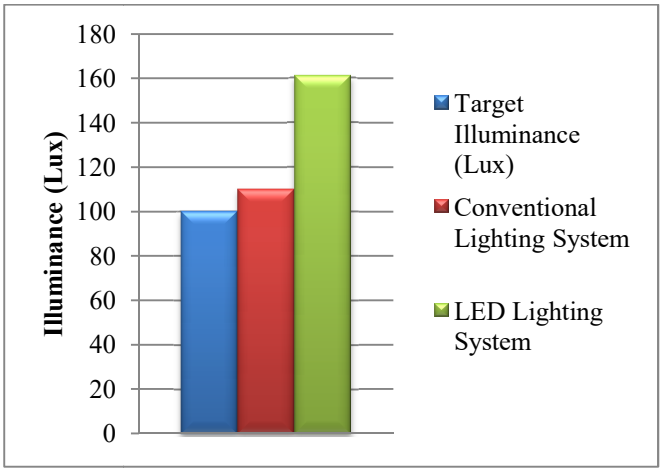


Fig. 9.339: Illuminance Comparison of STORE

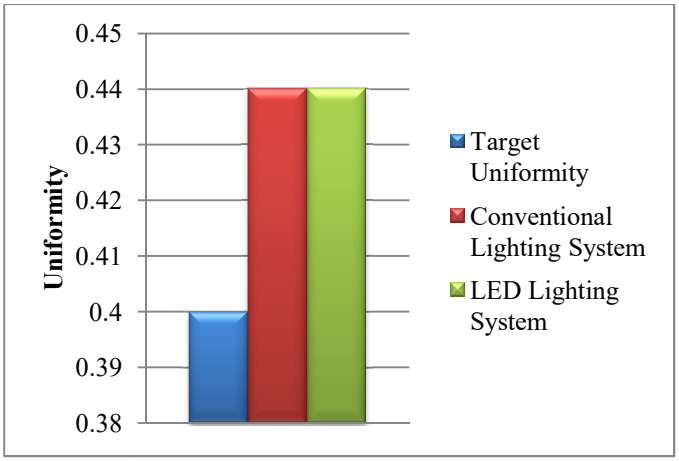


Fig. 9.340: Uniformity Comparison of STORE

In Fig. 9.339, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.340, the uniformity comparison is shown where uniformity achieved by using LED luminaires is as same as the conventional luminaires. Also target illuminance is achieved in both cases.

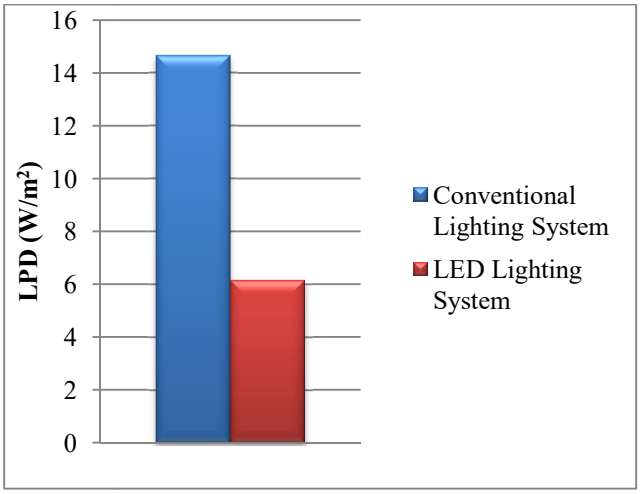


Fig. 9.341: LPD Comparison of STORE

In Fig. 9.341, LPD comparison is shown where LPD by using conventional luminaires is approx 2.75 times of using LED luminaires.

- **TOILET 1**

The Illuminance parameter comparison is shown in Table 9.213 and Power Consumption comparison

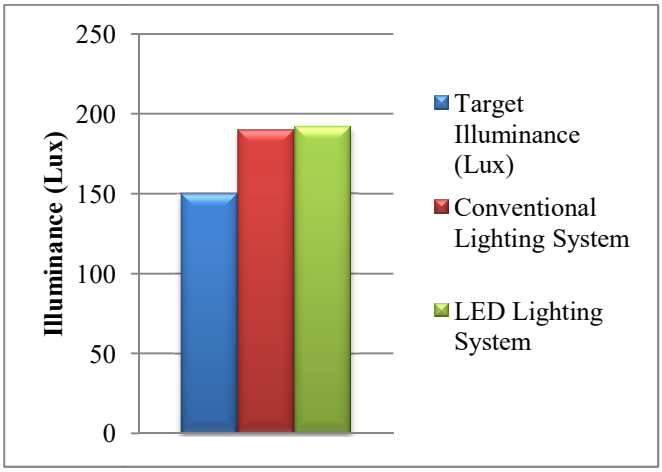


Fig. 9.342: Illuminance Comparison of TOILET 1

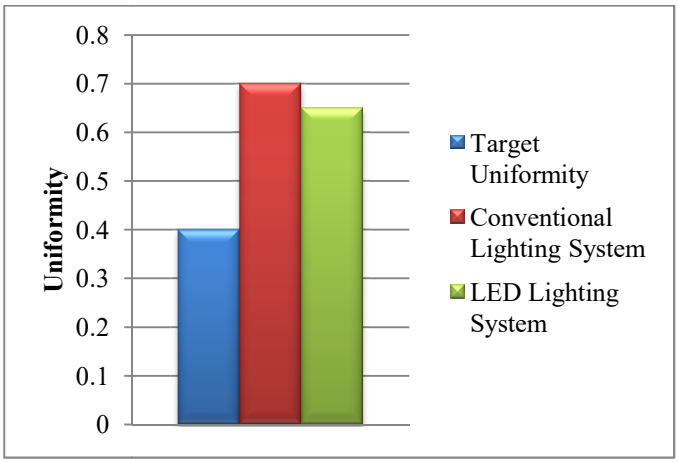


Fig. 9.343: Uniformity Comparison of TOILET 1

In Fig. 9.342, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.343, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

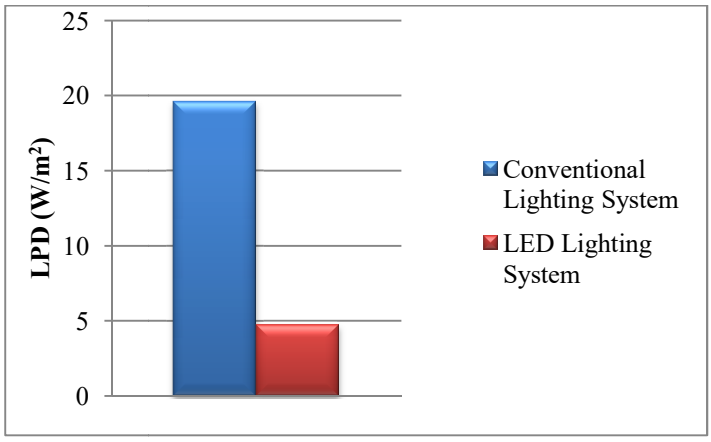


Fig. 9.344: LPD Comparison of TOILET 1

In Fig. 9.344, LPD comparison is shown where LPD by using conventional luminaires is approx 4.11 times of using LED luminaires.

➢ **TOILET 2**

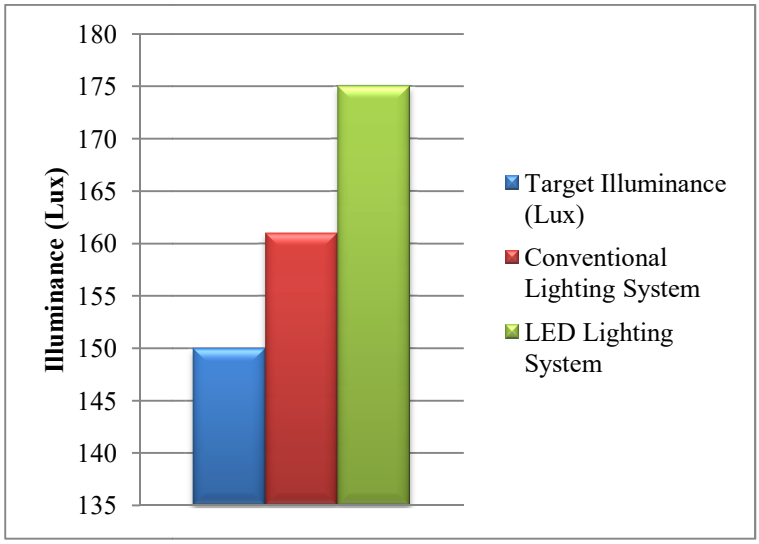


Fig. 9.345: Illuminance Comparison of TOILET 2

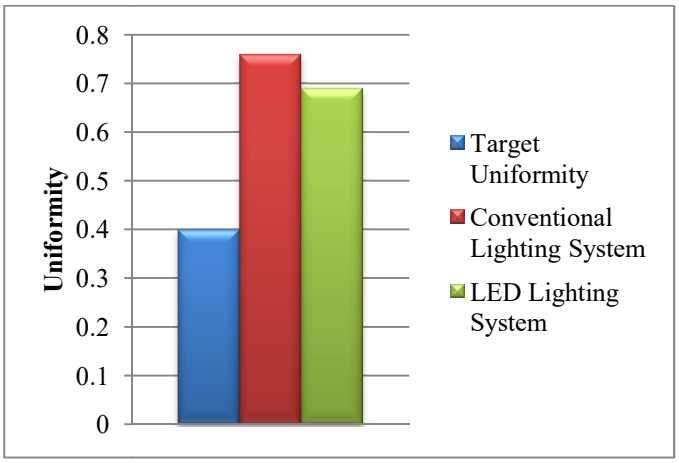


Fig. 9.346: Uniformity Comparison of TOILET 2

In Fig. 9.345, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.346, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

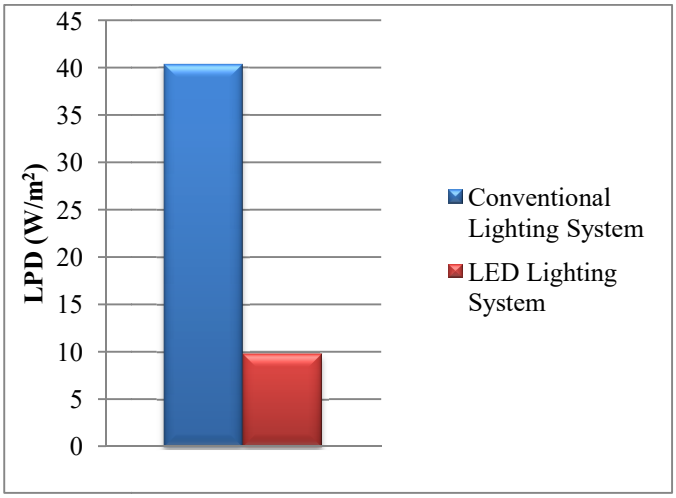


Fig. 9.347: LPD Comparison of TOILET 2

In Fig. 9.347, LPD comparison is shown where LPD by using conventional luminaires is approx 4.11 times of using LED luminaires.

- **TOILET 3**

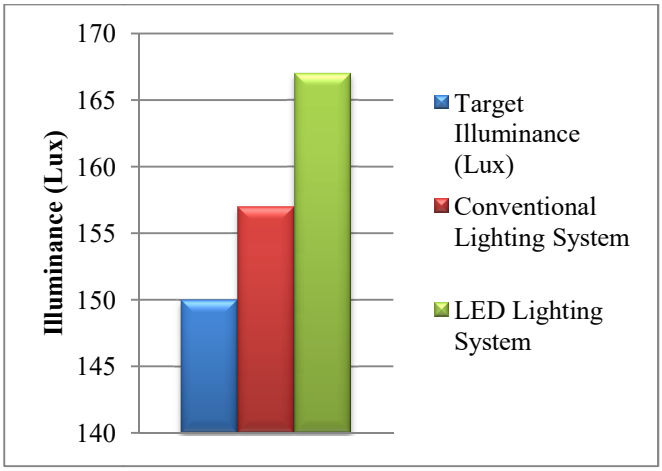


Fig. 9.348: Illuminance Comparison of TOILET 3

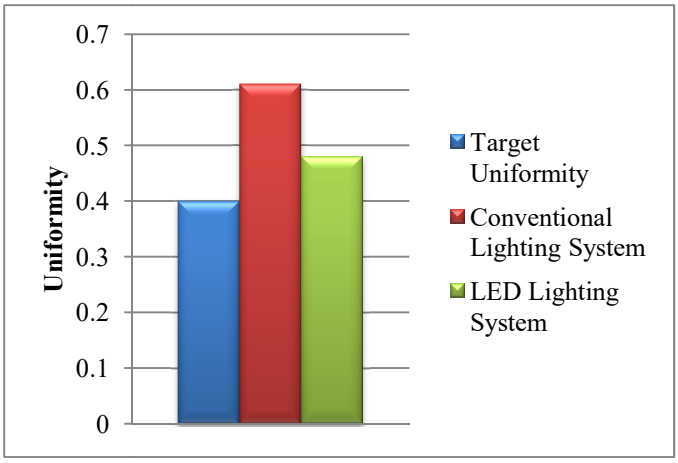


Fig. 9.349: Uniformity Comparison of TOILET 3

In Fig. 9.348, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved

in both cases. In Fig. 9.349, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

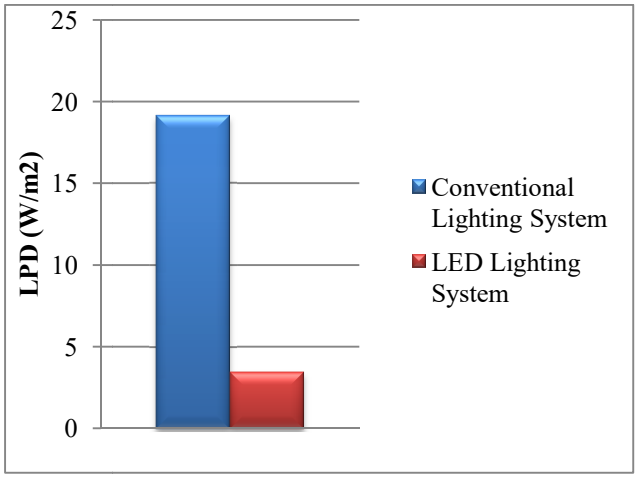


Fig. 9.350: LPD Comparison of TOILET 3

In Fig. 9.350, LPD comparison is shown where LPD by using conventional luminaires is 5.48 times of using LED luminaires.

- **TOILET**

The Illuminance parameter comparison is shown in Table 9.219 and Power Consumption comparison

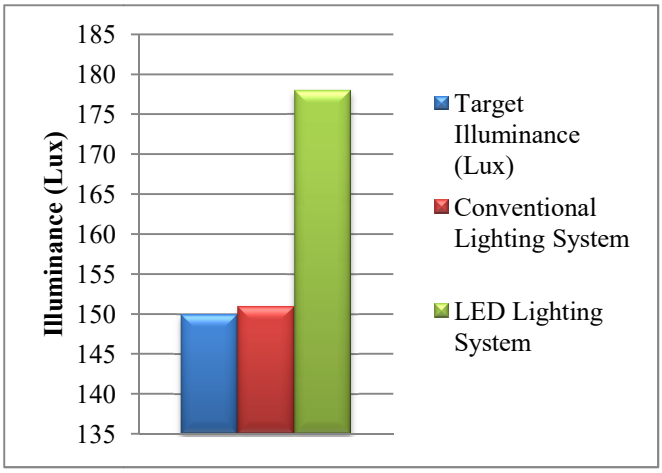


Fig. 9.351: Illuminance Comparison of TOILET

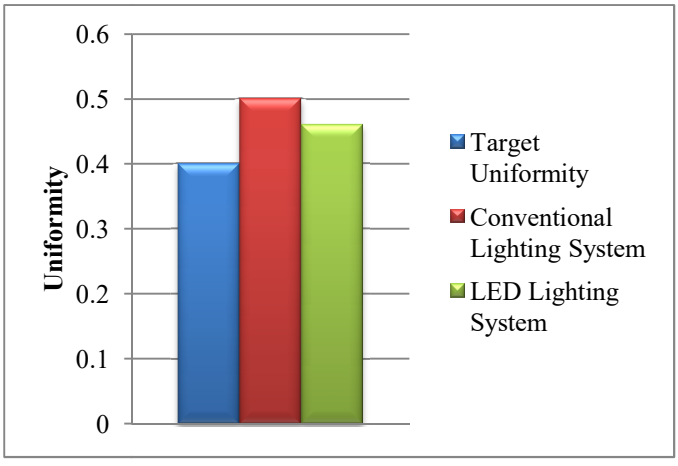


Fig. 9.352: Uniformity Comparison of TOILET

In Fig. 9.351, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases. In Fig. 9.352, the uniformity comparison is shown where uniformity achieved by using conventional luminaires is higher than the LED luminaires. Also target illuminance is achieved in both cases.

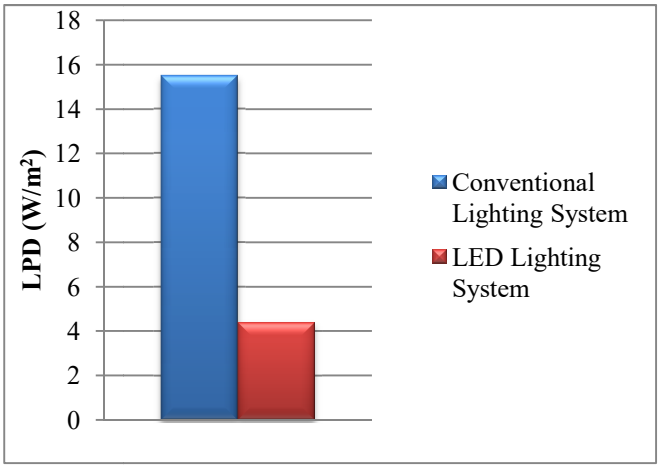


Fig. 9.353: LPD Comparison of TOILET

In Fig. 9.353, LPD comparison is shown where LPD by using conventional luminaires is approx 3.52 times of using LED luminaires.

- **VISITOR'S LOUNGE**

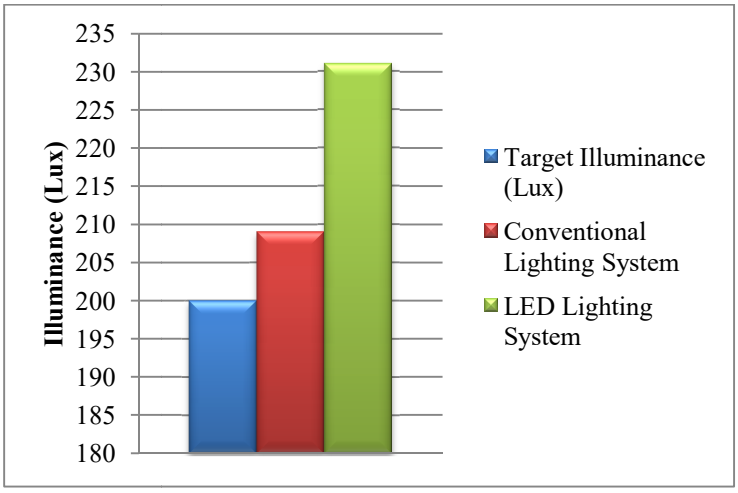


Fig. 9.354: Illuminance Comparison of VISITOR'S LOUNGE

In Fig. 9.354, the average illuminance comparison is shown where average illuminance achieved by using LED luminaires is higher than the conventional luminaires. Also target illuminance is achieved in both cases.

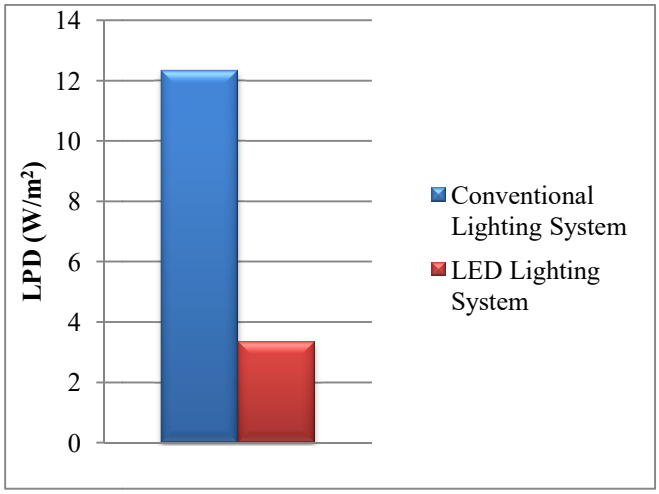


Fig. 9.355: LPD Comparison of VISITOR'S LOUNGE

In Fig. 9.355, LPD comparison is shown where LPD by using conventional luminaires is approx 3.66 times of using LED luminaires.

- **Area-wise Power Consumption**

The area-wise power consumption by using Conventional Luminaires and LED Luminaires are shown in Fig. 9.356 and Fig. 9.357 respectively. From both figure, Corridor has maximum power consumption i.e. 21% by using conventional luminaires and 18% by using LED luminaires.

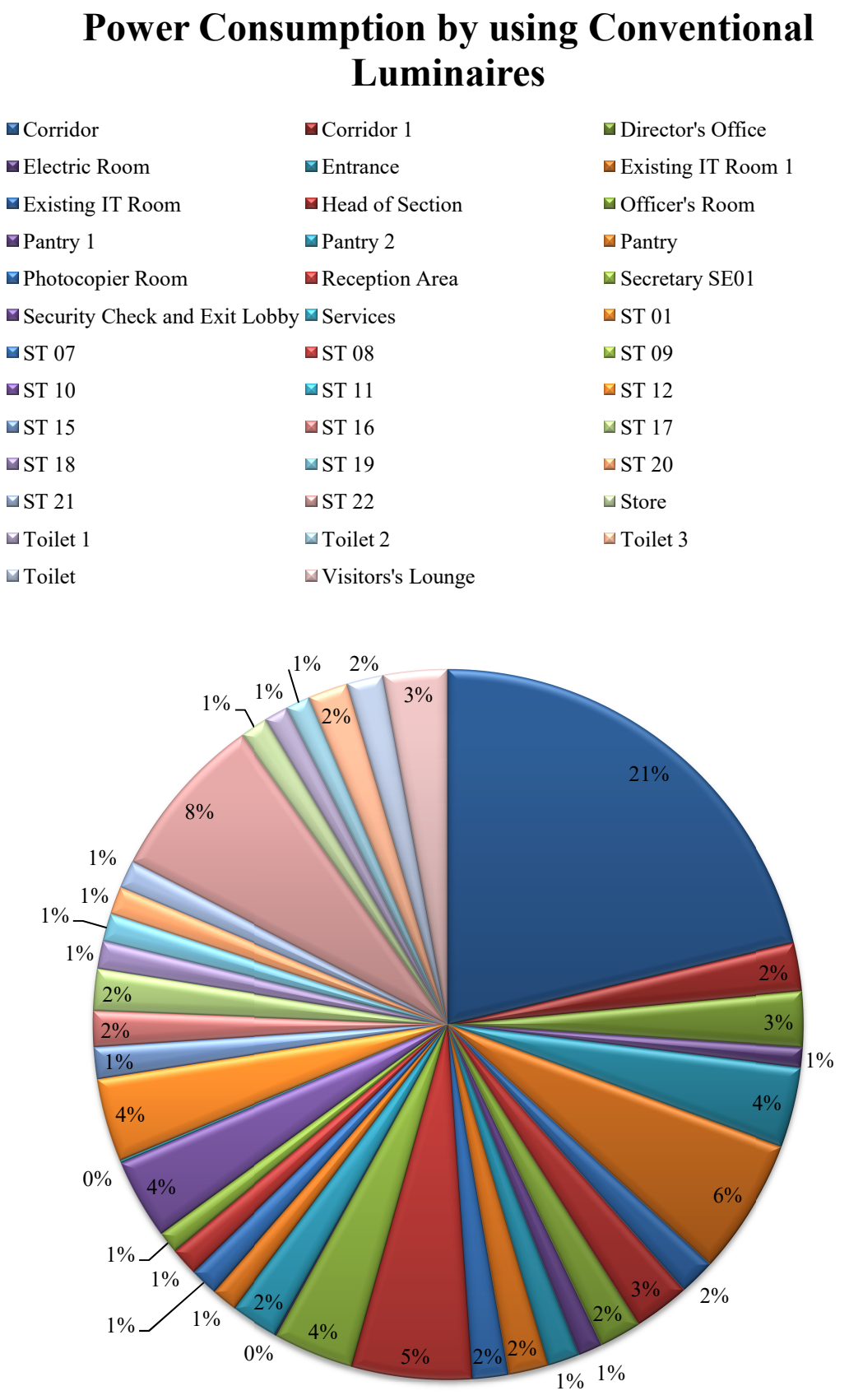


Fig. 9.356: Area-wise power consumption by using Conventional Luminaires

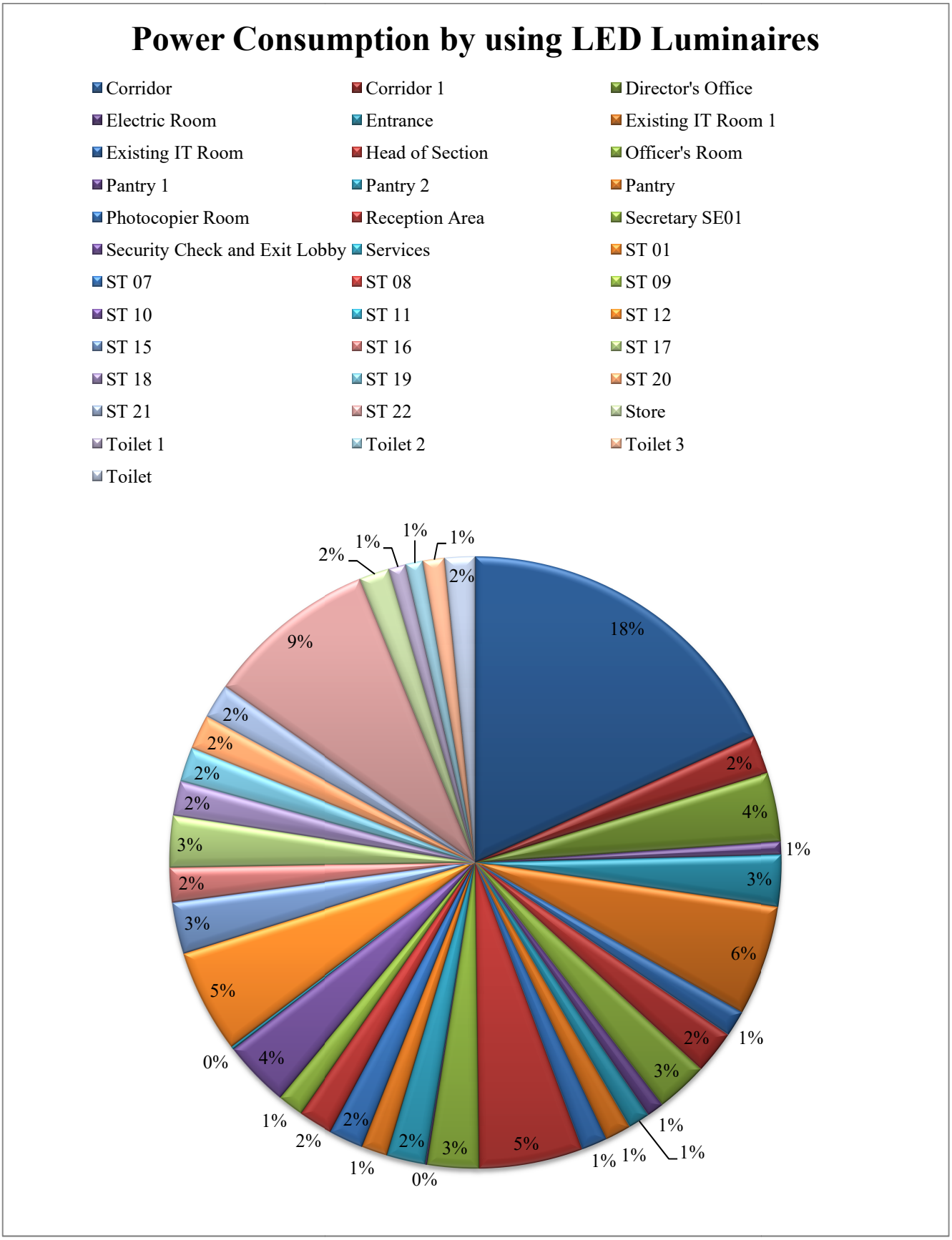


Fig. 9.357: Power Consumption by using LED Lumianire

9.6.2 LPD Evaluation of Office Building

Here LPD evaluation is done by Buidling Area Method.

Total Energy usage when using LED Luminaires: 6620.7 Watt

Total Floor Area: 1388.81 m^2

LPD: 4.77 W/m^2

Accoding to ECBC 2017, By Building Area method, the Lighting Power Density for Commercial Office spaces to satisfy ECBC Building Rating is **9.50 W/m^2**, to satisfy ECBC+ Building rating it is **7.60 W/m^2** and to satisfy SuperECBC Building, it is **5.0 W/m^2.**

The achieved LPD value is 4.6% less than SuperECBC Building LPD i.e. 5.0 W/m^2.

So, it can be stated that the design with LED Luminaire are well feasible and also it can be said as an Energy Efficient Design.

9.6.3 Economic Comparison between Conventional and LED Solution of Case Study on Office Building

- **Cost Details of Conventional Luminaires used in this Project**

Sl. No.	Luminaire	Qty	Price Per Fixture [55]	Total Cost
1	Conventional 2x2 Luminaire 3	67	2350	157450
2	Conventional Recessed Mounted Downlighter 1	405	825	334125

Total Cost of Conventional Luminaires: Rs. 494575

- **Cost Details of LED Luminaires used in this Project**

Sl. No.	Luminaire	Qty	Price Per Fixture [56]	Total Cost
1	LED Spot Light	7	380	2660
2	LED 2x2 Luminaire 3	100	3500	350000
3	LED 2x2 Luminaire 2	21	3700	77700
4	LED Recessed Mounted Downlighter 1	233	700	163100
5	LED Recessed Mounted Downlighter 2	36	850	30600

Total Cost of LED Luminaires: Rs. 624060

- **Total Annual Operating Cost of LED Luminaires**

Sl. No.	Parameter	LED Luminaires				
		LED Spot Light	**LED 2x2 Luminaire 3**	**LED 2x2 Luminaire 2**	**LED Recessed Mounted Downlighter 1**	**LED Recessed Mounted Downlighter 2**
1	**Power comsumption per luminaire in W**	3.5	24.8	34.2	12.4	15.9
2	**Total Quantity**	7	100	21	233	36
3	**Total Power Consumption in Watt**	24.5	2480	718.2	2889.2	572.4
4	**Usage of system per day in hours**	24	24	24	24	24
5	**Total working days/annum**	365	365	365	365	365
6	**Total power consumption per annum in W**	214620	21724800	6291432	25309392	5014224
7	**Total Energy consumption per annum in KWH**	214.62	21724.8	6291.432	25309.392	5014.224
8	**Electricity charges in Rs**	10	10	10	10	10
9	**Operating cost in Rs per annum**	2146.20	217248.00	62914.32	253093.92	50142.24
10	**Total Annual Operating Cost (Rs.)**	585544.68				

- **Total Annual Operating Cost of Conventional Luminaires**

Sl. No.	Parameter	Conventional Luminaires	
		Conventional 2x2 Luminaire 3	Conventional Recessed Mounted Downlighter 1
1	Power comsumption per luminaire in W	88	118
2	Total Quantity	67	405
3	Total Power Consumption in Watt	5896	47790
4	Usage of system per day in hours	24	24
5	Total working days/annum	365	365
6	Total Energy consumption per annum in W	51648960	418640400
7	Total Power consumption per annum in KWH	51648.96	418640.4
8	Electricity charges in Rs	10	10
9	Operating cost in Rs per annum	516489.60	4186404
10	Total Annual Operating Cost (Rs.)	4702893.60	

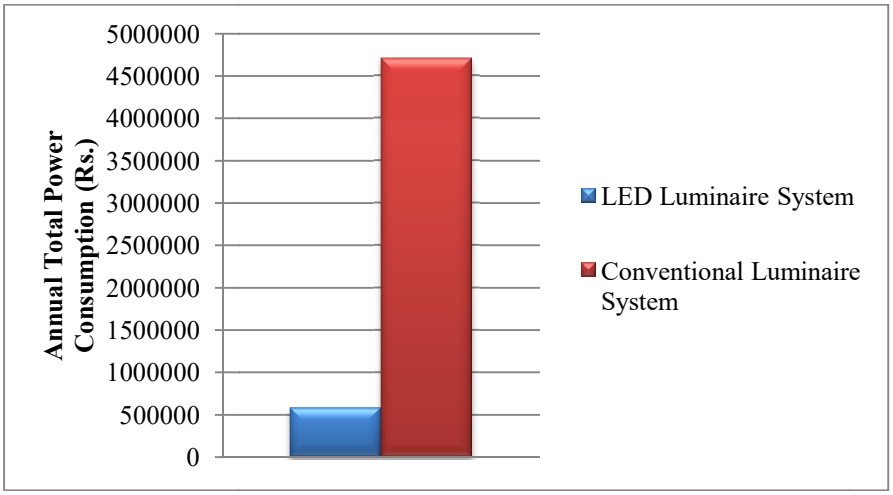


Fig. 9.358: Annual Operating Cost Comparison

Fig. 9.358 shows the annual operating comparison between LED and Conventional Luminaire simulation where it is seen that by using conventional luminaires, annual operating cost is approx. 8 times by using LED luminaires.

- **Annual Lamp Replacement and Maintenance Cost**

Sl. No.		Conventional 2x2 Luminaire 3	Conventional Recessed Mounted Downlighter 1
	Lamp Type	**3 nos. 36W CFL**	**2 nos. 13W CFL**
1	**Average Lamp Life**	6000	6000
2	**Number of lamps to be replaced per annum**	293.46	1182.60
3	**Price per Lamp [55]**	180	70
4	**Cost of lamp replacement (Rs)**	52822.8	82782
5	**Average cost of maintenance Rs. 25 per luminaire (conventional) per year**	1675	10125
9	**Total Cost of replacement and maintenance (Rs)**	147404.8	

- **Payback Period**

Sl. No.	Annual Power & Maintenance Cost (Rs)	LED Luminaires	Conventional Luminaires
1	Luminaire Power Consumption Cost	585544.68	4702893.6
2	Cost of Lamps Replaced Annualy and Maintenance Cost	NA	147404.80
	Comparison		
1	Present worth	624060	494575
2	Annual Running Cost	585545	4850298
	Payback Time		
0	Total Cost of operation at start	624060	494575
1	Total Cost of operation after 1st year	1209605	5344873
2	Total Cost of operation after 2nd year	1795149	10195172
3	Total Cost of operation after 3rd year	2380694	15045470
4	Total Cost of operation after 4th year	2966239	19895769

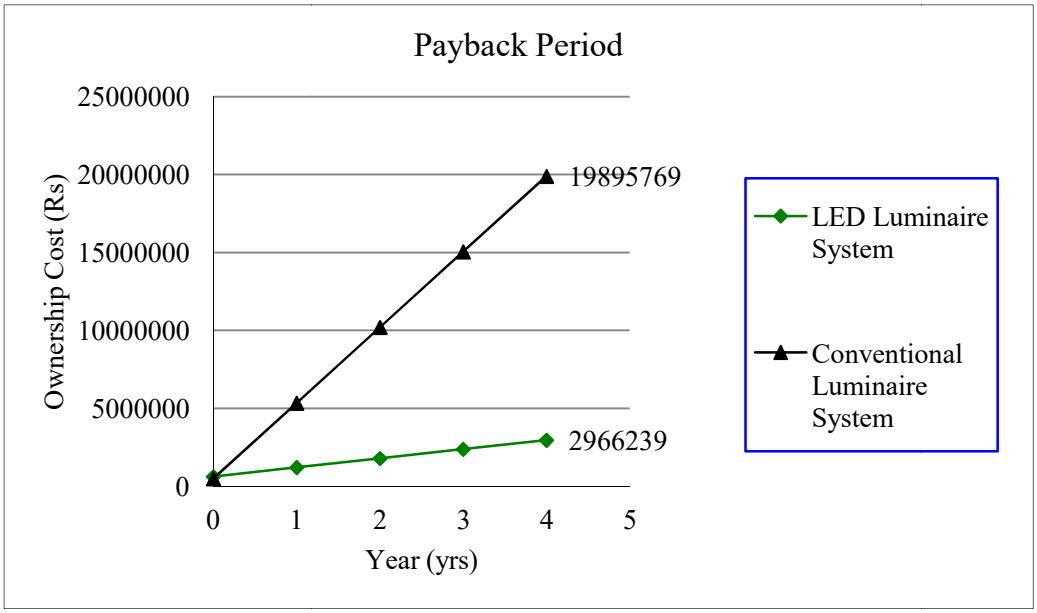


Fig. 9.359: Ownership Cost v/s Years

From Fig. 9.359, it is observed that, the intersection of two lines is at approxmimately 1 month.
So, by Break Even Method, Payback period is approx 1 month.

9.7 Case Studywise Annual Energy Savings in Rs.

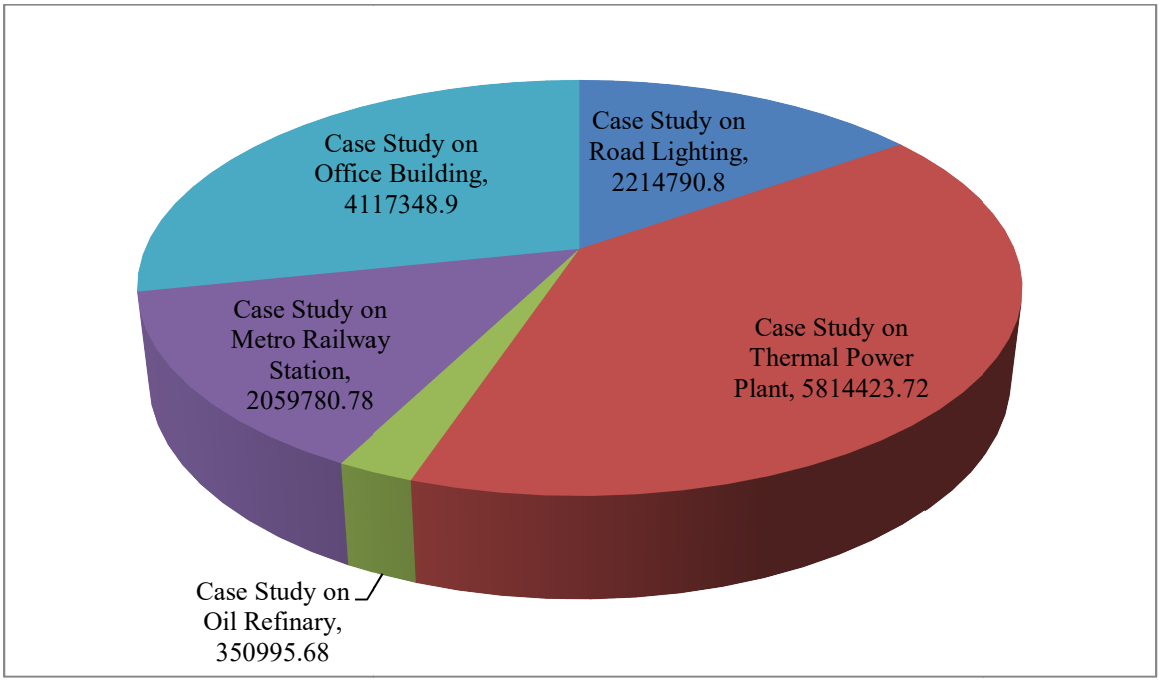


Fig. 9.360: Case Studywise Annual Energy Savings in Rs.

By studying all case studies, the cost savings by using energy efficient LED luminaires in case of Thermal Power Plant is highest among all the case studies that are shown in Fig. 9.360.
The annual energy savings in case of Case Study on Thermal Power Plant is highest among all the case Studies.

Chapter 10
Conclusions

10.1 Introduction

This project dealt with analyzing the processes and activities in various areas like Road Lighting, Industrial Area, Metro Railway Station and Office Building, so as to provide energy efficient lighting solution which will lead to efficient energy savings. A comparison of different lighting installation scheme in various areas was drawn in terms of light power density. From the comparison, appropriate energy efficient lighting solutions were recommended area wise.

10.2 Conclusions

In this thesis paper, different types of lighting applications like Road, Thermal Power Plant, Oil Refinery, Metro Railway Station and Office Building are taken into consideration where a simulation was done by using Conventional Luminaires and then a simulation was done by using LED Luminaires. The conclusions from these studies are :

- In every case, the electrical energy usage by using LED luminaires is found very less than using conventional luminaires. After conducting several simulations using different LED fixtures, it can be safely concluded that LED fixtures resulted in lower power consumption compared to all other fixtures, keeping all other standards intact. That being said, currently LED fixtures have higher prices compared to conventional fixtures, which may result in higher payback periods. But due to competitive market in Luminaire B2B industry, the LED Luminaire prices decreases rapidly from previous years and the discounted price give to customer which in turn dereases payback period in near future.
- Though the target illuminance, target uniformity and target transverse uniformity (in case of Road Lighitng) is same between two simulations for all case studies, average illuminance, uniformity and transverse uniformity (in case of Road Lighting) are not same in between two simulations which gives us to the conclusion that retrofitting is only possible when the system lumen packages and the photometric distribution of the LED and Conventional luminaires are nearly same. In case of LED, the photometric distributions are controlled by lens and Diffusers and in case of conventional luminaires, the photometric distributions are controlled by Reflectors, Refractors and Diffusers which in turn gives lower light output ratio due to absobtion of light by reflectors, refractors. LOR in case of LED luminaires is 100% as it is a compact system. But it is really difficult to have a LED and Conventional luminaire which matches exactly. It may lead to re-arrangement of total electrical layout while retrofitting.
- Dimensions of the luminaires is very much important while importing luminaires .ies files as changing the dimension also changes the average illuminance level and uniformity which also changes the values of Glare Index.
- Surge protector is also an important device in LED luminaires as due to undervoltage conditions, a surge may comes up which damages the driver circuit. So a new competition is gowing on the industry to use higher values of Surge protector.
- The use of Mid Power chip LED also reduces initial cost of LED. As the junction temperature is less in mid power LED chip and also it produces sufficient Lumen package, now a days it is used in most LED Luminaires. The requirement of heat sink is eliminated while using mid power LED chip as the body of the luminaire acts as a heat sink.

- Vibration proof potted driver is used in road lighting Luminaire. As in case of roadlighting, there is so much vibration on road created while the transportation of heavy vehicles so potted driver protectes the shoulder junction from vibration and also from liquid and dust particles.
- It creates problem while retrofitting conventional Luminaire with LED Luminaire as the light emitting area of conventional area and LED Luminaire are not same. So while retrofitting at existing pole, the light may goes beyond the road area and creates light pollution. That's why inbuilt mounting steps road lighting luminaires were used.

10.3 Challenge Faced

Most of the inputs of lighting simulations are generally received in terms of Client's Datasheet or Documents or Autocad file from where we can get only the dimensions of the room and not the details like color of the walls, clean or dusty environment. Thus we need to consider some standard values for the sake of calculation. But such calculation may differ from the actual value due to tolerances in calculation methods, testing procedure field condition (voltage, power supply and temperature variations).If the actual site condition does not meet with the input data, differences may happen and inconsistent result may produce.

In some cases, the Lighting levels specified in National Lighting Code- 2010 or relevant Indian Standards are not same as the values that are client specified. Client specifies that values based on operation time and accumulation of public in that area.

Unlike Interior area application, there are no standards for LPD evaluation for industrial area. In case of road lighting, there are no terms as related to LPD in interior application.

10.4 Further Study

More energy efficient LEDs with better lumen efficacy and less maintenance can be developed, which can further reduce Power Consumption. In India, now a day upto 150 Lumen/Watt system luminous efficacy Luminaire [58] has been developed. Application of daylight in industries sector is still not a common phenomenon, thus further research and application can be carried out how to implement daylight in industrial sectors.

LED lights consume very less energy and the control for light output in LED can be done very easily. Using Pulse Width Modulation (PWM) technology LED can be dimmed accurately makes it easy to integrate with daylight sensors. If the availability of daylight in several areas can be integrated with artificial sources using daylight sensor and dimmable LED drivers a good amount of dim period can be obtained for several luminaires leading to further savings in energy. Also lighting load can be connected to the solar energy obtained from solar panels inside office areas or in the terrace. During daytime installed solar panels can carry a significant part of electrical load. In the regions having long daylight availability usage of solar panel can be very effective.

In any metro station, Platform area consumes more energy comparative to other areas. So use of daylight and daylight sensor can reduce further annual operating cost.

In 2018-19, as new technology is growing day by day people are working on that for innovation. In smart lighting, android Smartphone or PC is used with Bluetooth and Wi-Fi for controlling purpose. Smart lighting provides Automatic Load shedding and dimming in peak & non-peak energy demand hours. Smart lighting is one of the easiest ways to save energy in an open office or any other modern workspace where every light point is connected to an intelligent system that delivers high-quality,

reliable illumination and sometimes even extraordinary value beyond illumination to the users. In future, smart lighting will be the key part of Internet of Things (IoT) that brings in the collaborative streaming of real-time data and artificial intelligence but the most striking feature is - it enables consumers to make better decisions thereby saving money. IoT is the concept of combining computers and networks to monitor and control devices to generate exchange and consume data with minimal human intervention. So, IoT is a boon and challenge at the same time because integrating systems, getting them to communicate using a standard protocol and providing interoperability across devices.

Unlike conventional luminaires, LED luminaires do not dim when supply voltage is reduces. Even if supply voltage reduces, LED driver maintains same lumen output hence consume same power. So LED can be dimmed even if supply voltage is reduced from feeder by adding autotransformer in feeder which gives the idea of light automation controller. The controller can be wired or wireless. Just a case of smart steet light is considered. Steet Lights can be controlled by Group level on off control and individual control.

In case of Office Lighting to implement LG7 guideline i.e. 30% of working plane illumination on ceiling, now a day drup down fecility is used in the diffuser from where some amount of luminous flux is thrown to the ceiling. Also the use of human centric lighting along with proper daylight sensor increases productivity of the employees. [53]

A new energy efficient technology is developing in industry like LEP i.e. Light Emitting Plasma. Lighting emitting plasma (LEP) are a full spectrum light from infrared to ultraviolet. Plasma bulbs are a solid state bulb that has no moving parts. They are not equipped, nor do they need, a fan which makes them a single piece of silent machinery. As a low Power Consumption bulb, they are incredibly energy efficient while offering all the benefits of being able to mimic the sun's spectrum closely. Plasma lights have almost a 100 CRI rating, meaning using them is the closest thing to using bottled sunlight that there is on the market. Plasma lights are not dimmable because they are at such a low Power Consumption already. The bulbs are only offered in two colors, one more heavily weighted with red spectrum and the other in the blue spectrum. The best pattern footprint to use in your grow is to use a blue plasma bulb as supplemental light to a mainly high pressure sodium (HPS) setup.

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Annexure I

The case studies were mentioned in this thesis are actually derived from practical project cases that I have handled during my internship. This is listed below:

Sl. No.	Case Study in this Thesis	Project Name
1	Case Study on Road Lighting	Electrification of Muchipara to Durgapur Barrage Road, DUrgapur
2	Case Study on Thermal Power Plant	NTPC Nabinagar Thermal Power Plant
3	Case Study on Oil Refinery	Numaligarh Oil Refinery
4	Case Study on Metro Railway Station	City Centre Metro Railway Station, Kolkata
5	Case Study on Office Building	Tata Consultancy Service Sabina Park (6^{th} floor), Kolkata

Annexure II

List of Lamps and Luminaires

The luminaires legend used in this thesis is different from simulation legends. The legends are listed below which may help in reading the rest annexures.

Sl. No.	Luminaire Legends in Case Study	Luminaire Legends in Simulation Report
1	Roadlighting Conventional Luminaire 1	SSGN1125IH
2	Road Lighting LED Luminaire 1	LSTN-200-WW-A
3	Conventional 2x2 Luminaire 1	CRCLU240EBS
4	Conventional Well Glass Luminaire 1	IWV1508IH/BC
5	Conventional Batten Type Luminaire 1	IGP1414HSB
6	Conventional Flameproof Wellglass Luminaire 1	FWL12/B 200 GLS
7	LED Wellglass Luminaire 1	LWV12-35-CDL
8	LED 2x2 Luminaire 1	LCTRI-36-CDL
9	LED 2x2 Luminaire 2	LCTLRN-36-FO-CDL
10	LED Tube Batten 1	IGP132LT8-16
11	LED Flameproof Luminaire 1	FWL1315-40-CDL
12	Conventional Batten Type Luminaire 2	IPFC1124EB
13	Conventional Batten Type Luminaire 2	IPFC1114EB
14	Conventional Canopy Luminaire 1	FADR1215IH(CA)
15	LED Batten 1	LPFC-36-CDL
16	LED Canopy Luminaire 1	LSFN-72-CDL
17	LED Tube Batten 2	IPFC112LT8-20
18	Conventional Clean-room Application Luminaire 1	CRFW12336EB
19	Conventional 2x2 Luminaire 2	T5CQ13414EBB
20	Conventional Surface- mounted Downlighter 1	DDSH118EB/G
21	LED Recessed- mounted Downlighter 1	LCDE-12-CDL
22	LED Surface- mounted Downlighter 1	LCDSPLN-R-12-CDL
23	LED Clean-room Application Luminaire 1	LCBOR-40-CDL
24	Conventional Recessed Mounted Downlighter 1	DDLHR213EB/G/S
25	Conventional 2x2 Luminaire 3	CRFQ11336EB_P5
26	LED Recessed Mounted Downlighter 2	LCDE-15-CDL
27	LED 2x2 Luminaire 3	LCTLRN-24-FO-CDL
28	LED Spot Light	LCSRR-4-CDL

Annexure III

Case Study on Road Lighting by using Conventional Luminaire

Here in case study, the points of the roads were denoted by alphabetical terms. It is explained below

Point A: Muchipara

Point B: HFC More

Point C: BDO More

Point D: Majhermath More

Point E: Graphite More

Point F: Old Rail Bridge

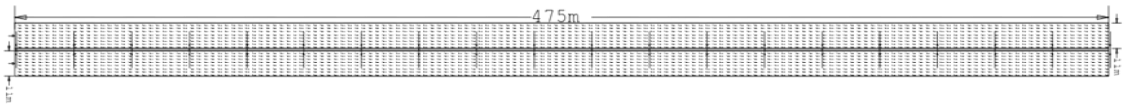
Point G: New Rail Bridge

Point H: Shyampur More

Point I: Sukumar Nagar

Point J: Durgapur Barrage

MUCHIPARA TO HFC MORE

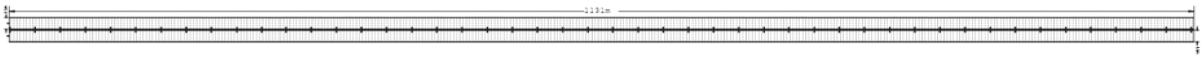


LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 28 DEGREE
ARM LENGTH 2 METER
POLE TO POLE SPACING 25 METER

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
	40	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_1_Illum	Illuminance	Lux	31.73	50.4	17.0	0.54	0.34
Road_2_Illum	Illuminance	Lux	31.73	50.4	17.2	0.54	0.34

HFC MORE TO BDO MORE

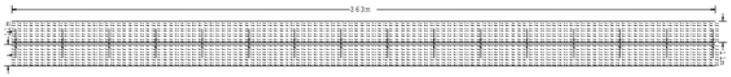


LUMINAIRE MOUNTING HEIGHT 11 METER
ARM LENGTH 2 METER
TILT 2 DEGREE
POLE TO POLE SPACING 24 METER

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	96	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	33.18	51.6	17.6	0.53	0.34
Road_3_Illum	Illuminance	Lux	33.19	51.5	17.7	0.53	0.34

BDO MORE TO MAJHERMATH MORE

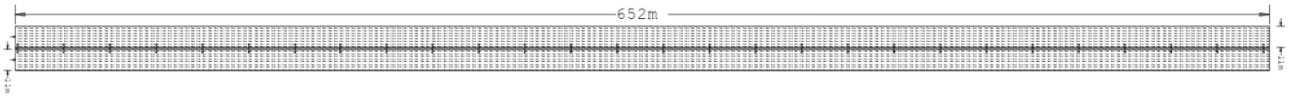


LUMINAIRE MOUNTING HEIGHT 11 METER
ARM LENGTH 2 METER
POLE TO POLE SPACING 24 METER
TILT 28 DEGREE

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
	32	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	34.05	54.8	18.2	0.53	0.33
Road_3_Illum	Illuminance	Lux	34.03	54.5	18.3	0.54	0.34

MAJHER MATH MORE TO GRAPHITE MORE

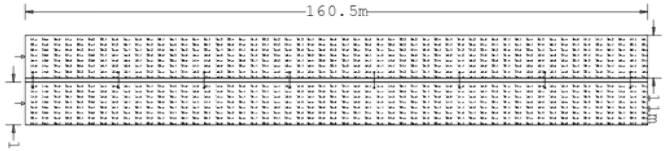


LUMINAIRE MOUNTING HEIGHT 11 METER
ARM LENGTH 2 METER
TILT 28 DEGREE
POLE TO POLE SPACING 24 METER

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	56	SSGN1125IH	0.700	250 WATT HPSC STREET LIGHT LUMINAIRE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	33.09	51.6	17.6	0.53	0.34
Road_3_Illum	Illuminance	Lux	33.08	51.6	17.8	0.54	0.34

GRAPHITE MORE TO OLD RAIL BRIDGE

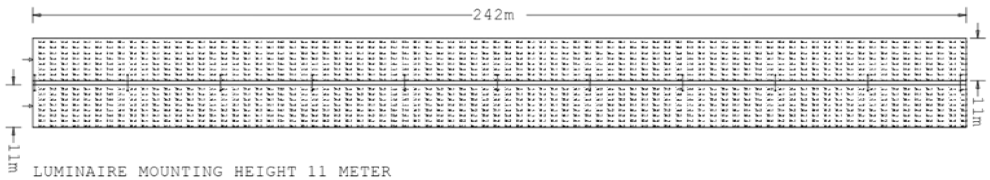


LUMINAIRE MOUNTING HEIGHT 11 METER
ARM LENGTH 2 METER
POLE TO POLE SPACING 24 METER
TILT 2 DEGREE

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	16	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	35.48	54.5	19.1	0.54	0.35
Road_3_Illum	Illuminance	Lux	35.49	54.5	18.9	0.53	0.35

NEW RAILBRIDGE TO SHYAMPUR MORE

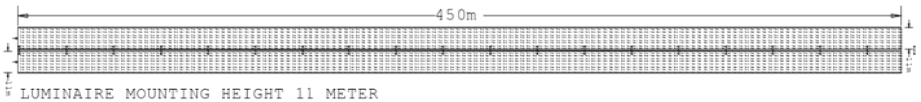


LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 28 DEGREE
ARM LENGTH 2 METER
POLE TO POLE SPACING 24 METER

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	22	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	32.86	51.6	17.7	0.54	0.34
Road_3_Illum	Illuminance	Lux	32.86	51.6	17.8	0.54	0.34

SHYAMPUR MORE TO SUKUMAR NAGAR



LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 28 DEGREE
ARM LENGTH 2 METER
POLE TO POLE SPACING 24 METER

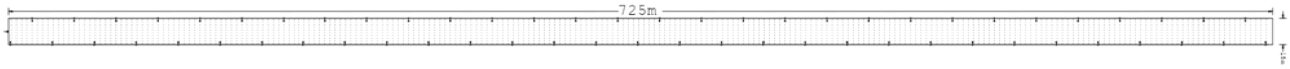
Luminaire Schedule

Symbol	Qty	Label	LLF	Description
——⊙	40	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

Calculation Summary

Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	33.03	51.6	17.5	0.53	0.34
Road_3_Illum	Illuminance	Lux	33.03	51.6	17.8	0.54	0.34

SUKUMAR NAGAR TO DURGAPUR BARRAGE



LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 27 DEGREE
ARM LENGTH 2 METER
POLE TO POLE SPACING 24 METER

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
	61	SSGN1125IH	0.700	250 WATT HPSV STREET LIGHT LUMINAIRE

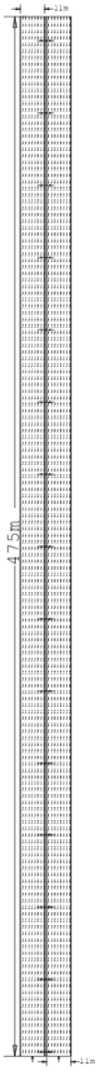
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_1_Illum	Illuminance	Lux	47.74	59.4	20.3	0.43	0.34

Annexure IV

Case Study on Road Lighting by using LED Luminaire

Here in case study, the points of the roads were denoted by alphabetical terms which is explained in Annexure II.

MUCHIPARA TO HFC MORE



Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊖	30	LSTN-200-WW-A	0.800	200 WATT LED STREET LIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
TILT ANGLE 11 DEGREE
ARM LENGTH 2 METER
POLE TO POLE DISTANCE 33 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_1_Illum	Illuminance	Lux	34.57	47.9	23.7	0.69	0.49
Road_2_Illum	Illuminance	Lux	34.57	47.9	23.7	0.69	0.49

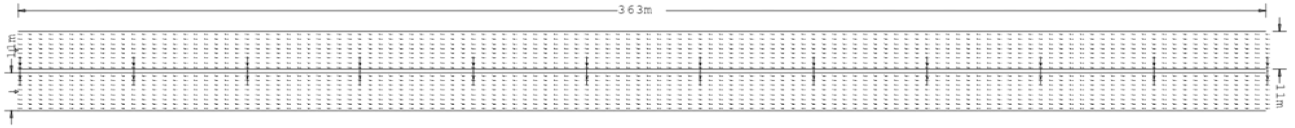
HFC MORE TO BDO MORE

Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
	70	LSTN-200-WW-A	0.800	200 WATT LED STREETLIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
TILT ANGLE 11 DEGREE
POLE TO POLE SPACING 33 METER
ARM LENGTH 2 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	34.61	48.0	24.6	0.71	0.51
Road_3_Illum	Illuminance	Lux	34.60	48.0	24.6	0.71	0.51

BDO MORE TO MAJHERMATH MORE

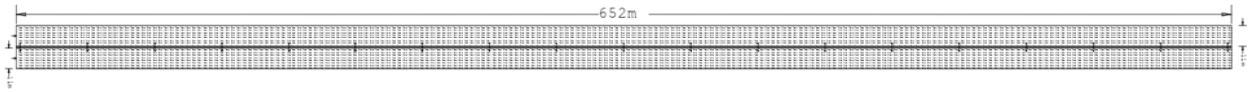


Luminaire Schedule						
Symbol	Qty	Label	Arrangement	Total Lamp Lumens	LLF	Description
——⊙	24	LSTN-200-WW-A	SINGLE	21770	0.800	200 WATT LED STREETLIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
ARM LENGTH 2 METER
POLE TO POLE SPACING 33 METER
TILT 11 DEGREE

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	34.61	48.0	24.6	0.71	0.51
Road_3_Illum	Illuminance	Lux	34.61	48.0	24.6	0.71	0.51

MAJHER MATH MORE TO GRAPHITE MORE

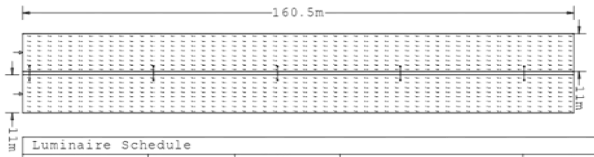


Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
	38	LSTN-200-WW-A	0.800	200 WATT LED STREETLIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
ARM LENGTH 2 METER
TILT 11 DEGREE
POLE TO POLE SPACING 36 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	31.74	47.2	20.9	0.66	0.44
Road_3_Illum	Illuminance	Lux	31.74	47.2	20.9	0.66	0.44

GRAPHITE MORE TO OLD RAIL BRIDGE

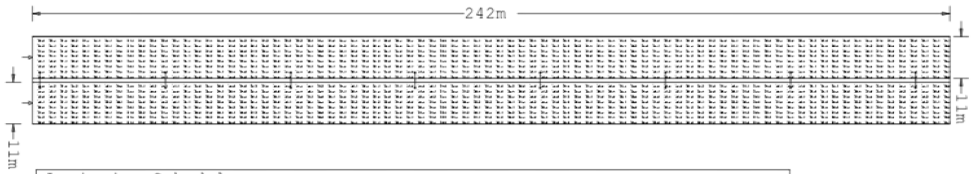


Luminaire Schedule						
Symbol	Qty	Label	Arrangement	Total Lamp Lumens	LLF	Description
——⊖	10	LSTN-200-W	SINGLE	21770	0.800	200 WATT LED STREETL

LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 11 DEGREE
POLE TO POLE SPACING 36 METER
ARM LENGTH 2 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	31.68	47.0	17.2	0.54	0.37
Road_3_Illum	Illuminance	Lux	31.68	47.0	17.2	0.54	0.37

NEW RAILBRIDGE TO SHYAMPUR MORE

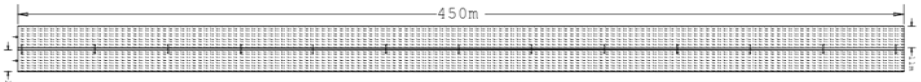


Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	16	LSTN-200-W	0.800	200 WATT LED STREETLIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 11 DEGREE
ARM LENGTH 2 METER
POLE TO POLE SPACING 33 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	34.64	48.1	24.6	0.71	0.51
Road_3_Illum	Illuminance	Lux	34.63	48.1	24.6	0.71	0.51

SHYAMPUR MORE TO SUKUMAR NAGAR

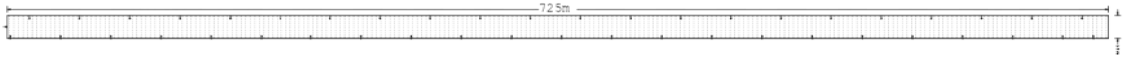


Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	26	LSTN-200-WW-A	0.800	200 WATT LED STREETLIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 11 DEGREE
ARM LENGTH 2 METER
POLE TO POLE SPACING 37 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_2_Illum	Illuminance	Lux	30.95	47.0	19.5	0.63	0.41
Road_3_Illum	Illuminance	Lux	30.95	47.0	19.5	0.63	0.41

SUKUMAR NAGAR TO DURGAPUR BARRAGE



Luminaire Schedule				
Symbol	Qty	Label	LLF	Description
——⊙	45	LSTN-200-WW-A	0.800	200 WATT LED STREETLIGHT

LUMINAIRE MOUNTING HEIGHT 11 METER
TILT 11 DEGREE
POLE TO POLE SPACING 33 METER
ARM LENGTH 2 METER

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Min/Avg	Min/Max
Road_1_Illum	Illuminance	Lux	49.74	73.9	27.3	0.55	0.37

Annexure V
Case Study on Thermal Power Plant by using Conventional Luminaire

NTPC Nabinagar Thermal Power Plant (Conventional Luminaire)

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY:

Date: 15.11.2018
Operator: Ankit Ghosh

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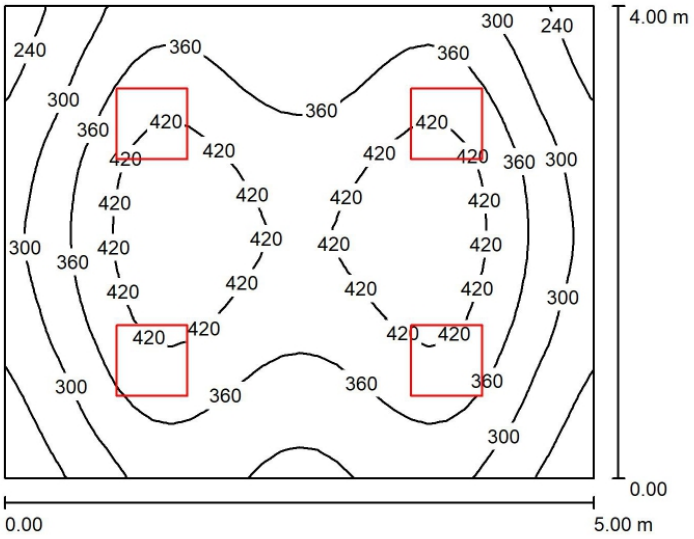
Office Room / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:52

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	356	202	469	0.568
Floor	20	292	188	356	0.646
Ceiling	70	72	53	202	0.735
Walls (4)	50	174	68	391	/

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.502, Ceiling / Working Plane: 0.203.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. CRCLU240EB/S COMMERCIAL LUMINAIRE (1.000)	3430	7000	88.0
			Total: 13721	Total: 28000	352.0

Specific connected load: 17.60 W/m² = 4.94 W/m²/100 lx (Ground area: 20.00 m²)

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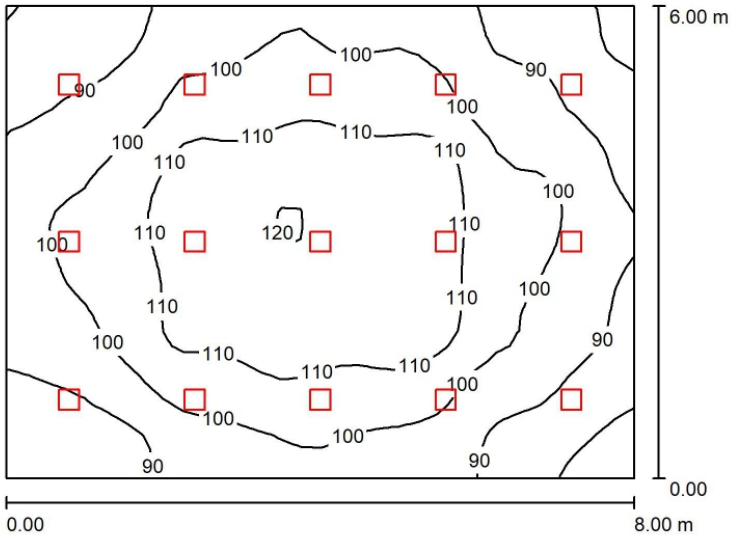
Battery Room / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:78

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	100	75	122	0.750
Floor	10	86	70	99	0.809
Ceiling	50	169	69	539	0.407
Walls (4)	30	110	40	376	/

Workplane:
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.190, Ceiling / Working Plane: 1.684.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	15	Crompton Greaves Ltd. FWL12/B_200W GLS FLAMEPROOF (1.000)	1968	3000	200.0
			Total: 29519	Total: 45000	3000.0

Specific connected load: 62.50 W/m² = 62.22 W/m²/100 lx (Ground area: 48.00 m²)

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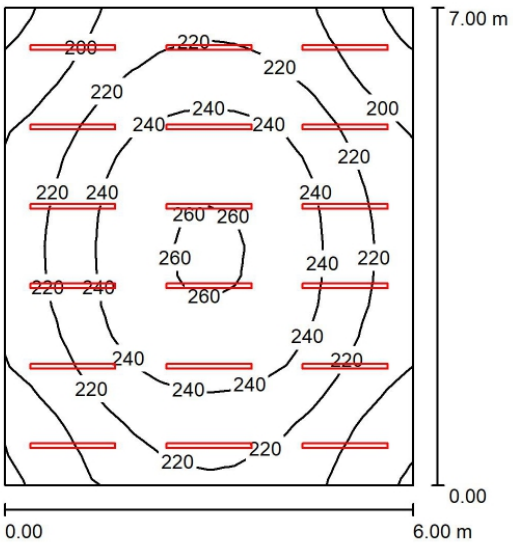
Motor Control Centre / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:90

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	224	178	263	0.791
Floor	10	191	158	219	0.827
Ceiling	50	291	47	1929	0.163
Walls (4)	30	227	85	837	/

Workplane:
Height: 0.760 m
Grid: 16 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.096, Ceiling / Working Plane: 1.295.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	18	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 54289	Total: 58500	963.0

Specific connected load: 22.93 W/m² = 10.21 W/m²/100 lx (Ground area: 42.00 m²)

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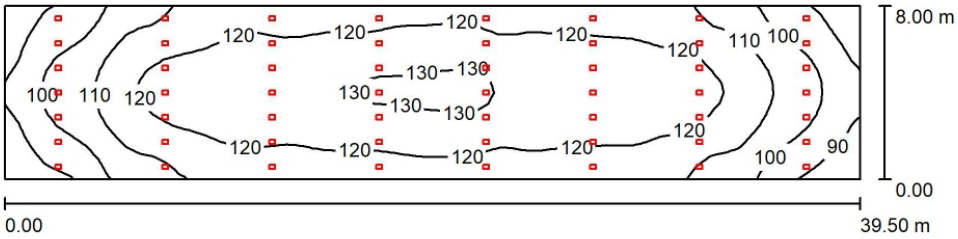
Transformer Room / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:283

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	115	83	132	0.723
Floor	10	105	74	120	0.704
Ceiling	50	117	34	643	0.289
Walls (4)	30	122	49	675	/

Workplane:

Height:	0.760 m
Grid:	64 x 16 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.145, Ceiling / Working Plane: 1.009.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	56	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 139063	Total: 190400	5320.0

Specific connected load: 16.84 W/m² = 14.62 W/m²/100 lx (Ground area: 316.00 m²)

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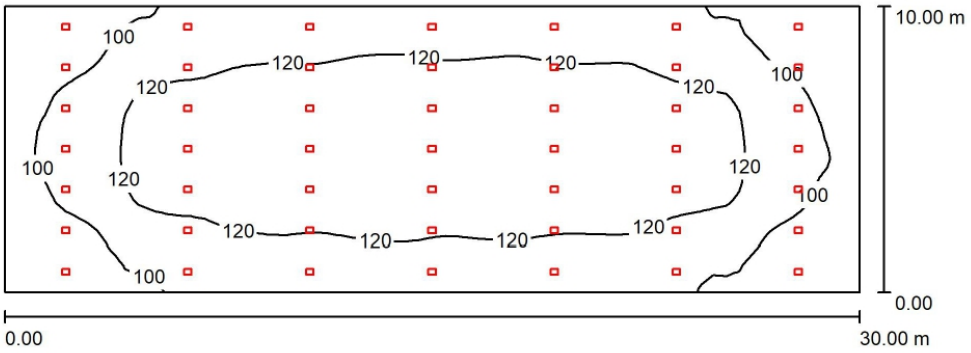
Pump House / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:215

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	115	81	138	0.704
Floor	10	105	73	126	0.695
Ceiling	50	110	36	654	0.330
Walls (4)	30	121	51	498	/

Workplane:
Height: 0.760 m
Grid: 64 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.139, Ceiling / Working Plane: 0.958.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	49	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 121680	Total: 166600	4655.0

Specific connected load: 15.52 W/m² = 13.53 W/m²/100 lx (Ground area: 300.00 m²)

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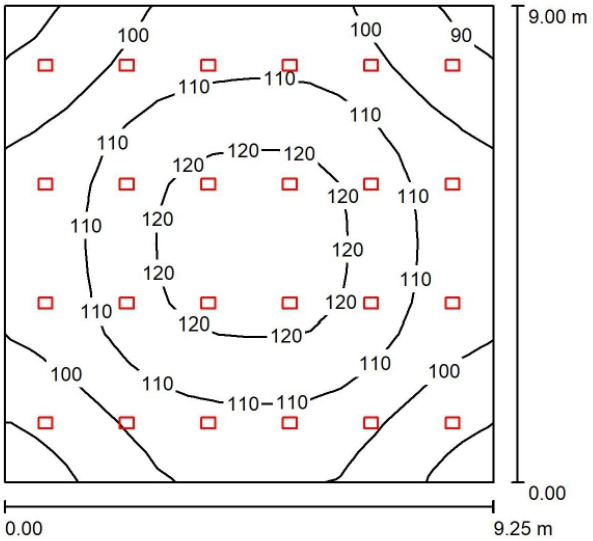
Drive House / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:116

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	107	87	124	0.808
Floor	10	95	81	108	0.849
Ceiling	50	184	86	650	0.469
Walls (4)	30	140	49	511	/

Workplane:
Height: 0.760 m
Grid: 16 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.391, Ceiling / Working Plane: 1.711.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	24	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 59599	Total: 81600	2280.0

Specific connected load: 27.39 W/m² = 25.50 W/m²/100 lx (Ground area: 83.25 m²)

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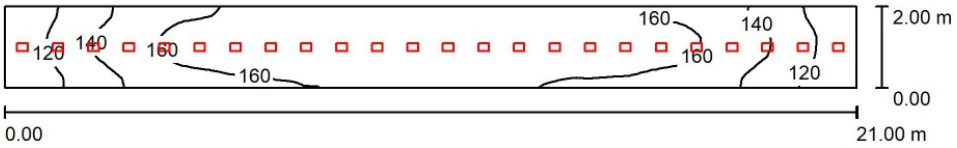
Corridor / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:151

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	154	101	178	0.660
Floor	10	125	89	143	0.709
Ceiling	50	315	134	750	0.427
Walls (4)	30	194	38	1182	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.426, Ceiling / Working Plane: 2.046.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	24	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 59599	Total: 81600	2280.0

Specific connected load: 54.29 W/m² = 35.31 W/m²/100 lx (Ground area: 42.00 m²)

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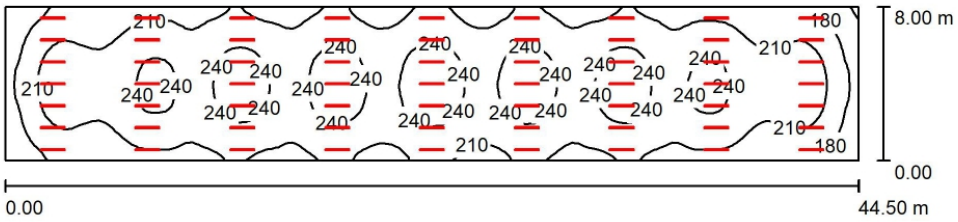
Switch Gear Room / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:319

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	220	147	256	0.667
Floor	10	204	147	231	0.723
Ceiling	70	150	39	1936	0.262
Walls (4)	50	186	95	812	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.908, Ceiling / Working Plane: 0.684.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	63	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 190011	Total: 204750	3370.5

Specific connected load: 9.47 W/m² = 4.30 W/m²/100 lx (Ground area: 356.00 m²)

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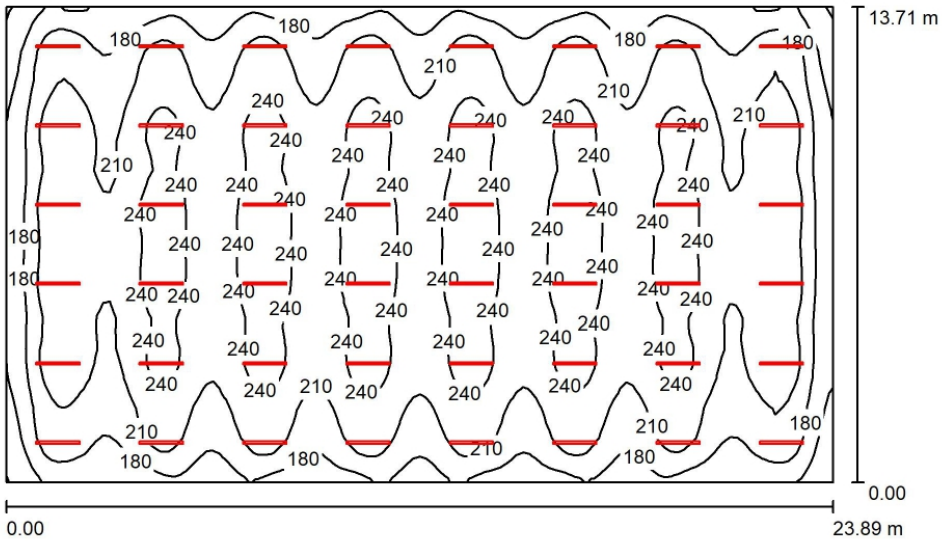
Cable Cellar Room / Summary



Height of Room: 2.500 m, Mounting Height: 2.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:177

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	216	120	264	0.555
Floor	10	197	113	234	0.574
Ceiling	50	109	21	1858	0.197
Walls (4)	30	169	76	312	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.851, Ceiling / Working Plane: 0.506.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	48	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 144770	Total: 156000	2568.0

Specific connected load: 7.84 W/m² = 3.63 W/m²/100 lx (Ground area: 327.53 m²)

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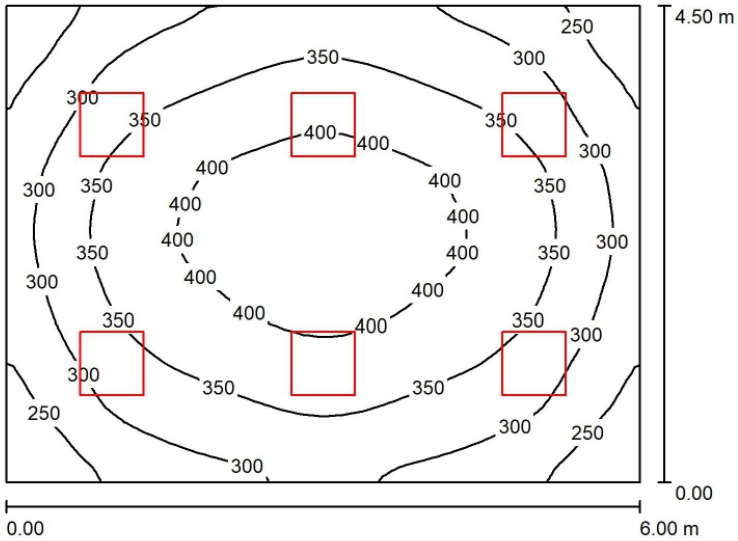
Remote Input Output (RIO) Room / Summary



Height of Room: 3.500 m, Mounting Height: 3.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:58

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	337	201	435	0.597
Floor	10	285	199	349	0.699
Ceiling	70	68	45	200	0.662
Walls (4)	50	180	67	342	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.565, Ceiling / Working Plane: 0.201.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. CRCLU240EB/S COMMERCIAL LUMINAIRE (1.000)	3430	7000	88.0
			Total: 20581	Total: 42000	528.0

Specific connected load: 19.56 W/m² = 5.80 W/m²/100 lx (Ground area: 27.00 m²)

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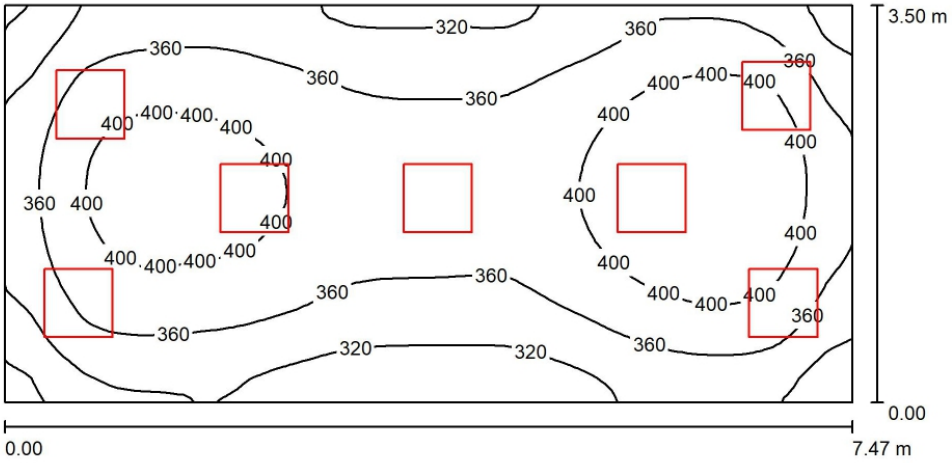
Wagon Tripler Control Room / Summary



Height of Room: 3.500 m, Mounting Height: 3.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:54

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	367	262	441	0.713
Floor	10	307	246	340	0.802
Ceiling	70	80	35	208	0.434
Walls (4)	50	220	82	611	/

Workplane:

Height:	0.760 m
Grid:	128 x 32 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.648, Ceiling / Working Plane: 0.217.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. CRCLU240EB/S COMMERCIAL LUMINAIRE (1.000)	3430	7000	88.0
			Total: 24011	Total: 49000	616.0

Specific connected load: 23.56 W/m² = 6.42 W/m²/100 lx (Ground area: 26.14 m²)

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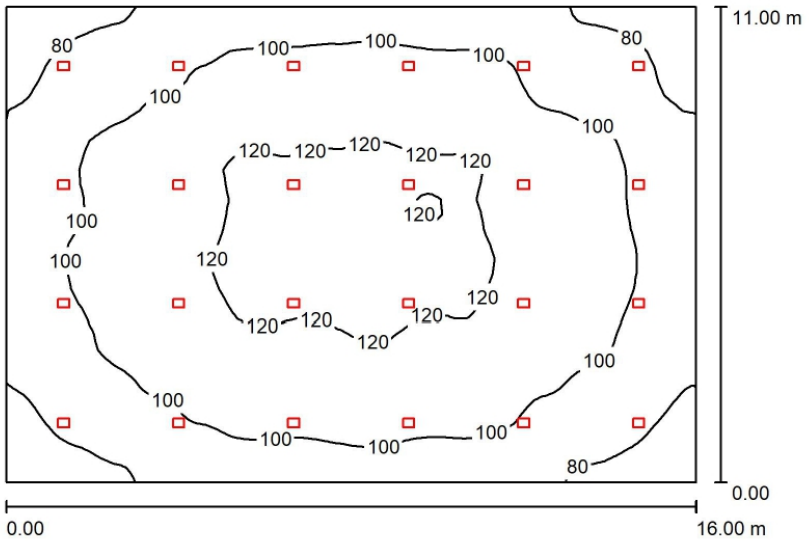
Transfer Point / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:142

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	102	68	125	0.662
Floor	10	92	62	111	0.680
Ceiling	50	92	36	639	0.395
Walls (4)	30	105	48	207	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.119, Ceiling / Working Plane: 0.903.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	24	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 59599	Total: 81600	2280.0

Specific connected load: 12.95 W/m² = 12.67 W/m²/100 lx (Ground area: 176.00 m²)

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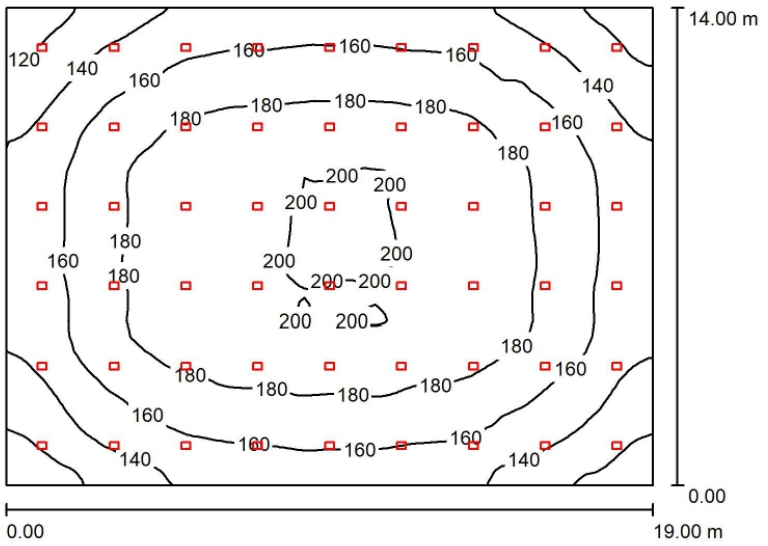
Junction Tower / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.70 Values in Lux, Scale 1:180

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	167	109	202	0.650
Floor	10	152	100	186	0.658
Ceiling	50	137	58	662	0.426
Walls (4)	30	170	83	339	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.088, Ceiling / Working Plane: 0.817.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	54	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 134097	Total: 183600	5130.0

Specific connected load: 19.29 W/m² = 11.54 W/m²/100 lx (Ground area: 266.00 m²)

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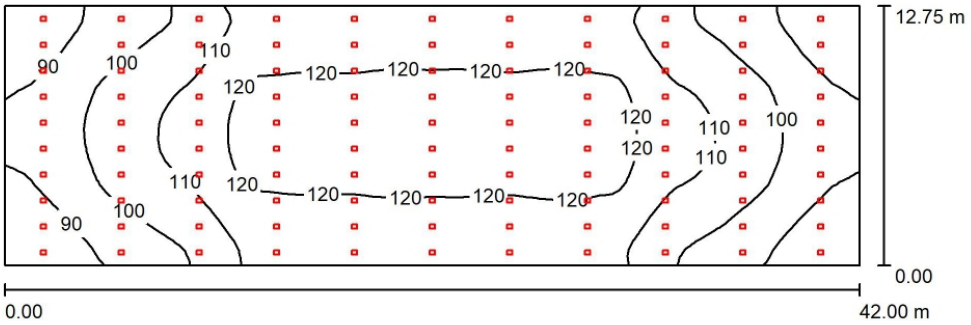
Bunker Area / Summary



Height of Room: 10.000 m, Mounting Height: 10.000 m, Light loss factor: 0.70

Values in Lux, Scale 1:301

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	109	81	126	0.746
Floor	10	102	78	119	0.761
Ceiling	50	138	47	671	0.343
Walls (4)	30	124	49	652	/

Workplane:

Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.186, Ceiling / Working Plane: 1.263.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	110	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 273160	Total: 374000	10450.0

Specific connected load: 19.51 W/m² = 17.97 W/m²/100 lx (Ground area: 535.50 m²)

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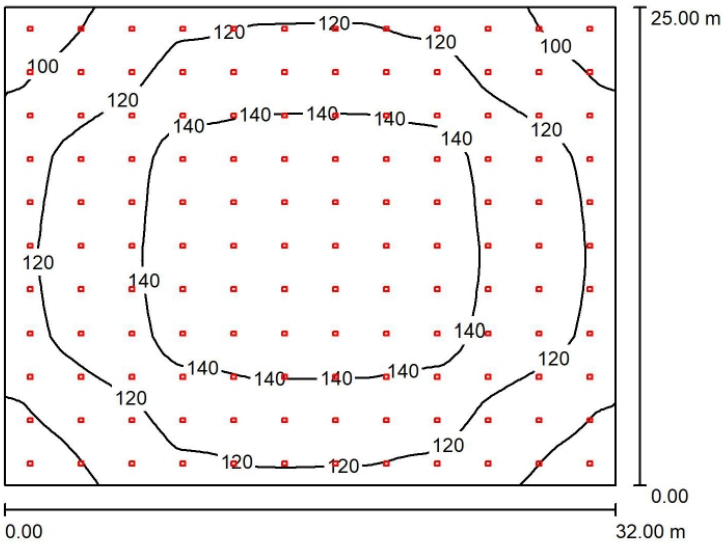
Crusher House / Summary



Height of Room: 8.000 m, Mounting Height: 8.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:321

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	128	88	157	0.689
Floor	10	122	83	149	0.680
Ceiling	50	114	47	652	0.410
Walls (4)	30	136	67	322	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.111, Ceiling / Working Plane: 0.885.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	132	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 327792	Total: 448800	12540.0

Specific connected load: 15.68 W/m² = 12.24 W/m²/100 lx (Ground area: 800.00 m²)

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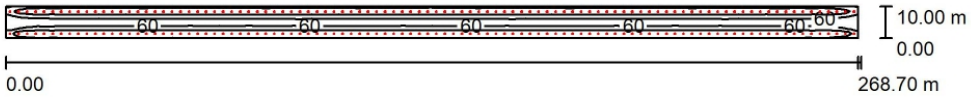
Belt Conveyor / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:1921

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	75	42	99	0.563
Floor	10	69	45	81	0.660
Ceiling	50	51	12	623	0.235
Walls (4)	30	88	40	172	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.344, Ceiling / Working Plane: 0.688.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	200	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 496655	Total: 680000	19000.0

Specific connected load: 7.07 W/m² = 9.48 W/m²/100 lx (Ground area: 2687.00 m²)

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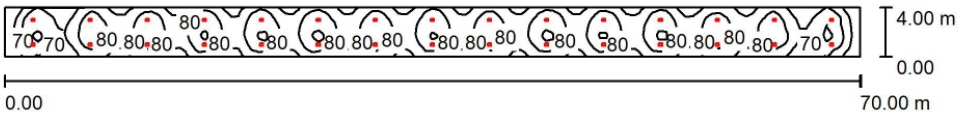
Pipe Conveyor / Summary



Height of Room: 3.200 m, Mounting Height: 3.200 m, Light loss factor: 0.70 Values in Lux, Scale 1:501

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	77	50	93	0.656
Floor	10	65	44	73	0.680
Ceiling	50	71	19	626	0.270
Walls (4)	30	75	28	250	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.088, Ceiling / Working Plane: 0.913.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	30	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 74498	Total: 102000	2850.0

Specific connected load: 10.18 W/m² = 13.25 W/m²/100 lx (Ground area: 280.00 m²)

Annexure VI
Case Study on Thermal Power Plant by using LED Luminaire

NTPC Nabinagar Thermal Power Plant (LED Luminaire)

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY:

Date: 15.11.2018
Operator: Ankit Ghosh

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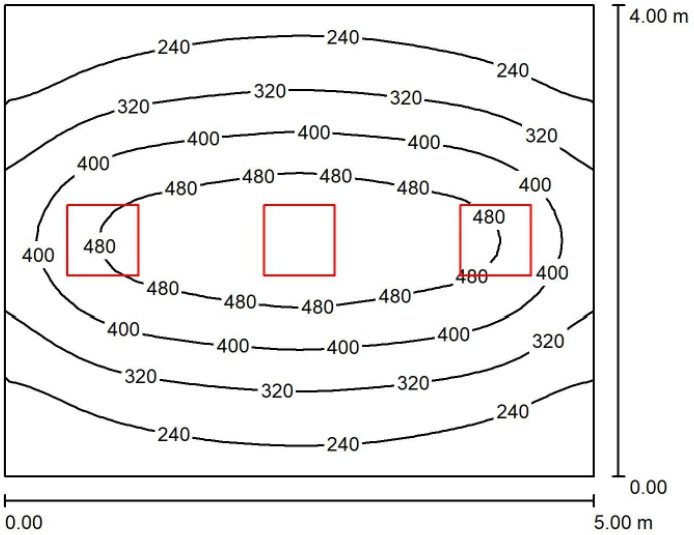
Office Room / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:52

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	345	163	549	0.473
Floor	20	281	175	382	0.624
Ceiling	70	76	47	104	0.623
Walls (4)	50	180	65	544	/

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

UGR Lengthways- Across to luminaire axis
Left Wall 17 17
Lower Wall 18 18
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.544, Ceiling / Working Plane: 0.220.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves consumer electrcal Ltd. 01 LCTRI-36-CDL (1.000)	3964	3965	33.4
			Total: 11892	Total: 11895	100.3

Specific connected load: 5.01 W/m² = 1.45 W/m²/100 lx (Ground area: 20.00 m²)

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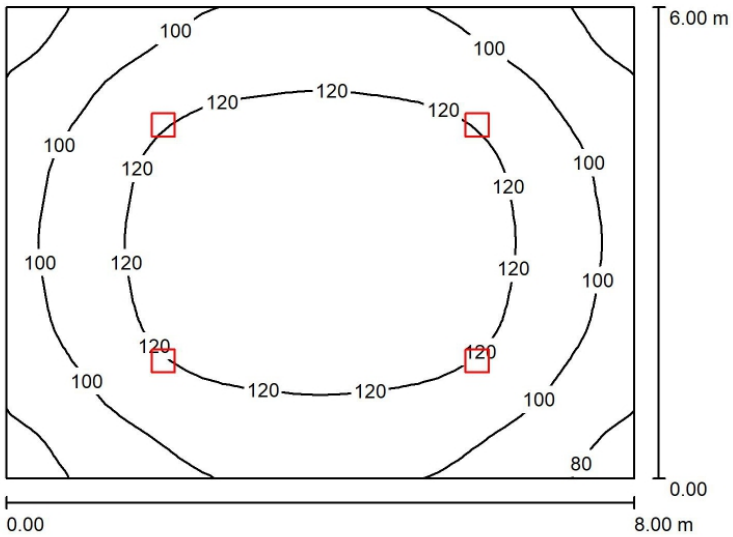
Battery Room / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:78

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	72	137	0.648
Floor	10	96	64	117	0.673
Ceiling	50	16	10	18	0.670
Walls (4)	30	66	11	157	/

Workplane:
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.624, Ceiling / Working Plane: 0.140.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. 01 FWL1315-40-CDL (1.000)	3637	3641	39.7
			Total: 14547	Total: 14564	158.7

Specific connected load: 3.31 W/m² = 2.98 W/m²/100 lx (Ground area: 48.00 m²)

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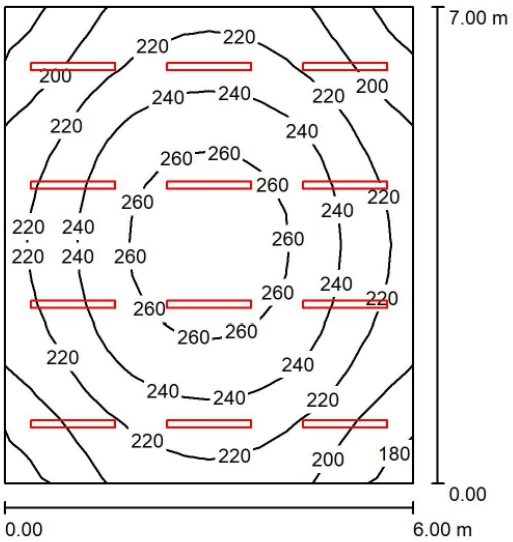
Motor Control Centre / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:90

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	228	175	272	0.765
Floor	10	196	151	229	0.769
Ceiling	50	206	55	1938	0.264
Walls (4)	30	205	85	554	/

Workplane:
Height: 0.760 m
Grid: 16 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.978, Ceiling / Working Plane: 0.905.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	12	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 41909	Total: 41926	397.9

Specific connected load: 9.47 W/m² = 4.15 W/m²/100 lx (Ground area: 42.00 m²)

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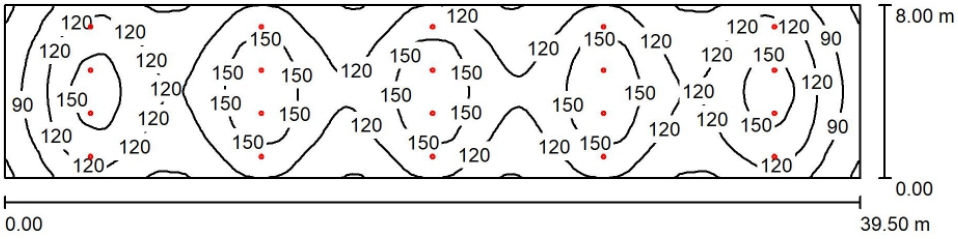
Transformer Room / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:283

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	125	56	171	0.451
Floor	10	115	58	148	0.506
Ceiling	50	16	10	84	0.635
Walls (4)	30	65	14	331	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.530, Ceiling / Working Plane: 0.132.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	20	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 73853	Total: 74590	698.0

Specific connected load: 2.21 W/m² = 1.77 W/m²/100 lx (Ground area: 316.00 m²)

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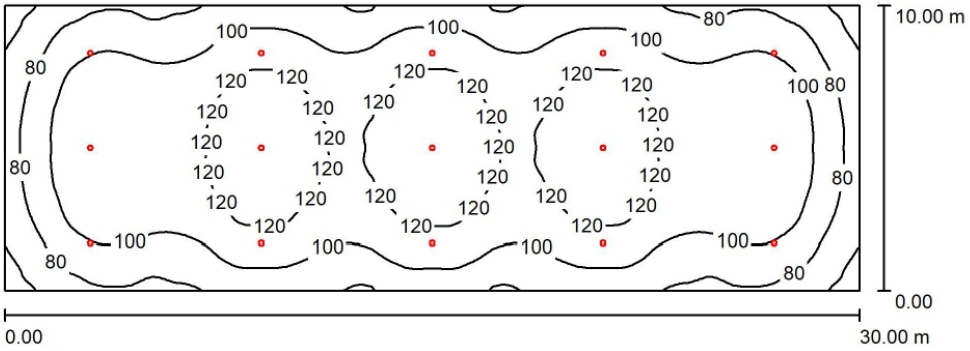
Pump House / Summary



Height of Room: 5.500 m, Mounting Height: 5.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:215

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	105	50	134	0.476
Floor	10	98	49	121	0.502
Ceiling	50	13	10	77	0.780
Walls (4)	30	52	11	127	/

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

UGR Lengthways- Across to luminaire axis
Left Wall 26 26
Lower Wall 26 26
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.496, Ceiling / Working Plane: 0.124.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	15	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 55390	Total: 55943	523.5

Specific connected load: 1.75 W/m² = 1.67 W/m²/100 lx (Ground area: 300.00 m²)

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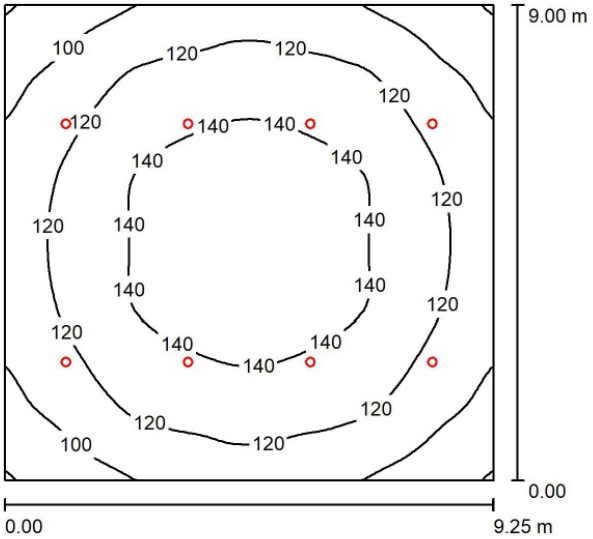
Drive House / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:116

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	123	79	152	0.641
Floor	10	110	76	135	0.685
Ceiling	50	22	15	96	0.709
Walls (4)	30	80	18	271	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.682, Ceiling / Working Plane: 0.177.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 29541	Total: 29836	279.2

Specific connected load: 3.35 W/m² = 2.73 W/m²/100 lx (Ground area: 83.25 m²)

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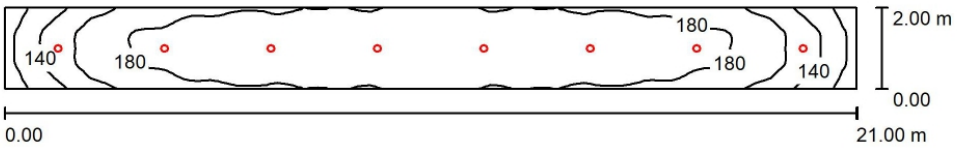
Corridor / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:151

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	176	105	199	0.598
Floor	10	145	93	164	0.642
Ceiling	50	35	26	92	0.737
Walls (4)	30	119	29	348	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.751, Ceiling / Working Plane: 0.200.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 29541	Total: 29836	279.2

Specific connected load: 6.65 W/m² = 3.77 W/m²/100 lx (Ground area: 42.00 m²)

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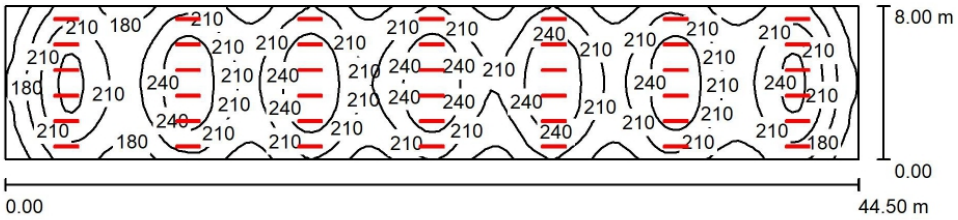
Switch Gear Room / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:319

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	212	130	269	0.613
Floor	10	197	128	235	0.651
Ceiling	70	109	31	2210	0.288
Walls (4)	50	158	77	724	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.783, Ceiling / Working Plane: 0.517.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	42	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 146682	Total: 146740	1392.7

Specific connected load: 3.91 W/m² = 1.84 W/m²/100 lx (Ground area: 356.00 m²)

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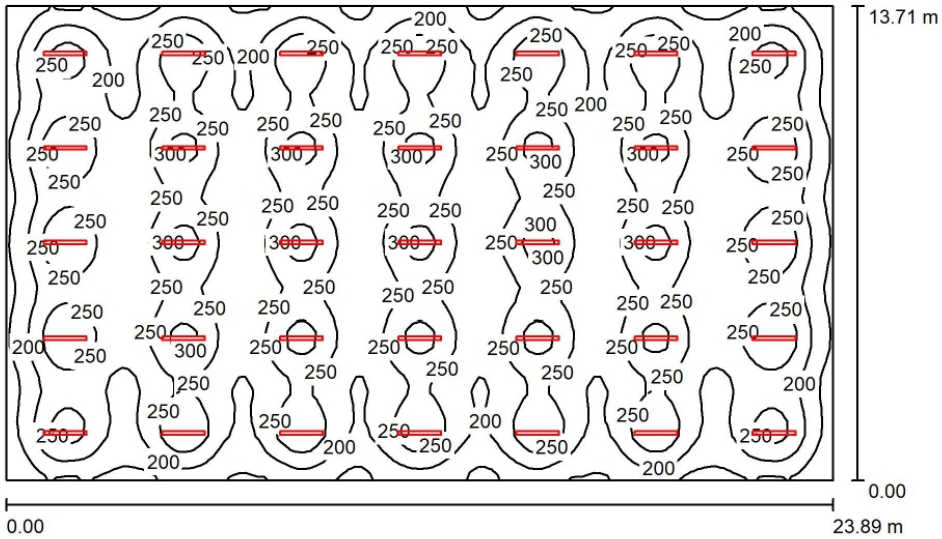
Cable Cellar Room / Summary



Height of Room: 2.500 m, Mounting Height: 2.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:177

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	230	107	325	0.465
Floor	10	211	108	257	0.514
Ceiling	50	88	22	2112	0.248
Walls (4)	30	147	51	253	/

Workplane:

Height:	0.760 m
Grid:	128 x 32 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.652, Ceiling / Working Plane: 0.372.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	35	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 122235	Total: 122283	1160.6

Specific connected load: 3.54 W/m² = 1.54 W/m²/100 lx (Ground area: 327.53 m²)

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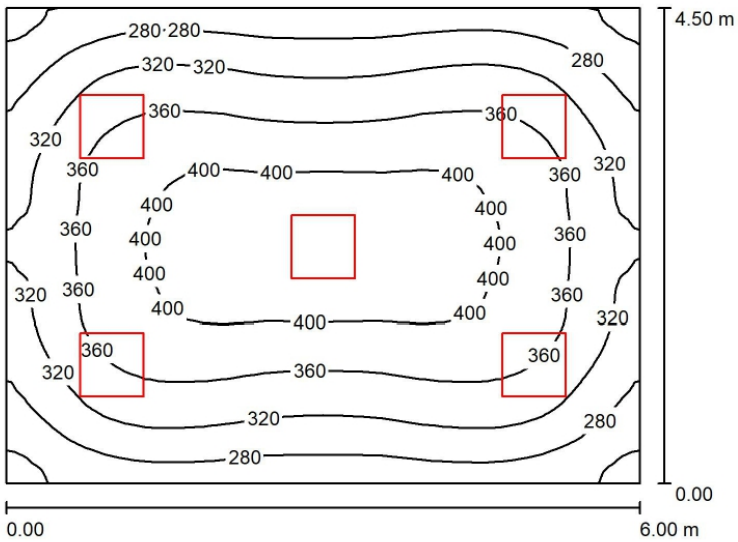
Remote Input Output (RIO) Room / Summary



Height of Room: 3.500 m, Mounting Height: 3.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:58

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	342	229	423	0.670
Floor	10	288	210	346	0.730
Ceiling	70	81	52	103	0.636
Walls (4)	50	215	99	421	/

Workplane:

Height:	0.760 m
Grid:	128 x 32 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.683, Ceiling / Working Plane: 0.238.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	5	Crompton Greaves consumer electrcal Ltd. 01 LCTRI-36-CDL (1.000)	3964	3965	33.4
			Total: 19820	Total: 19825	167.2

Specific connected load: 6.19 W/m² = 1.81 W/m²/100 lx (Ground area: 27.00 m²)

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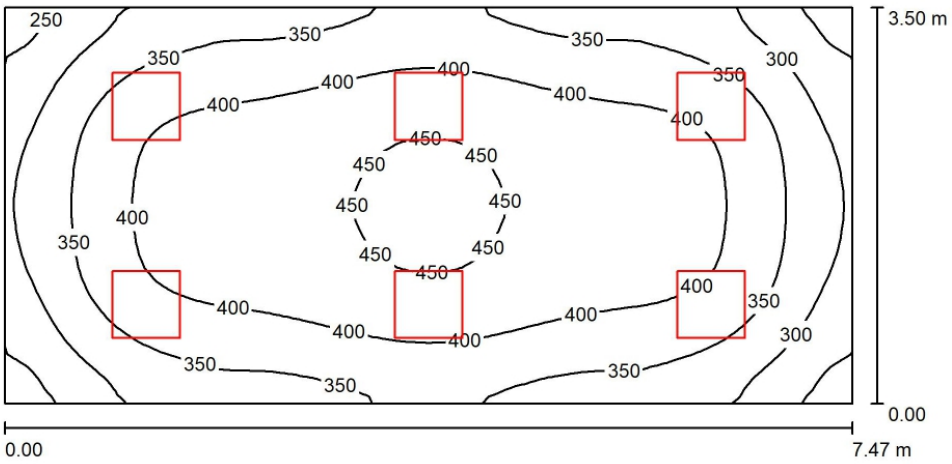
Wagon Tripler Control Room / Summary



Height of Room: 3.500 m, Mounting Height: 3.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:54

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	374	233	461	0.623
Floor	10	314	207	379	0.659
Ceiling	70	79	42	106	0.527
Walls (4)	50	222	77	474	/

Workplane:

Height:	0.760 m
Grid:	128 x 32 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.643, Ceiling / Working Plane: 0.211.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 21149	Total: 21176	205.1

Specific connected load: 7.84 W/m² = 2.10 W/m²/100 lx (Ground area: 26.14 m²)

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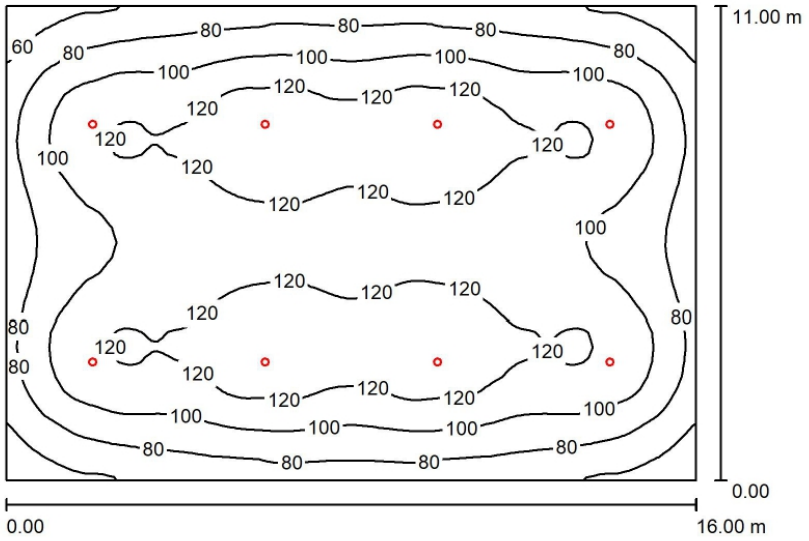
Transfer Point / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:142

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	103	45	136	0.436
Floor	10	95	47	120	0.498
Ceiling	50	11	8.27	80	0.728
Walls (4)	30	45	9.48	94	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m

UGR Lengthways- Across to luminaire axis
Left Wall 26 26
Lower Wall 26 26
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.425, Ceiling / Working Plane: 0.111.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 29541	Total: 29836	279.2

Specific connected load: 1.59 W/m² = 1.54 W/m²/100 lx (Ground area: 176.00 m²)

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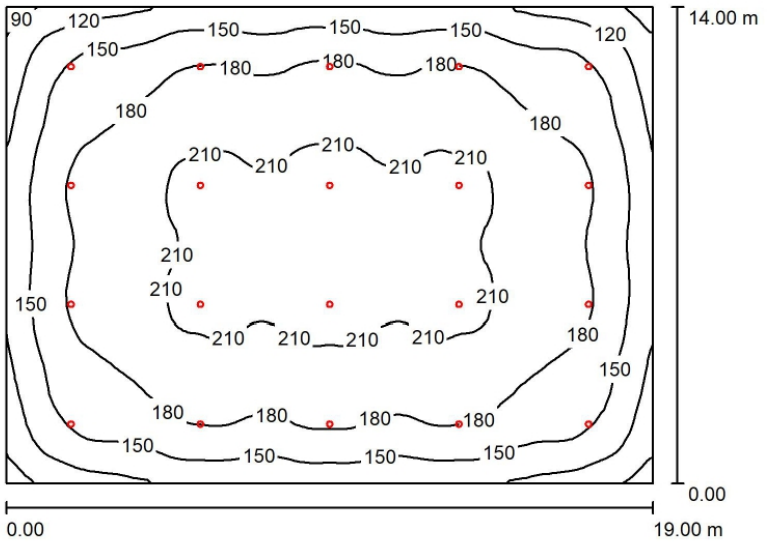
Junction Tower / Summary



Height of Room: 4.500 m, Mounting Height: 4.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:180

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	178	81	224	0.453
Floor	10	166	81	210	0.488
Ceiling	50	20	17	92	0.822
Walls (4)	30	80	17	129	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m

UGR Lengthways- Across to luminaire axis
Left Wall 26 26
Lower Wall 26 26
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.455, Ceiling / Working Plane: 0.115.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	20	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 73853	Total: 74590	698.0

Specific connected load: 2.62 W/m² = 1.48 W/m²/100 lx (Ground area: 266.00 m²)

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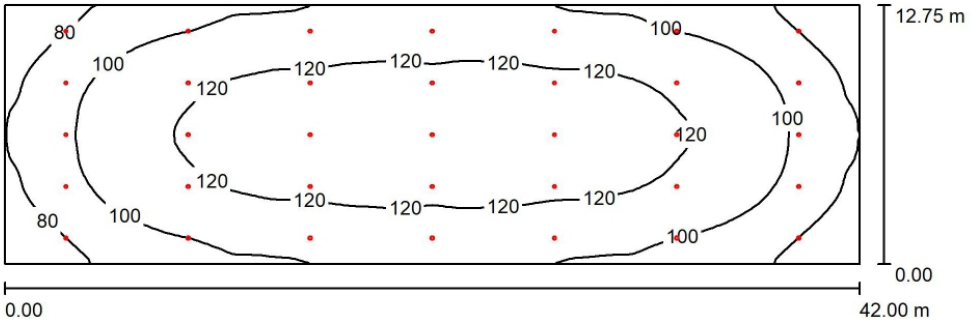
Bunker Area / Summary



Height of Room: 10.000 m, Mounting Height: 10.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:301

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	108	62	132	0.577
Floor	10	102	60	125	0.588
Ceiling	50	17	14	92	0.867
Walls (4)	30	64	17	213	/

Workplane:

Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.611, Ceiling / Working Plane: 0.155.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	35	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 129243	Total: 130533	1221.5

Specific connected load: 2.28 W/m² = 2.12 W/m²/100 lx (Ground area: 535.50 m²)

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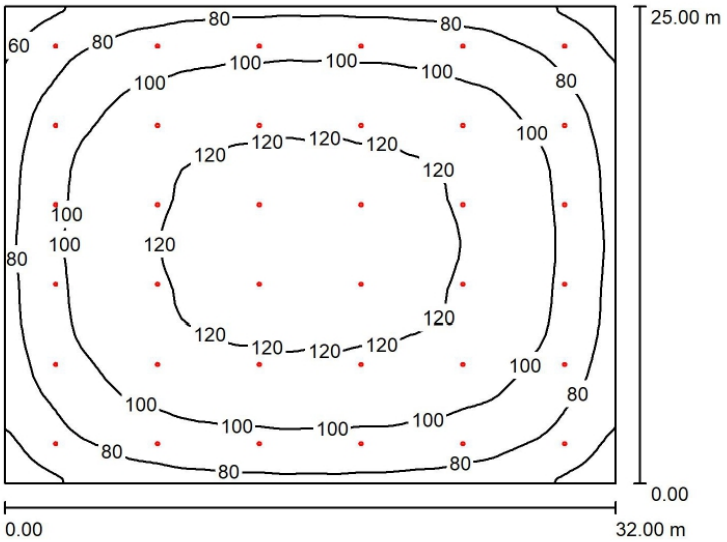
Crusher House / Summary



Height of Room: 8.000 m, Mounting Height: 8.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:321

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	101	49	128	0.481
Floor	10	97	48	125	0.495
Ceiling	50	12	9.90	88	0.848
Walls (4)	30	49	11	87	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m

UGR Lengthways- Across to luminaire axis
Left Wall 26 26
Lower Wall 26 26
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.492, Ceiling / Working Plane: 0.116.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	36	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 132936	Total: 134262	1256.4

Specific connected load: 1.57 W/m² = 1.56 W/m²/100 lx (Ground area: 800.00 m²)

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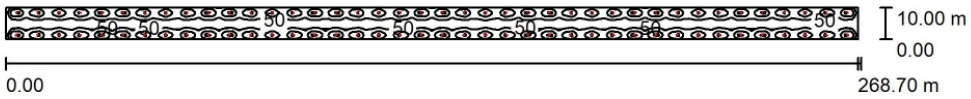
Belt Conveyor / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:1921

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	76	22	237	0.290
Floor	10	71	33	139	0.462
Ceiling	50	8.76	6.33	22	0.723
Walls (4)	30	44	7.19	176	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.565, Ceiling / Working Plane: 0.115.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	80	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 295414	Total: 298360	2792.0

Specific connected load: 1.04 W/m² = 1.37 W/m²/100 lx (Ground area: 2687.00 m²)

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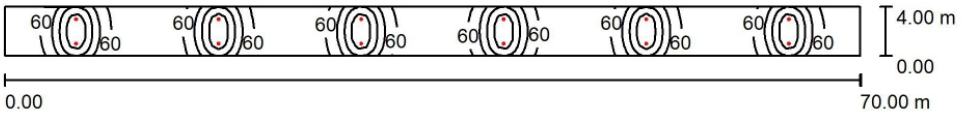
Pipe Conveyor / Summary



Height of Room: 3.200 m, Mounting Height: 3.200 m, Light loss factor: 0.80 Values in Lux, Scale 1:501

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	90	10	285	0.113
Floor	10	78	15	192	0.197
Ceiling	50	11	4.66	67	0.436
Walls (4)	30	43	5.68	326	/

Workplane:
Height: 0.760 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.503, Ceiling / Working Plane: 0.119.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	12	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 44312	Total: 44754	418.8

Specific connected load: 1.50 W/m² = 1.66 W/m²/100 lx (Ground area: 280.00 m²)

Annexure VII
Case Study on Oil Refinery by using Conventional Luminaire

Numaligarh Oil refinary Conventional

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY:

Date: 12.09.2018
Operator: Ankit Ghosh

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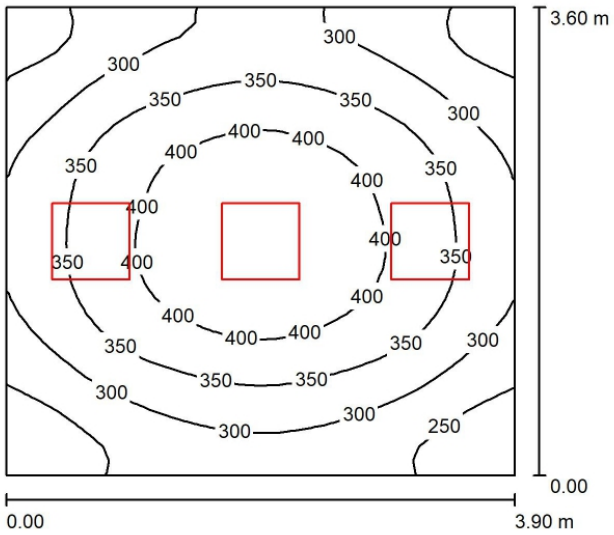
Office Room / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:47

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	334	210	438	0.626
Floor	20	262	190	310	0.725
Ceiling	70	72	46	203	0.641
Walls (4)	50	168	63	513	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.521, Ceiling / Working Plane: 0.215.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. CRCLU240EB/S COMMERCIAL LUMINAIRE (1.000)	3430	7000	88.0
			Total: 10290	Total: 21000	264.0

Specific connected load: 18.80 W/m² = 5.62 W/m²/100 lx (Ground area: 14.04 m²)

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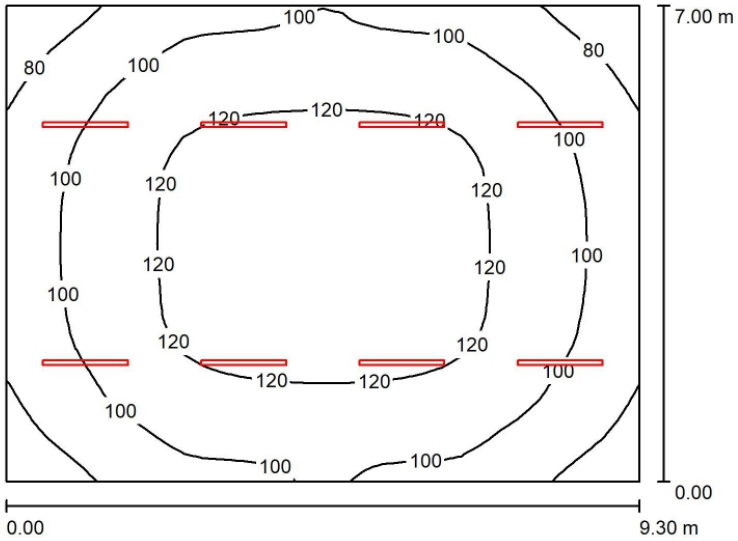
Electrical Workshop / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:90

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	107	69	131	0.647
Floor	10	93	62	113	0.668
Ceiling	50	89	18	1346	0.198
Walls (4)	30	89	42	161	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.908, Ceiling / Working Plane: 0.826.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 24128	Total: 26000	428.0

Specific connected load: 6.57 W/m² = 6.12 W/m²/100 lx (Ground area: 65.10 m²)

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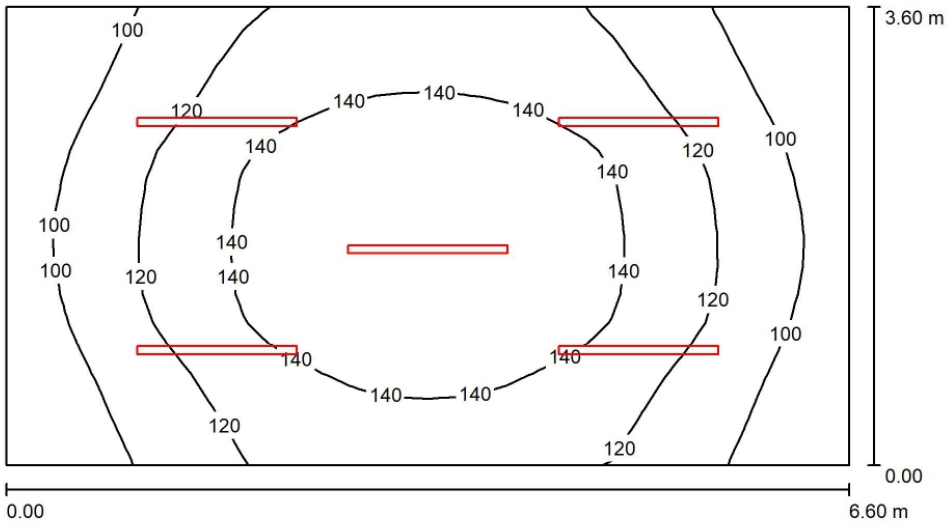
Radio Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:48

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	123	83	155	0.671
Floor	10	99	73	119	0.739
Ceiling	50	150	27	1832	0.179
Walls (4)	30	112	41	391	/

Workplane:

Height:	0.760 m
Grid:	32 x 16 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.025, Ceiling / Working Plane: 1.214.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	5	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 15080	Total: 16250	267.5

Specific connected load: 11.26 W/m² = 9.14 W/m²/100 lx (Ground area: 23.76 m²)

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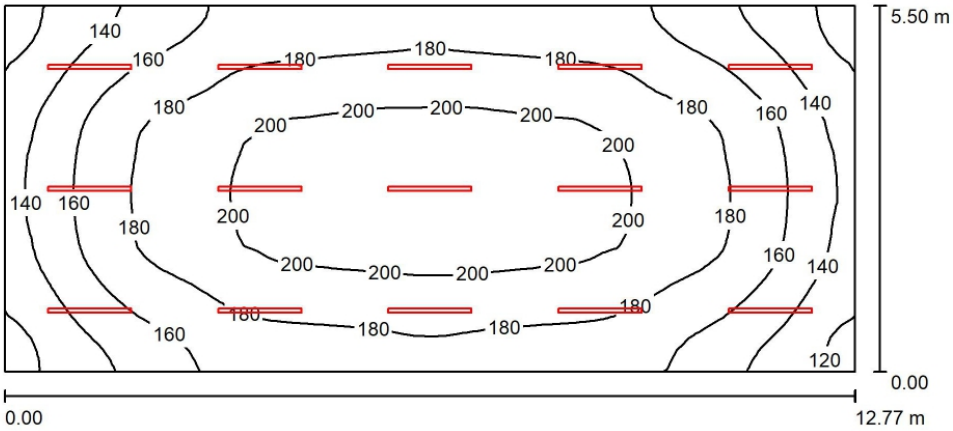
PMCC HT & LT Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:92

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	174	112	210	0.642
Floor	10	150	103	180	0.685
Ceiling	50	154	30	1893	0.194
Walls (4)	30	153	67	412	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.968, Ceiling / Working Plane: 0.876.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	15	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 45241	Total: 48750	802.5

Specific connected load: 11.43 W/m² = 6.56 W/m²/100 lx (Ground area: 70.23 m²)

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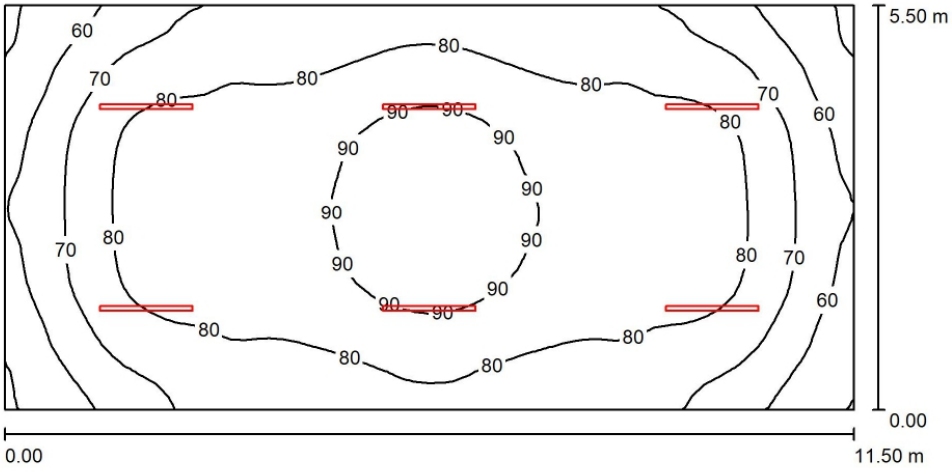
Isolator Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:83

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	78	48	96	0.623
Floor	10	66	46	80	0.689
Ceiling	50	67	14	1666	0.202
Walls (4)	30	66	29	181	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.936, Ceiling / Working Plane: 0.852.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 18096	Total: 19500	321.0

Specific connected load: 5.08 W/m² = 6.53 W/m²/100 lx (Ground area: 63.25 m²)

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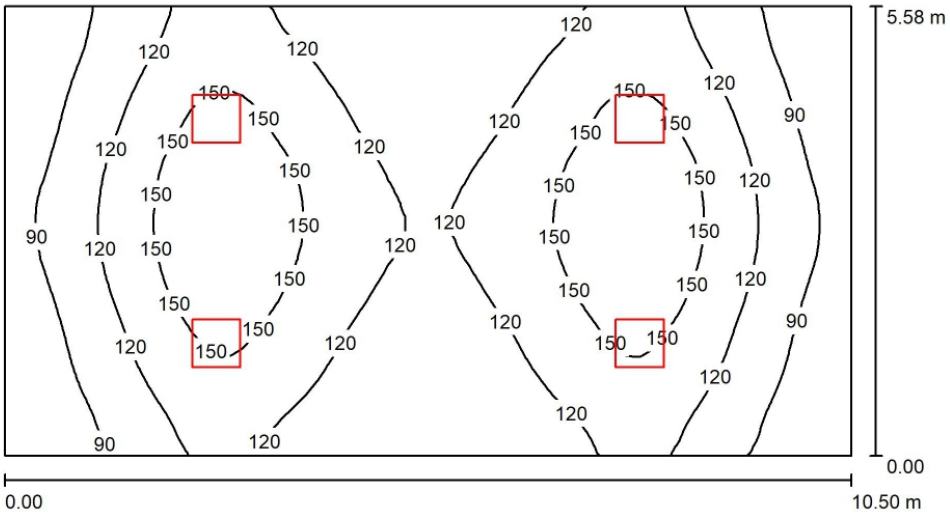
Variable Frequency Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:76

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	120	63	174	0.524
Floor	20	107	66	138	0.614
Ceiling	70	27	18	167	0.663
Walls (4)	50	62	24	191	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.520, Ceiling / Working Plane: 0.227.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. CRCLU240EB/S COMMERCIAL LUMINAIRE (1.000)	3430	7000	88.0
			Total: 13721	Total: 28000	352.0

Specific connected load: 6.01 W/m² = 5.00 W/m²/100 lx (Ground area: 58.59 m²)

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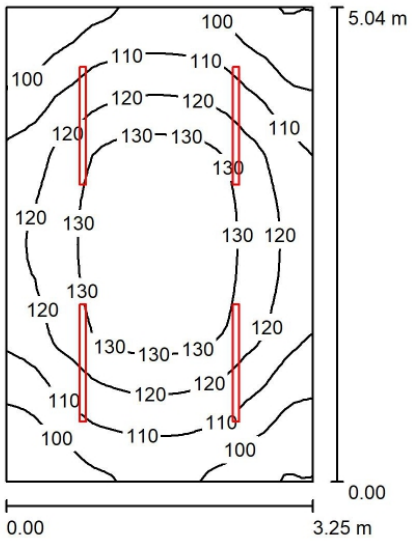
Capacitor Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:65

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	117	89	138	0.762
Floor	10	92	73	106	0.799
Ceiling	50	175	34	1472	0.192
Walls (4)	30	119	39	429	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.156, Ceiling / Working Plane: 1.500.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 12064	Total: 13000	214.0

Specific connected load: 13.06 W/m² = 11.19 W/m²/100 lx (Ground area: 16.38 m²)

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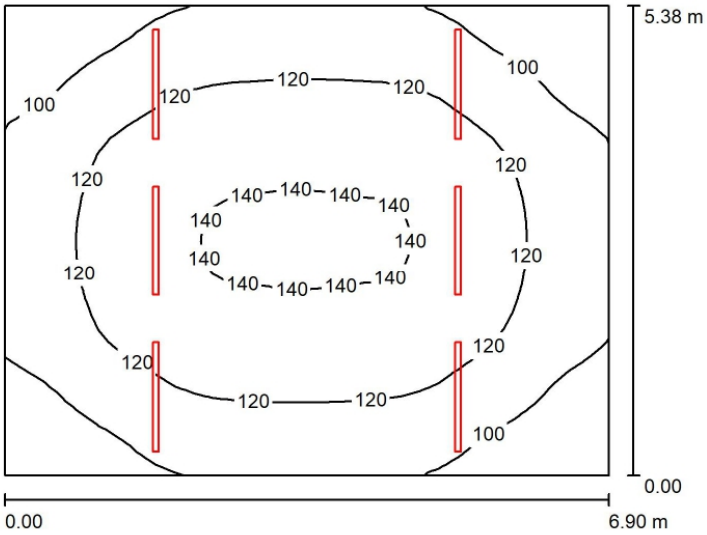
PLC Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:70

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	117	83	142	0.708
Floor	10	97	72	116	0.735
Ceiling	50	114	23	1375	0.198
Walls (4)	30	101	43	289	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.950, Ceiling / Working Plane: 0.977.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. IGP1414HSB INDUSTRIAL LUMINARIE (1.000)	3016	3250	53.5
			Total: 18096	Total: 19500	321.0

Specific connected load: 8.65 W/m² = 7.39 W/m²/100 lx (Ground area: 37.12 m²)

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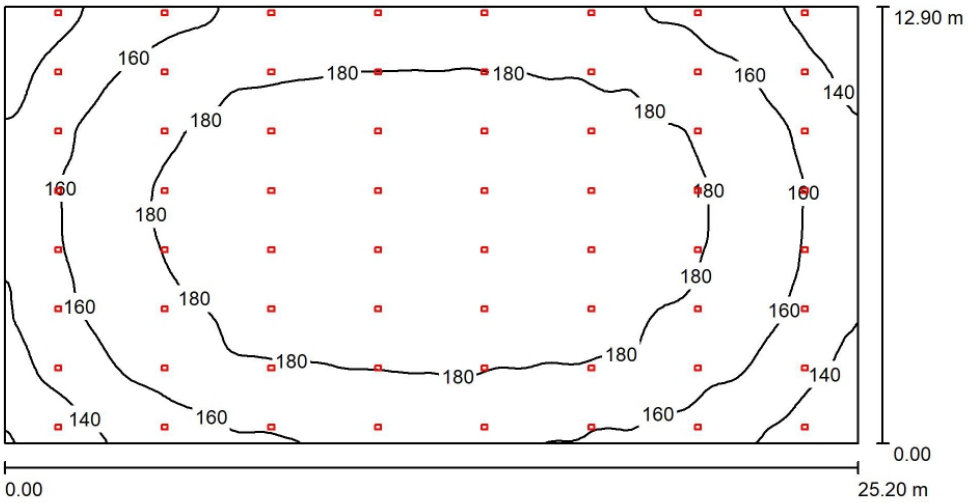
HB Pump Shed / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:181

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	171	119	198	0.695
Floor	10	158	115	185	0.728
Ceiling	50	143	30	4519	0.209
Walls (4)	30	181	86	5267	/

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.141, Ceiling / Working Plane: 0.827.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	64	Crompton Greaves Ltd. IWV1508IHBC INDUSTRIAL BULK HEAD LUMINAIRE (1.000)	2483	3400	95.0
			Total: 158929	Total: 217600	6080.0

Specific connected load: 18.70 W/m² = 10.91 W/m²/100 lx (Ground area: 325.08 m²)

Annexure VIII
Case Study on Oil Refinery by using LED Luminaire

Numaligarh Oil refinary LED Luminaires

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY:

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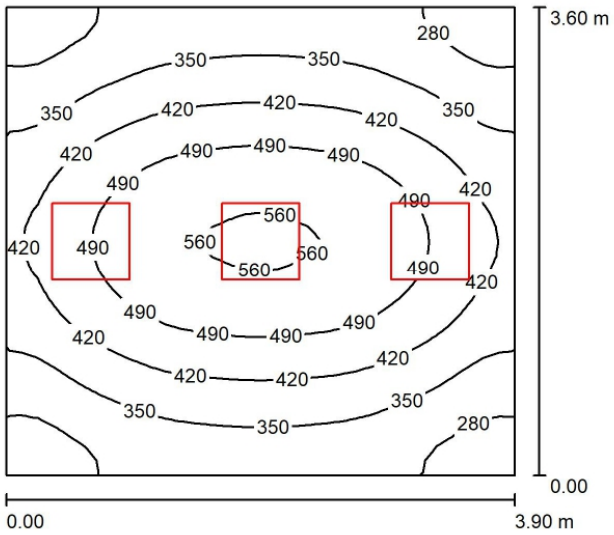
Office Room / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:47

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	406	233	570	0.575
Floor	20	319	217	402	0.680
Ceiling	70	117	71	200	0.608
Walls (4)	50	241	98	899	/

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

UGR Lengthways- Across to luminaire axis
Left Wall 16 16
Lower Wall 16 16
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.647, Ceiling / Working Plane: 0.287.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves consumer electrcal Ltd. 01 LCTRI-36-CDL (1.000)	3964	3965	33.4
			Total: 11892	Total: 11895	100.3

Specific connected load: 7.14 W/m² = 1.76 W/m²/100 lx (Ground area: 14.04 m²)

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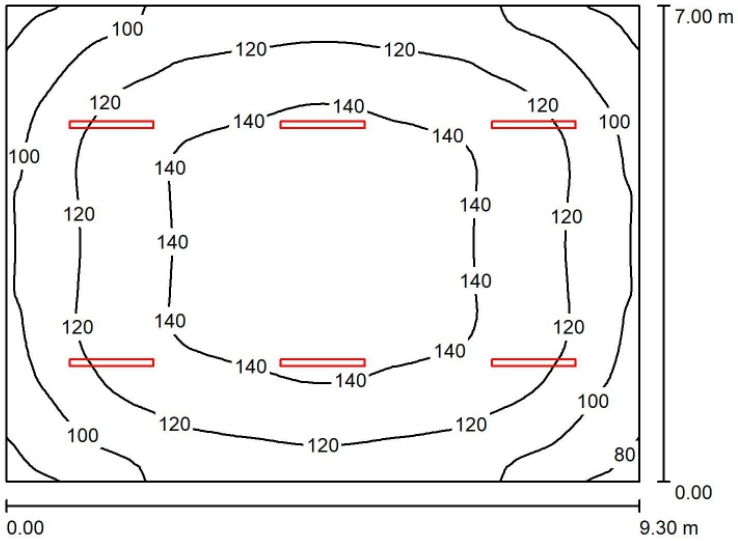
Electrical Workshop / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:90

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	123	74	151	0.599
Floor	10	106	68	130	0.639
Ceiling	50	70	20	1905	0.283
Walls (4)	30	89	34	162	/

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

UGR (CIE, SHR = 0.25.)

	Lengthways-	Across
Left Wall	20	18
Lower Wall	21	19

to luminaire axis

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.779, Ceiling / Working Plane: 0.573.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 20955	Total: 20963	199.0

Specific connected load: 3.06 W/m² = 2.49 W/m²/100 lx (Ground area: 65.10 m²)

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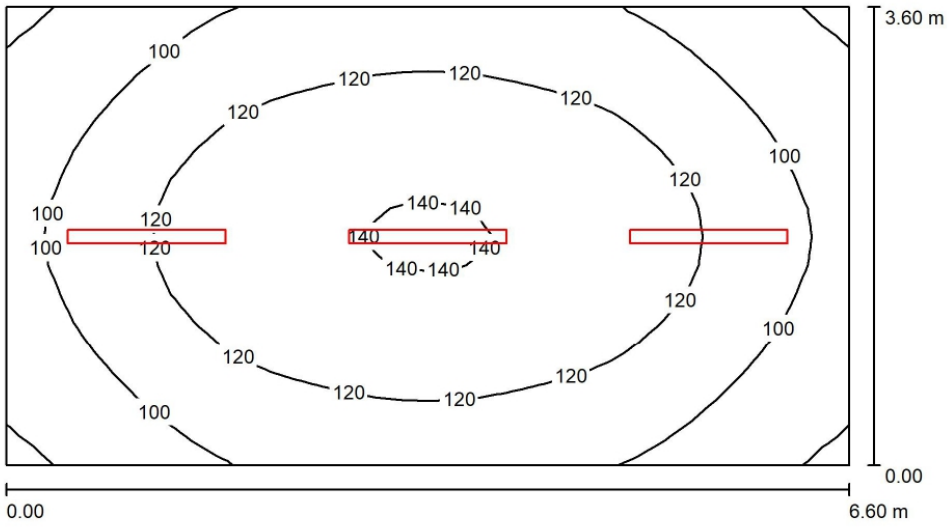
Radio Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:48

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	113	78	142	0.688
Floor	10	91	67	109	0.741
Ceiling	50	91	23	1904	0.253
Walls (4)	30	90	38	228	/

Workplane:

Height:	0.760 m
Grid:	32 x 16 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.881, Ceiling / Working Plane: 0.807.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 10477	Total: 10481	99.5

Specific connected load: 4.19 W/m² = 3.70 W/m²/100 lx (Ground area: 23.76 m²)

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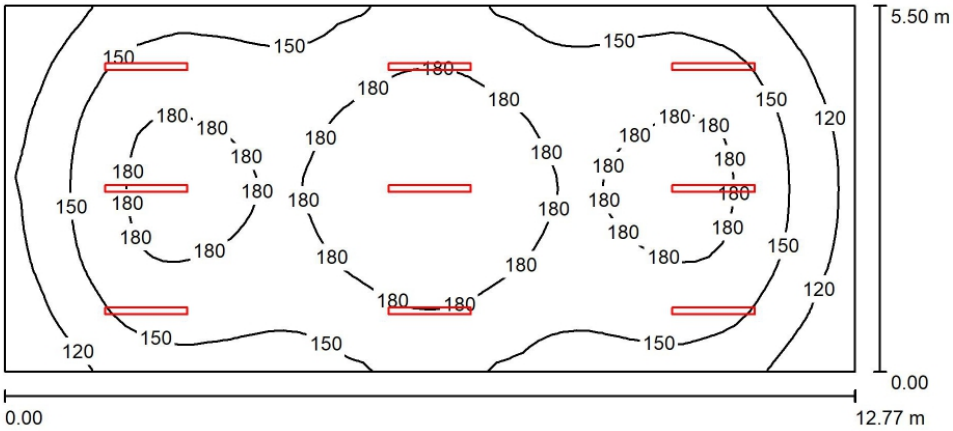
PMCC HT & LT Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:92

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	160	92	205	0.573
Floor	10	139	89	172	0.639
Ceiling	50	98	23	2124	0.234
Walls (4)	30	119	50	420	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.811, Ceiling / Working Plane: 0.608.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 31432	Total: 31444	298.4

Specific connected load: 4.25 W/m² = 2.65 W/m²/100 lx (Ground area: 70.23 m²)

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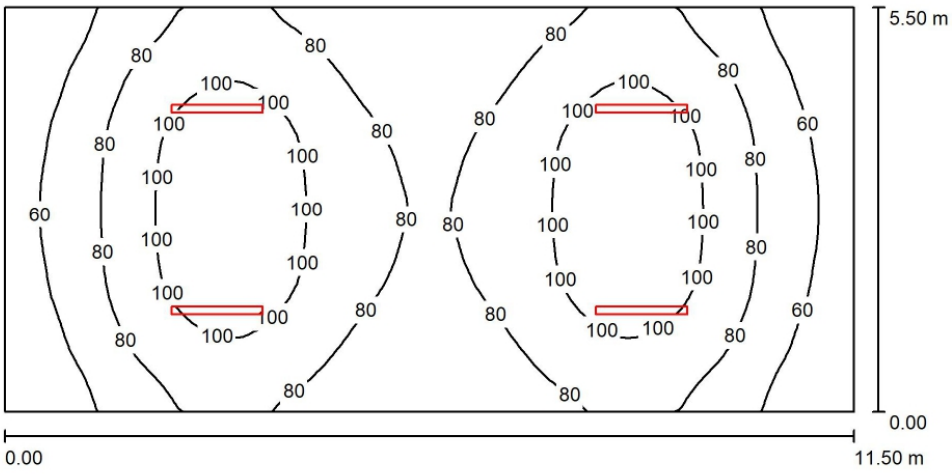
Isolator Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:83

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	82	45	112	0.543
Floor	10	70	43	89	0.609
Ceiling	50	49	11	1920	0.220
Walls (4)	30	58	22	198	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.768, Ceiling / Working Plane: 0.596.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 13970	Total: 13975	132.6

Specific connected load: 2.10 W/m² = 2.56 W/m²/100 lx (Ground area: 63.25 m²)

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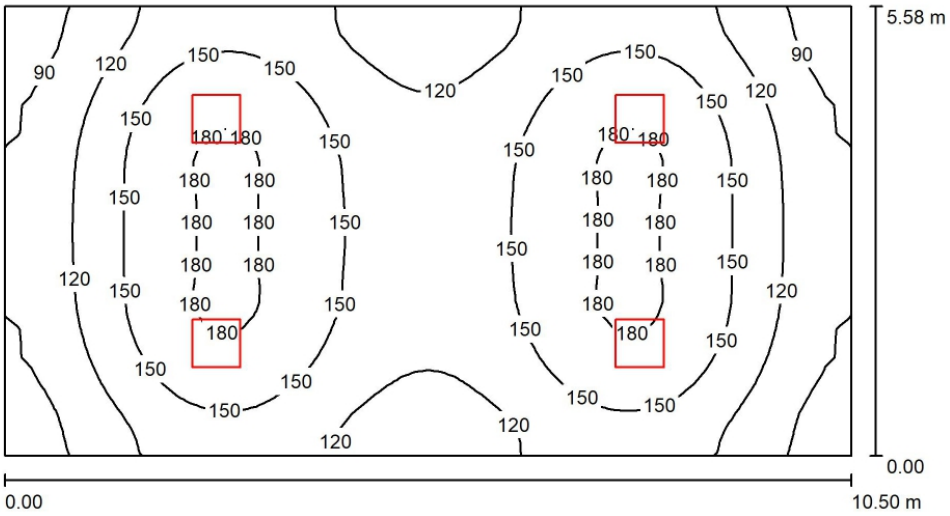
Variable Frequency Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:76

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	138	75	186	0.546
Floor	20	122	75	152	0.614
Ceiling	70	31	22	40	0.716
Walls (4)	50	76	27	178	/

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

UGR (CIE, SHR = 0.25.)

	Lengthways-	Across
Left Wall	17	17
Lower Wall	16	16

to luminaire axis

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.571, Ceiling / Working Plane: 0.227.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 14099	Total: 14118	136.7

Specific connected load: 2.33 W/m² = 1.69 W/m²/100 lx (Ground area: 58.59 m²)

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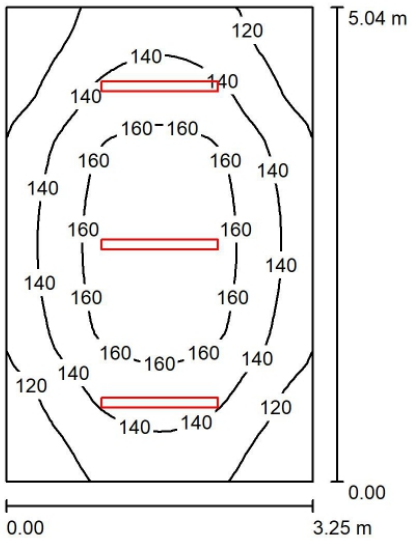
Capacitor Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 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	/	141	102	175	0.720
Floor	10	110	85	131	0.767
Ceiling	50	135	31	2067	0.227
Walls (4)	30	117	46	471	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.933, Ceiling / Working Plane: 0.954.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 10477	Total: 10481	99.5

Specific connected load: 6.07 W/m² = 4.30 W/m²/100 lx (Ground area: 16.38 m²)

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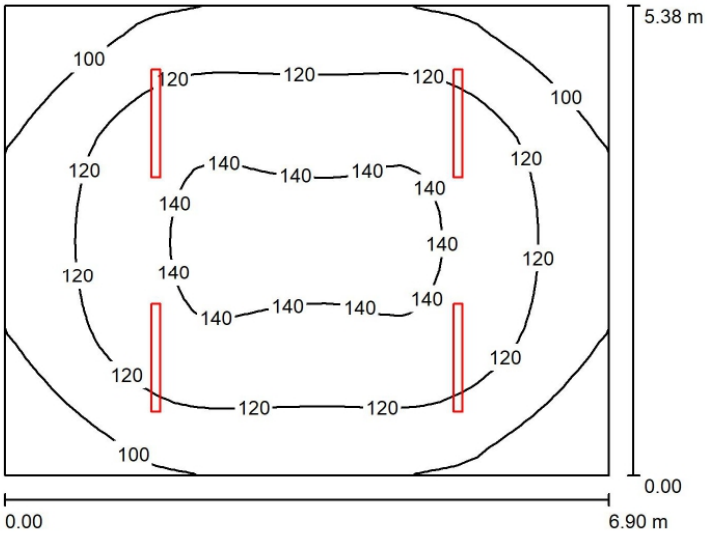
PLC Room / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:70

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	119	80	144	0.673
Floor	10	99	68	119	0.688
Ceiling	50	78	19	1907	0.238
Walls (4)	30	88	36	157	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.812, Ceiling / Working Plane: 0.659.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. 01 IGP132LT8-16 (1.000)	3492	3494	33.2
			Total: 13970	Total: 13975	132.6

Specific connected load: 3.57 W/m² = 3.01 W/m²/100 lx (Ground area: 37.12 m²)

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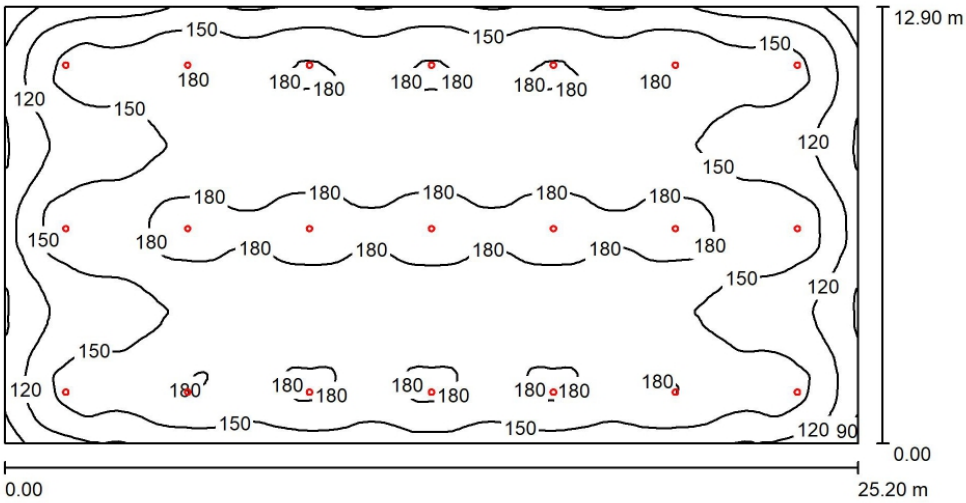
HB Pump Shed / Summary



Height of Room: 4.000 m, Mounting Height: 4.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:181

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	156	72	198	0.459
Floor	10	146	74	178	0.504
Ceiling	50	18	14	88	0.795
Walls (4)	30	76	15	156	/

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

UGR (CIE, SHR = 0.25.)

	Lengthways-	Across
Left Wall	26	26
Lower Wall	26	26

to luminaire axis

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.495, Ceiling / Working Plane: 0.116.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	21	Crompton Greaves Ltd. 01 LWV12-35-CDL (1.000)	3693	3730	34.9
			Total: 77546	Total: 78320	732.9

Specific connected load: 2.25 W/m² = 1.45 W/m²/100 lx (Ground area: 325.08 m²)

Annexure IX
Case Study on Metro Railway Station by using Conventional Luminaire

CC METRO - PLATFORM AREA (Conventional)

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY :

Date: 08.06.2018
Operator: Ankit Ghosh

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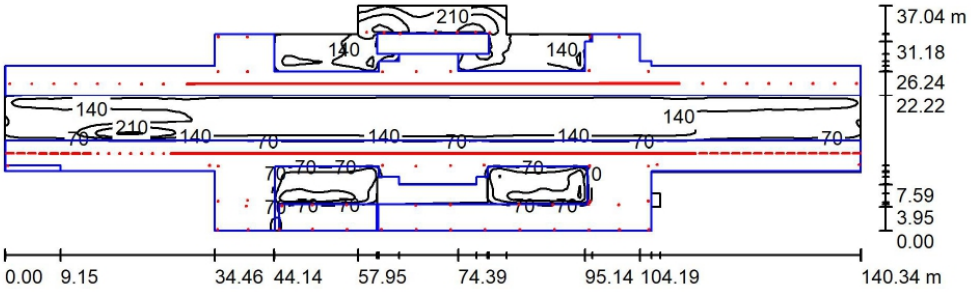
PLATFORM AREA / Summary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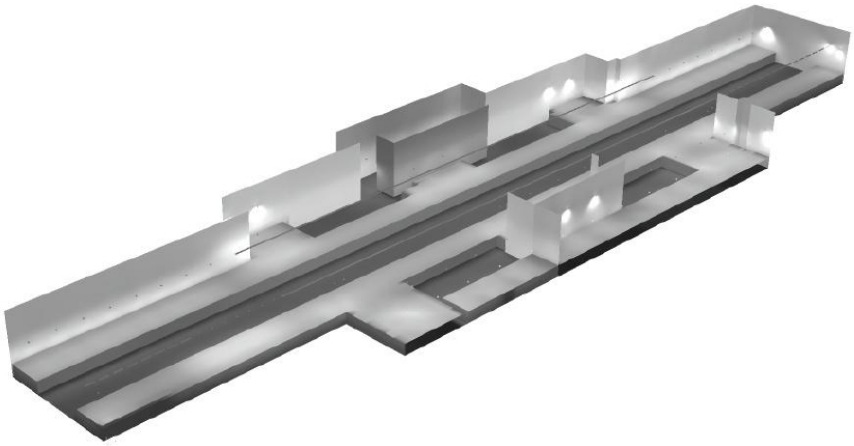
PLATFORM AREA / 3D Rendering



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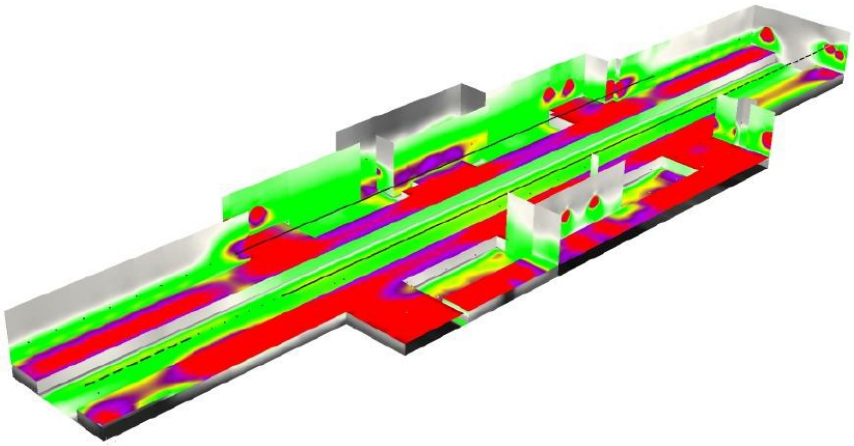
PLATFORM AREA / False Color Rendering



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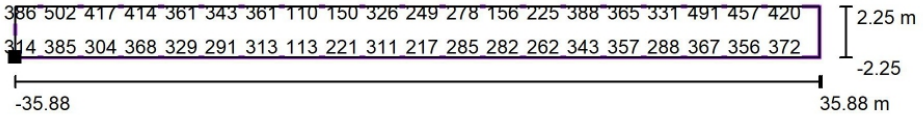
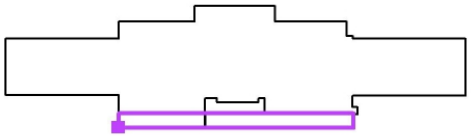
PLATFORM AREA / PASSAGE AREA / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 545

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (34.563 m, -9.300 m, 1.800 m)



Grid: 237 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
323	82	592	0.26	0.14

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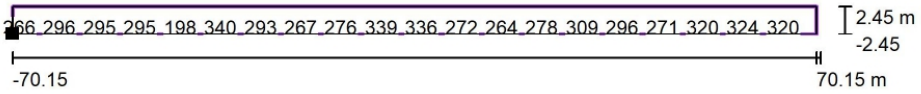
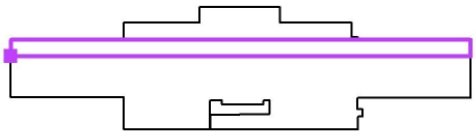
PLATFORM AREA / PLATFORM 1 - FRONT / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 1064

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (0.239 m, 13.245 m, 1.600 m)



Grid: 162 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
305	167	479	0.55	0.35

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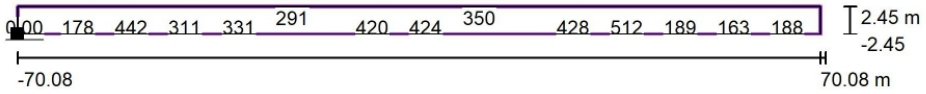
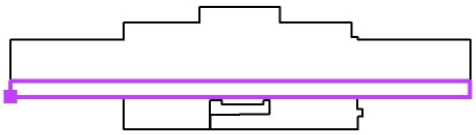
PLATFORM AREA / PLATFORM 2 - FRONT / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 1063

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (0.200 m, 0.800 m, 1.650 m)



Grid: 166 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
317	0.00	609	0.00	0.00

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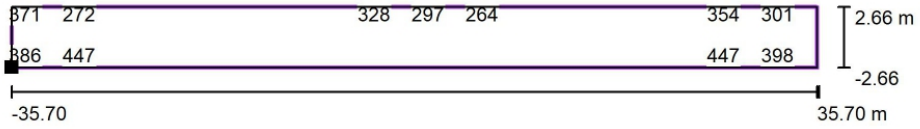
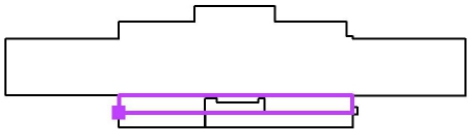
PLATFORM AREA / PLATFORM 2 - REAR / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 542

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (34.691 m, -4.629 m, 1.600 m)



Grid: 28 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
347	250	512	0.72	0.49

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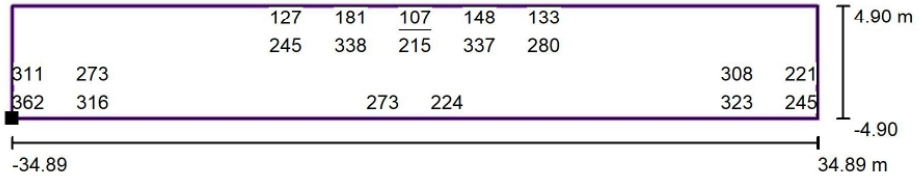
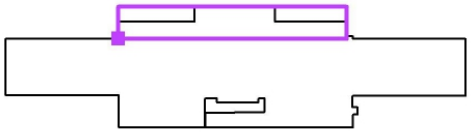
PLATFORM AREA / PLATFORM 1 - REAR / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 530

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (34.500 m, 18.200 m, 1.650 m)



Grid: 33 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
254	107	386	0.42	0.28

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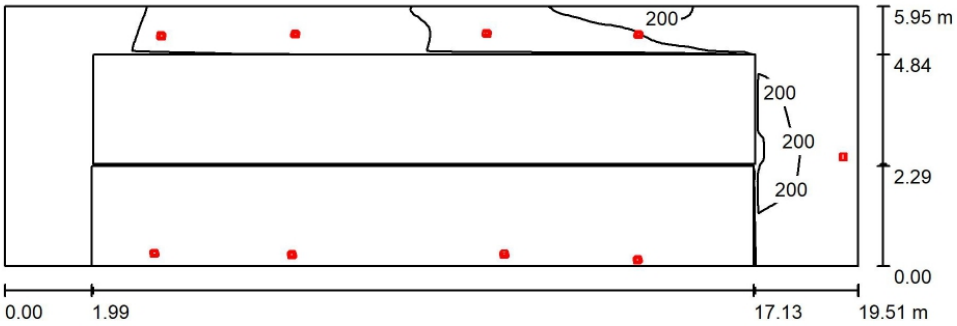
STAIRCASE - PLATFORM 1 LEFT / Summary



Height of Room: 10.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	110	9.08	213	0.083
Floors (10)	20	59	0.13	326	/
Ceiling	70	85	29	279	0.341
Walls (4)	50	132	2.06	1357	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.172, Ceiling / Working Plane: 0.788.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. FADR1215IH (CA) CANOPY LIGHTLUMINARIE (1.000)	8843	11000	172.0
			Total: 79584	Total: 99000	1548.0

Specific connected load: 13.34 W/m² = 12.15 W/m²/100 lx (Ground area: 116.01 m²)

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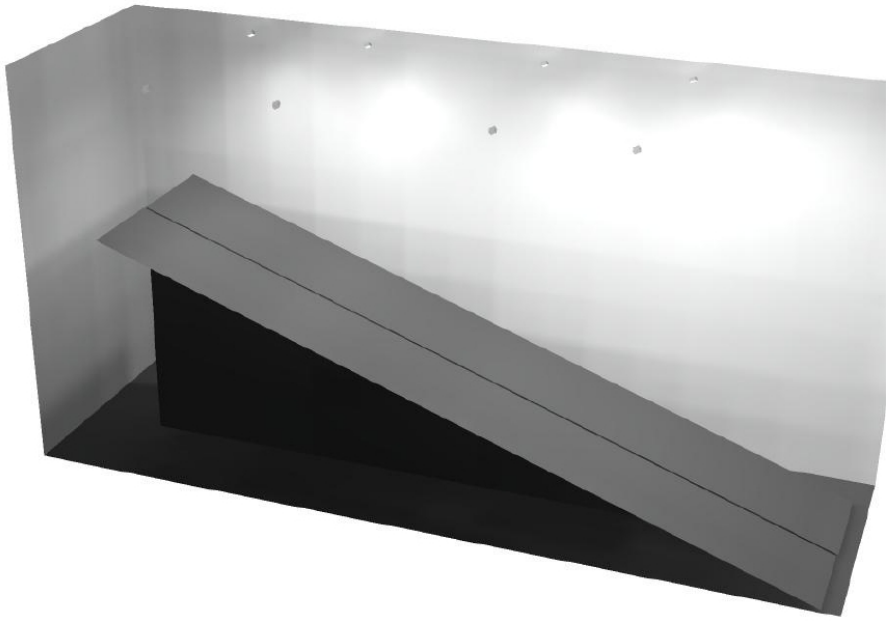
STAIRCASE - PLATFORM 1 LEFT / 3D Rendering



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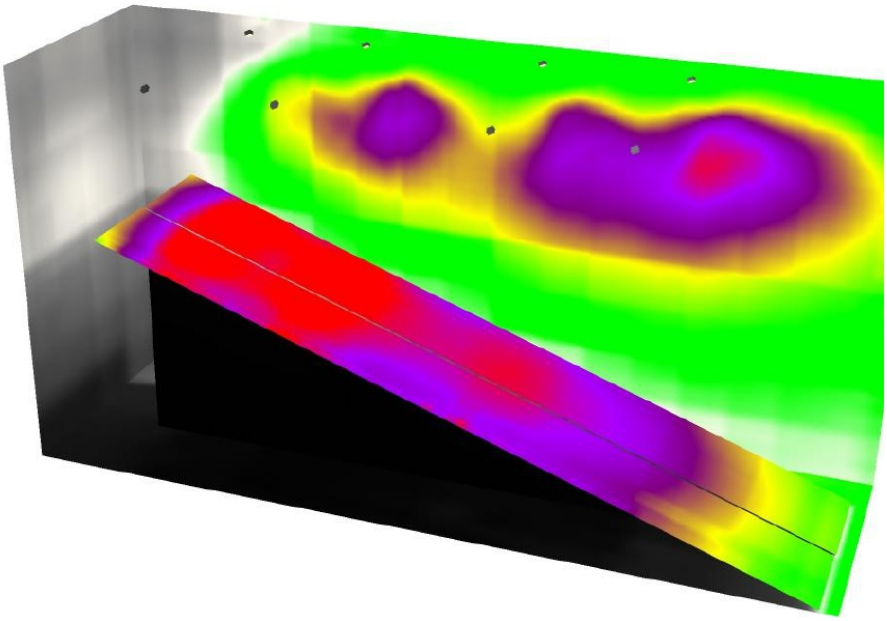
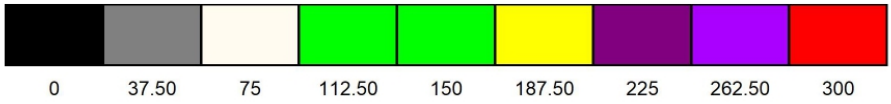
STAIRCASE - PLATFORM 1 LEFT / False Color Rendering





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STAIRCASE - PLATFORM 1 LEFT / STAIRCASE / Value Chart (E, Perpendicular)

319	323	310	311	323	317	297	282	276	281	288	287	275	265	258	247	233	215	199	183
323	319	307	314	329	322	305	290	285	287	297	296	283	273	266	256	242	222	206	189
322	314	302	312	328	319	304	292	287	289	300	298	287	275	268	260	244	224	207	190

1.13 m

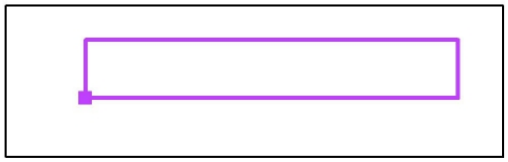
-1.13

-7.73

7.73 m

Values in Lux, Scale 1 : 111

Position of surface in room:
Marked point: (44.872 m, 19.861 m, 5.836 m)



Grid: 20 x 3 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
279	183	329	0.66	0.56

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STAIRCASE - PLATFORM 1 LEFT / ESCALATOR / Value Chart (E, Perpendicular)

329	325	310	314	329	320	301	288	281	284	291	292	282	271	264	254	239	220	204	187
322	320	306	307	319	309	288	273	269	272	278	278	271	261	254	243	228	210	194	179
290	293	281	288	293	283	266	251	249	256	261	261	256	248	240	228	214	198	182	168

1.13 m

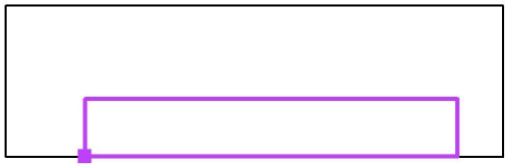
-1.13

-7.73

7.73 m

Values in Lux, Scale 1 : 111

Position of surface in room:
Marked point: (44.853 m, 17.572 m, 5.845 m)



Grid: 20 x 3 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
266	168	329	0.63	0.51

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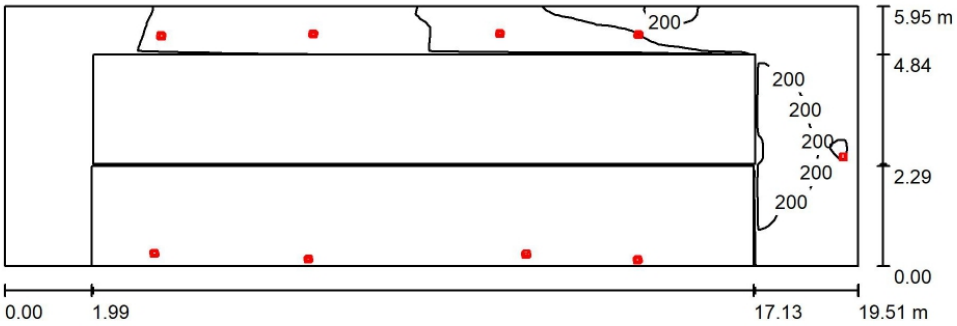
STAIRCASE - PLATFORM 1 RIGHT / Summary



Height of Room: 10.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	8.80	218	0.079
Floors (10)	20	58	0.13	314	/
Ceiling	70	85	28	282	0.331
Walls (4)	50	133	2.03	1365	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.164, Ceiling / Working Plane: 0.779.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. FADR1215IH (CA) CANOPY LIGHTLUMINARIE (1.000)	8843	11000	172.0
			Total: 79584	Total: 99000	1548.0

Specific connected load: 13.34 W/m² = 12.00 W/m²/100 lx (Ground area: 116.01 m²)

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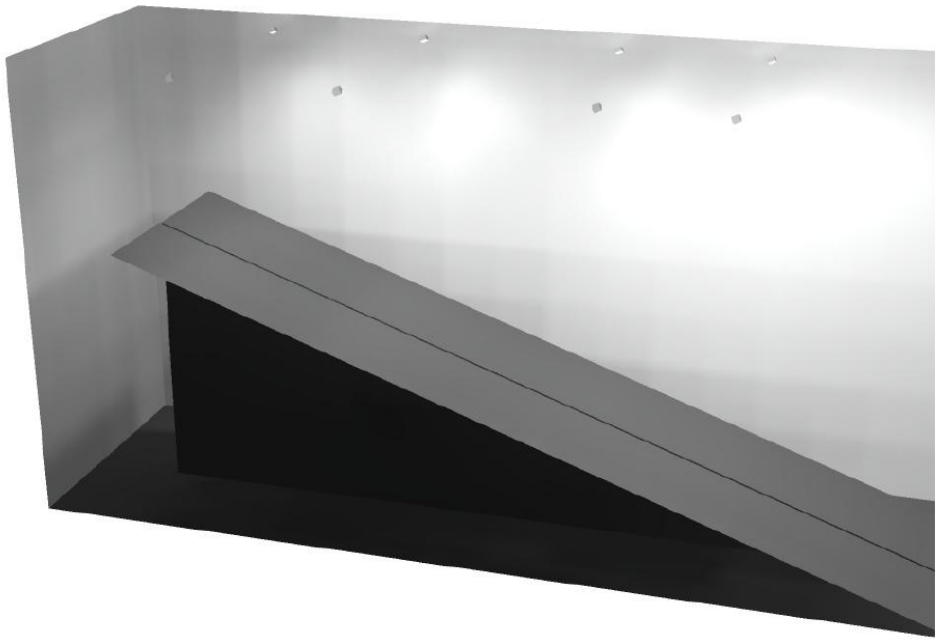
STAIRCASE - PLATFORM 1 RIGHT / 3D Rendering



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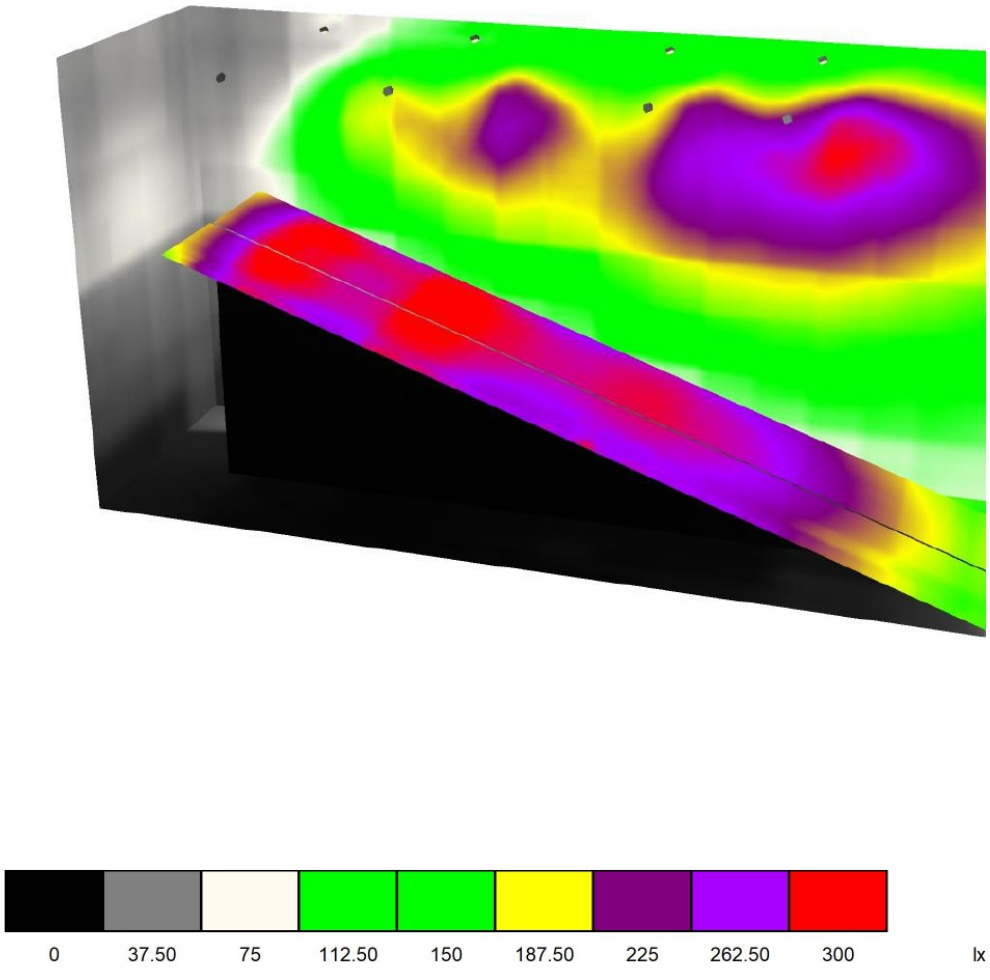
STAIRCASE - PLATFORM 1 RIGHT / False Color Rendering



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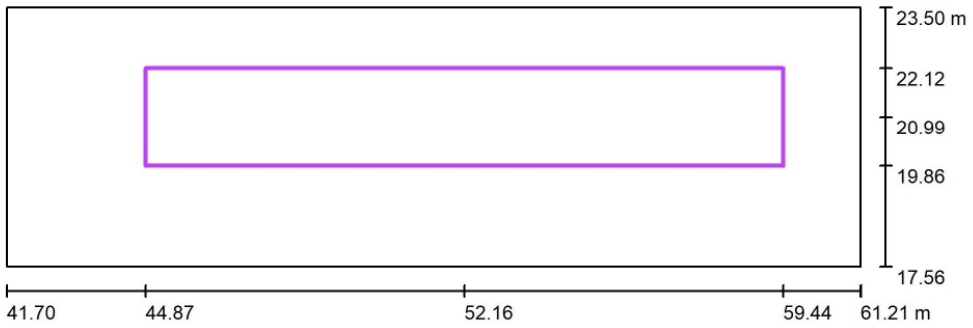
STAIRCASE - PLATFORM 1 RIGHT / STAIRCASE / Summary



Scale 1 : 140

Position: (52.155 m, 20.990 m, 3.257 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	276	187	318	0.68	0.59	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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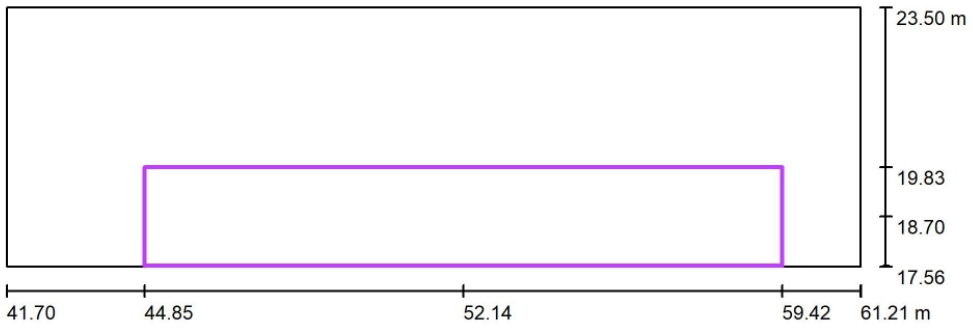
STAIRCASE - PLATFORM 1 RIGHT / ESCALATOR / Summary



Scale 1 : 140

Position: (52.137 m, 18.700 m, 3.266 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	264	172	317	0.65	0.54	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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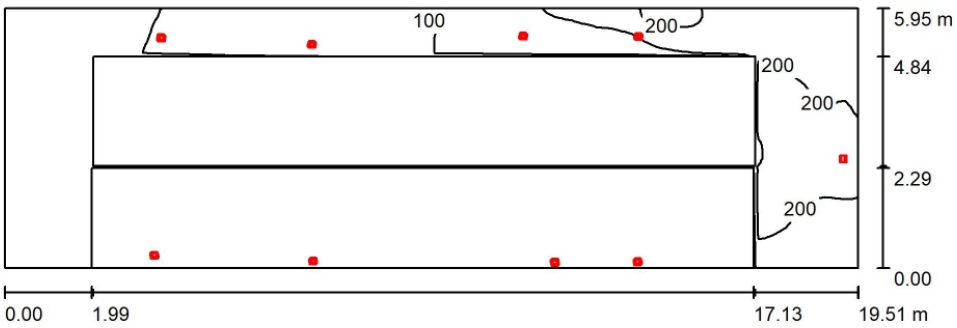
STAIRCASE - PLATFORM 2 LEFT / Summary



Height of Room: 10.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	112	8.74	222	0.078
Floors (10)	20	58	0.13	307	/
Ceiling	70	85	28	285	0.328
Walls (4)	50	134	2.04	1597	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.159, Ceiling / Working Plane: 0.774.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. FADR1215IH (CA) CANOPY LIGHTLUMINARIE (1.000)	8843	11000	172.0
			Total: 79584	Total: 99000	1548.0

Specific connected load: 13.34 W/m² = 11.90 W/m²/100 lx (Ground area: 116.01 m²)

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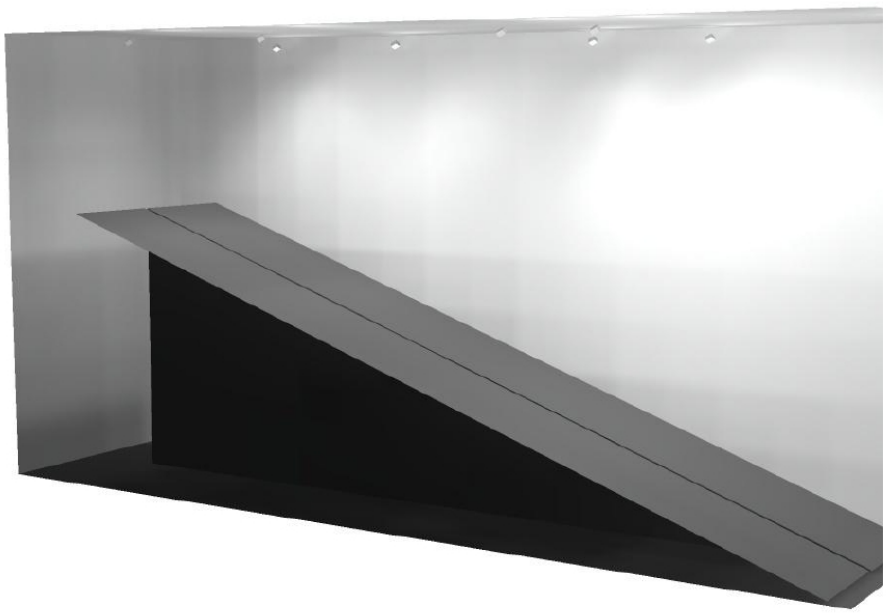
STAIRCASE - PLATFORM 2 LEFT / 3D Rendering



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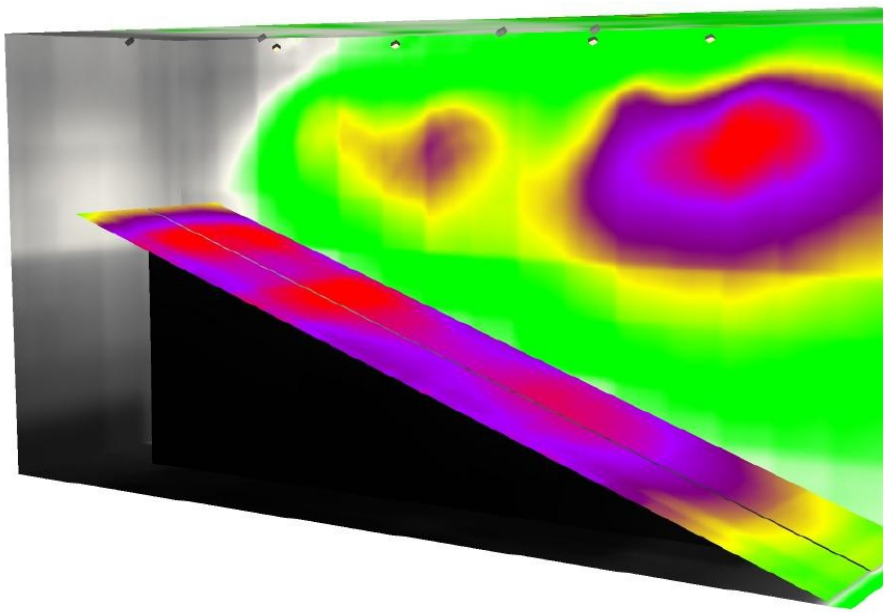
STAIRCASE - PLATFORM 2 LEFT / False Color Rendering



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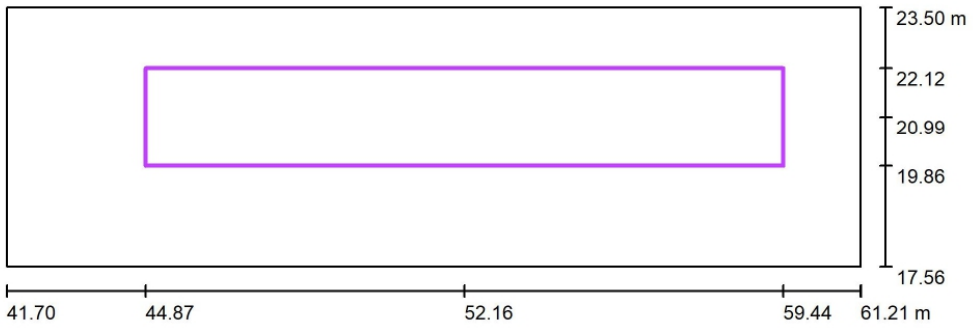
STAIRCASE - PLATFORM 2 LEFT / STAIRCASE / Summary



Scale 1 : 140

Position: (52.155 m, 20.990 m, 3.257 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	274	191	313	0.70	0.61	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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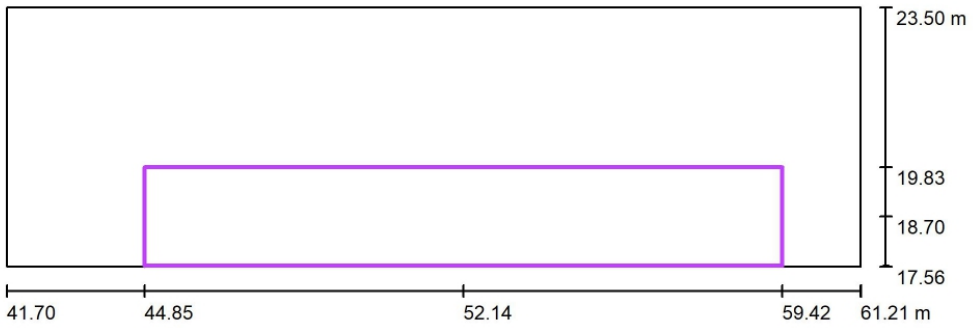
STAIRCASE - PLATFORM 2 LEFT / ESCALATOR / Summary



Scale 1 : 140

Position: (52.137 m, 18.700 m, 3.266 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	262	176	313	0.67	0.56	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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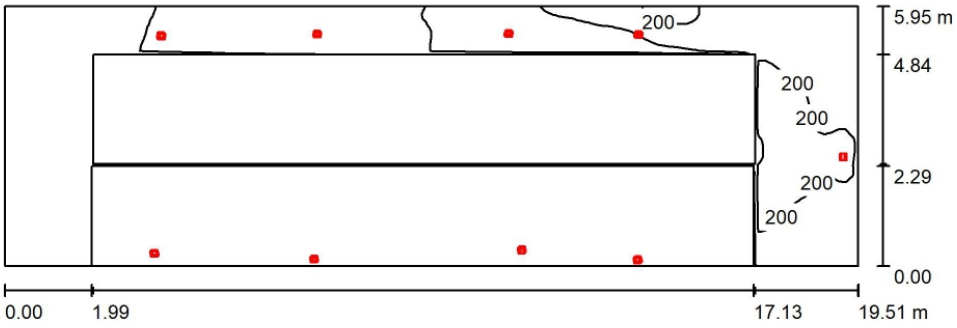
STAIRCASE - PLATFORM 2 RIGHT / Summary



Height of Room: 10.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	8.74	219	0.078
Floors (10)	20	58	0.13	311	/
Ceiling	70	85	28	283	0.329
Walls (4)	50	133	2.01	1367	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.161, Ceiling / Working Plane: 0.776.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. FADR1215IH (CA) CANOPY LIGHTLUMINARIE (1.000)	8843	11000	172.0
			Total: 79584	Total: 99000	1548.0

Specific connected load: 13.34 W/m² = 11.97 W/m²/100 lx (Ground area: 116.01 m²)

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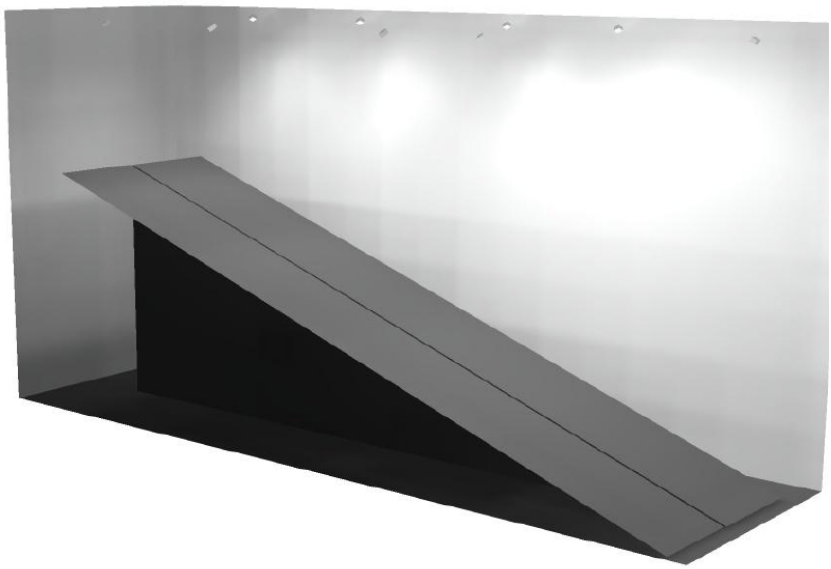
STAIRCASE - PLATFORM 2 RIGHT / 3D Rendering



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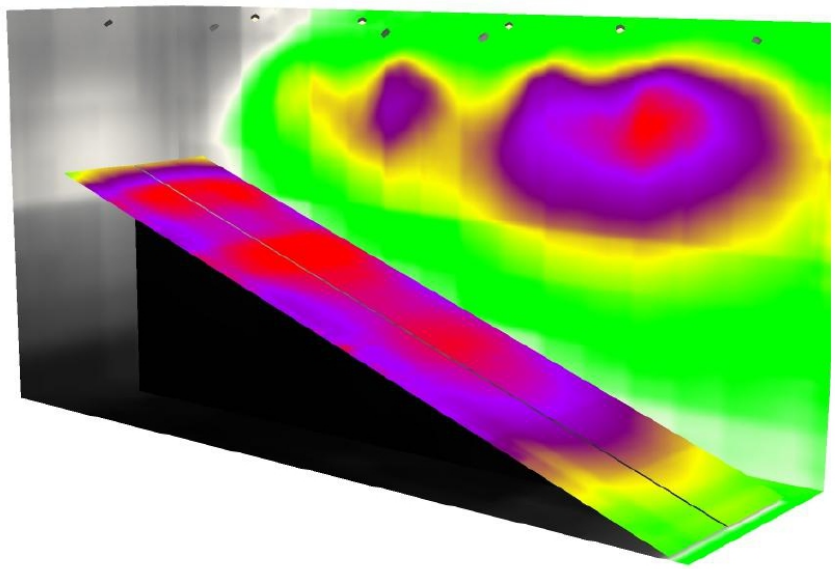
STAIRCASE - PLATFORM 2 RIGHT / False Color Rendering



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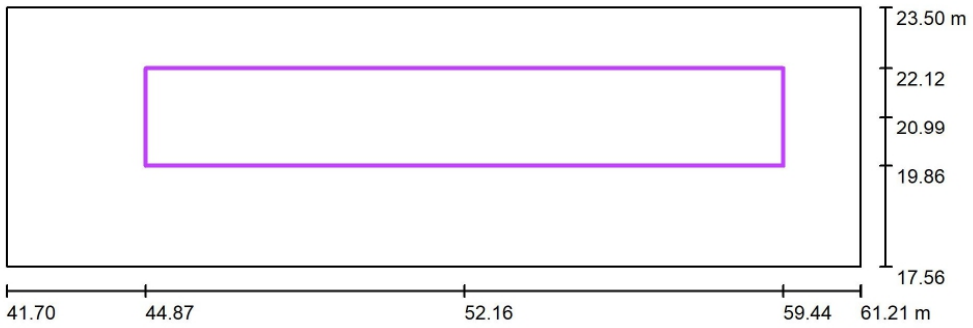
STAIRCASE - PLATFORM 2 RIGHT / STAIRCASE / Summary



Scale 1 : 140

Position: (52.155 m, 20.990 m, 3.257 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	276	188	317	0.68	0.59	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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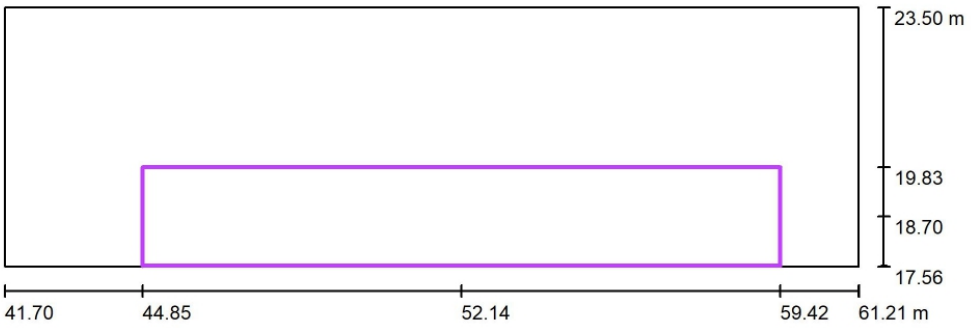
STAIRCASE - PLATFORM 2 RIGHT / ESCALATOR / Summary



Scale 1 : 140

Position: (52.137 m, 18.700 m, 3.266 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	264	173	315	0.66	0.55	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

City Centre Metro Concourse Area

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY

Date: 13.06.2018
Operator: Ankit Ghosh

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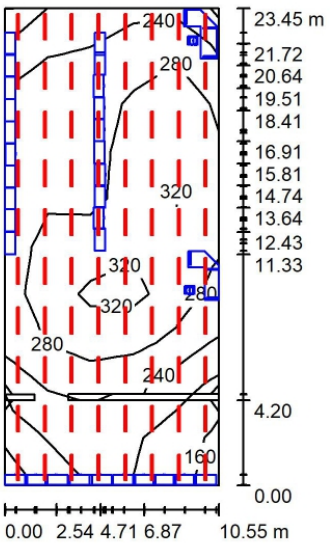
AUXILIARY SUBSTATION / Summary



Height of Room: 6.380 m, Mounting Height: 5.380 m, Light loss factor: 0.70 Values in Lux, Scale 1:302

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	268	158	343	0.588
Floor	20	224	50	310	0.224
Ceiling	70	137	100	200	0.732
Walls (12)	50	242	5.33	741	/

Workplane:
Height: 0.760 m
Grid: 10 x 5 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.968, Ceiling / Working Plane: 0.510.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	80	Crompton Greaves Ltd. IPFC1114EB INDUSTRIAL LUMINARIE (1.000)	2359	3250	40.0
			Total: 188743	Total: 260000	3200.0

Specific connected load: 13.07 W/m² = 4.87 W/m²/100 lx (Ground area: 244.82 m²)

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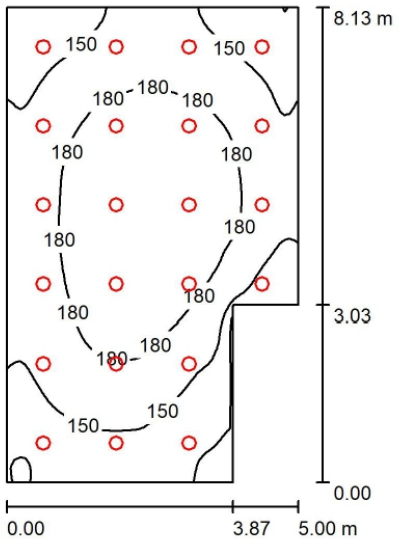
LOBBY AREA / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:105

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	165	102	202	0.621
Floor	20	165	105	203	0.636
Ceiling	70	72	44	809	0.615
Walls (6)	50	115	69	351	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.696, Ceiling / Working Plane: 0.437.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	22	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 14722	Total: 26400	451.0

Specific connected load: 12.12 W/m² = 7.36 W/m²/100 lx (Ground area: 37.22 m²)

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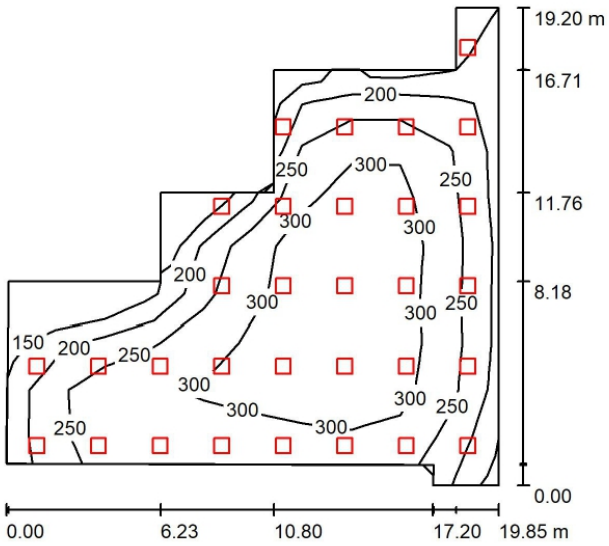
UNPAID AREA_ 1 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:247

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	260	108	337	0.415
Floor	20	262	74	341	0.283
Ceiling	70	58	30	209	0.515
Walls (12)	50	126	40	1533	/

Workplane:
Height: 0.000 m
Grid: 10 x 10 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.483, Ceiling / Working Plane: 0.223.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	31	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 101200	Total: 151280	1937.5

Specific connected load: 7.90 W/m² = 3.04 W/m²/100 lx (Ground area: 245.26 m²)

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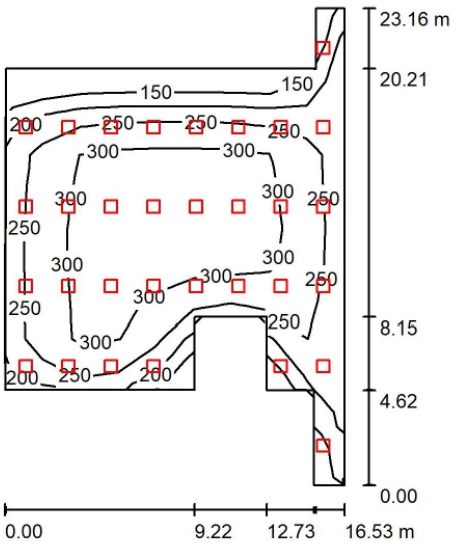
UNPAID AREA_ 2 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:298

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	268	128	369	0.476
Floor	20	259	109	376	0.423
Ceiling	70	56	34	263	0.609
Walls (12)	50	119	38	1707	/

Workplane:
Height: 0.000 m
Grid: 13 x 9 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.466, Ceiling / Working Plane: 0.218.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	32	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 104465	Total: 156160	2000.0

Specific connected load: 7.82 W/m² = 2.92 W/m²/100 lx (Ground area: 255.70 m²)

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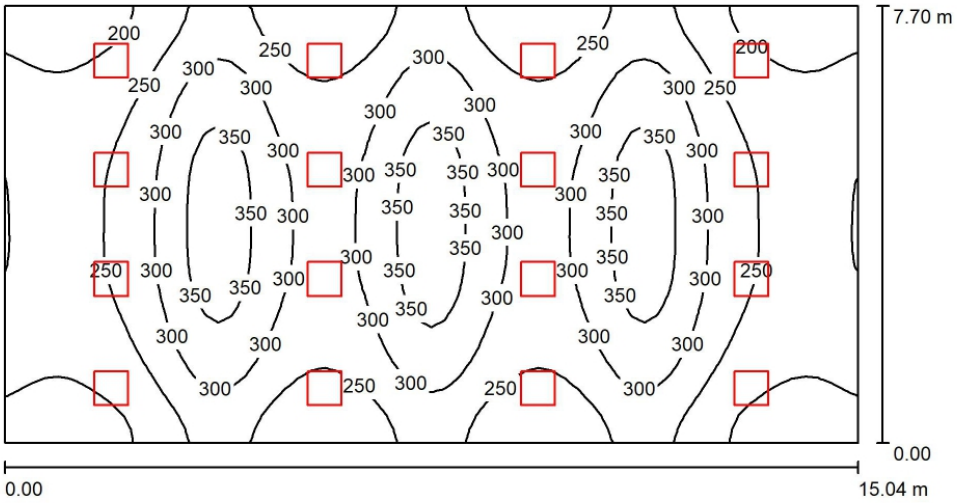
CONCOURSE PAID AREA_3M / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:108

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	272	166	378	0.610
Floor	20	272	175	376	0.641
Ceiling	70	60	41	132	0.683
Walls (4)	50	130	45	285	/

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

UGR Lengthways- Across to luminaire axis
Left Wall 18 15
Lower Wall 17 15
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.476, Ceiling / Working Plane: 0.221.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	16	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 52232	Total: 78080	1000.0

Specific connected load: 8.64 W/m² = 3.17 W/m²/100 lx (Ground area: 115.79 m²)

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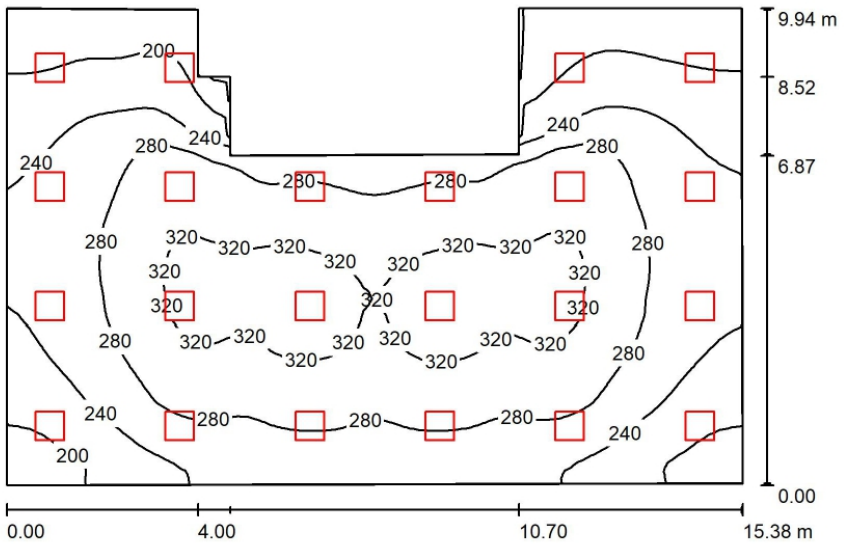
CONCOURSE PAID AREA_4.3M / Summary



Height of Room: 4.300 m, Mounting Height: 4.300 m, Light loss factor: 0.70 Values in Lux, Scale 1:128

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	266	158	339	0.594
Floor	20	266	158	338	0.597
Ceiling	70	70	53	223	0.762
Walls (10)	50	157	53	1465	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.587, Ceiling / Working Plane: 0.261.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	22	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 71820	Total: 107360	1375.0

Specific connected load: 10.34 W/m² = 3.88 W/m²/100 lx (Ground area: 133.00 m²)

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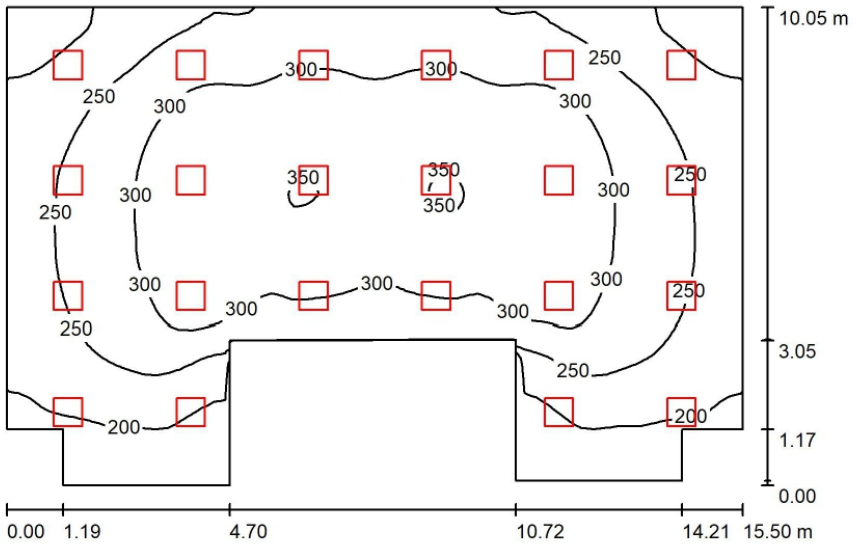
CONCOURSE PAID AREA_4.3M / Summary



Height of Room: 4.300 m, Mounting Height: 4.300 m, Light loss factor: 0.70 Values in Lux, Scale 1:129

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	271	152	355	0.561
Floor	20	271	159	355	0.586
Ceiling	70	68	38	184	0.563
Walls (12)	50	149	49	1642	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.548, Ceiling / Working Plane: 0.251.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	22	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 71820	Total: 107360	1375.0

Specific connected load: 10.26 W/m² = 3.79 W/m²/100 lx (Ground area: 133.99 m²)

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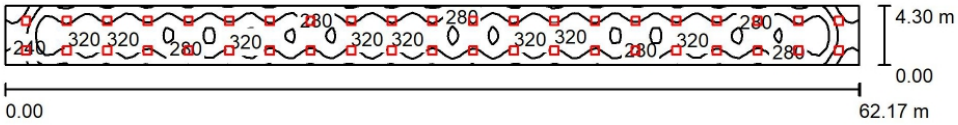
STATION ENTRANCES 1 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:445

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	280	166	335	0.595
Floor	20	279	169	335	0.605
Ceiling	70	66	49	138	0.746
Walls (4)	50	150	51	245	/

Workplane:
Height: 0.000 m
Grid: 128 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.543, Ceiling / Working Plane: 0.236.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	42	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 137110	Total: 204960	2625.0

Specific connected load: 9.82 W/m² = 3.51 W/m²/100 lx (Ground area: 267.21 m²)

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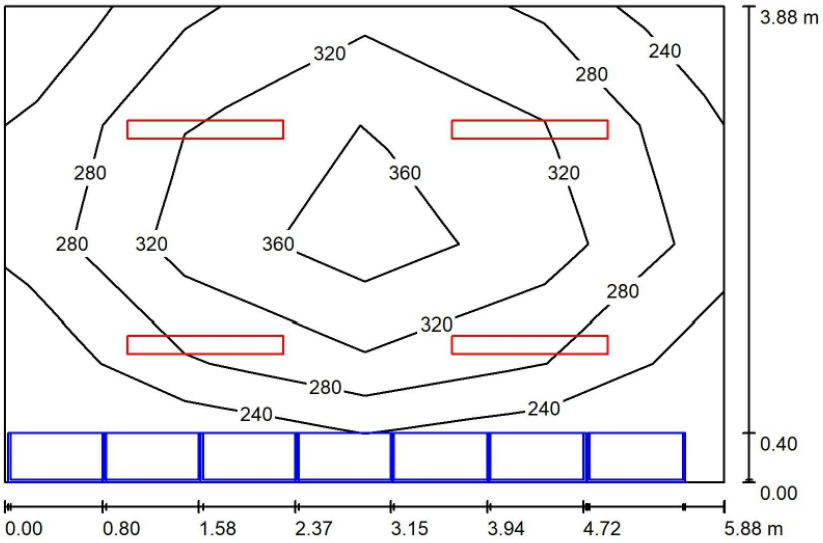
ELECTRICAL UPS / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:50

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	315	229	388	0.727
Floor	20	226	29	308	0.127
Ceiling	70	156	83	529	0.534
Walls (4)	50	173	0.86	583	/

Workplane:
Height: 0.760 m
Grid: 4 x 4 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.687, Ceiling / Working Plane: 0.543.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. IPFC1124EB INDUSTRIAL LUMINARIE (1.000)	4684	6500	80.0
			Total: 18738	Total: 26000	320.0

Specific connected load: 14.06 W/m² = 4.47 W/m²/100 lx (Ground area: 22.77 m²)

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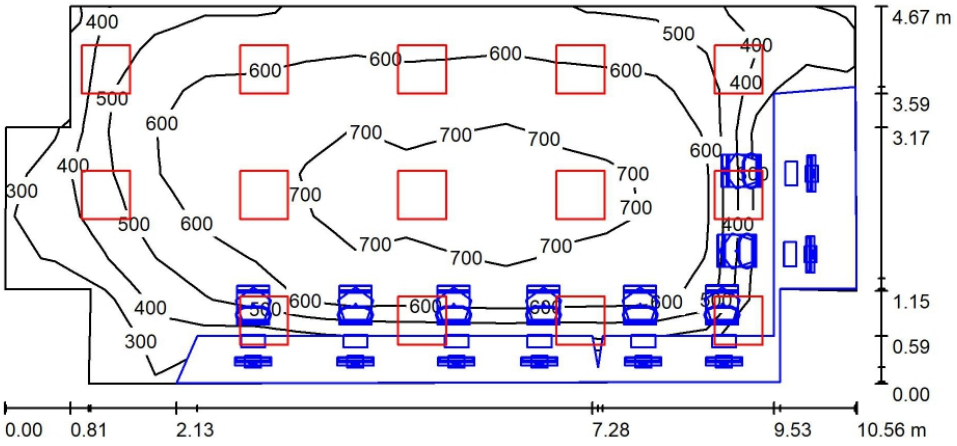
TER / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:76

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	579	260	743	0.449
Floor	20	421	50	650	0.119
Ceiling	70	120	77	231	0.640
Walls (10)	50	238	42	1254	/

Workplane:

Height:	0.760 m
Grid:	17 x 9 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.458, Ceiling / Working Plane: 0.208.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	14	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 45703	Total: 68320	875.0

Specific connected load: 19.16 W/m² = 3.31 W/m²/100 lx (Ground area: 45.66 m²)

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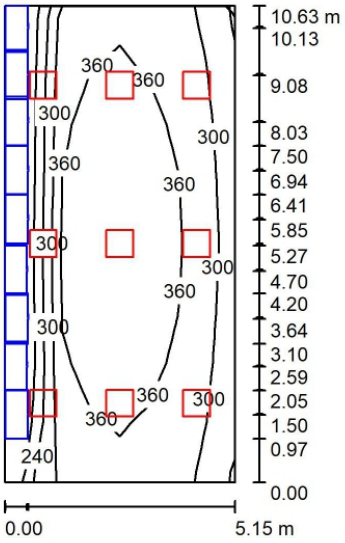
UPS / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:137

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	349	140	393	0.401
Floor	20	271	19	419	0.069
Ceiling	70	75	43	223	0.576
Walls (4)	50	109	3.84	486	/

Workplane:
Height: 0.760 m
Grid: 8 x 8 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.312, Ceiling / Working Plane: 0.218.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 29381	Total: 43920	562.5

Specific connected load: 10.28 W/m² = 2.94 W/m²/100 lx (Ground area: 54.72 m²)

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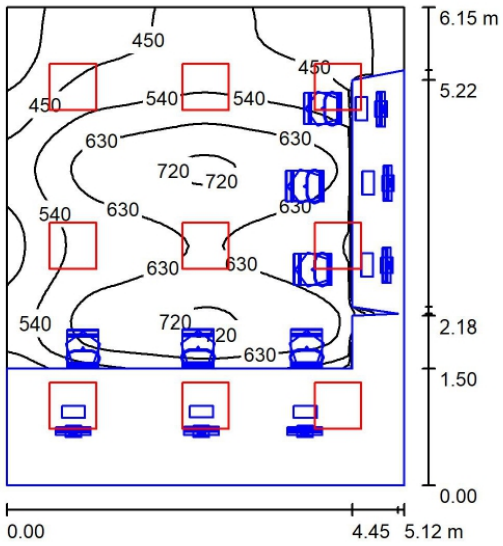
SER SIGNAL RELAY / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:79

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	565	292	741	0.517
Floor	20	319	26	596	0.081
Ceiling	70	117	84	197	0.715
Walls (4)	50	220	32	421	/

Workplane:
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.447, Ceiling / Working Plane: 0.207.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 29381	Total: 43920	562.5

Specific connected load: 17.85 W/m² = 3.16 W/m²/100 lx (Ground area: 31.52 m²)

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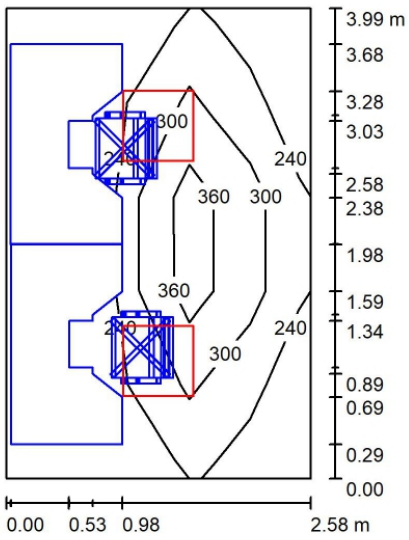
TICKET OFFICE MACHINE 1 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:52

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	306	204	456	0.668
Floor	20	148	25	261	0.169
Ceiling	70	66	45	142	0.671
Walls (4)	50	132	27	324	/

Workplane:

Height:	0.760 m
Grid:	5 x 5 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.511, Ceiling / Working Plane: 0.228.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 6529	Total: 9760	125.0

Specific connected load: 12.12 W/m² = 3.97 W/m²/100 lx (Ground area: 10.31 m²)

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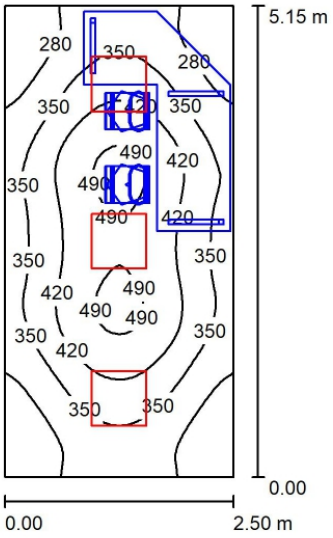
TICKET OFFICE MACHINE 2 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:67

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	365	209	511	0.571
Floor	20	219	28	364	0.126
Ceiling	70	87	54	170	0.625
Walls (4)	50	172	34	436	/

Workplane:
Height: 0.760 m
Grid: 32 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.516, Ceiling / Working Plane: 0.238.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 9794	Total: 14640	187.5

Specific connected load: 14.56 W/m² = 3.99 W/m²/100 lx (Ground area: 12.88 m²)

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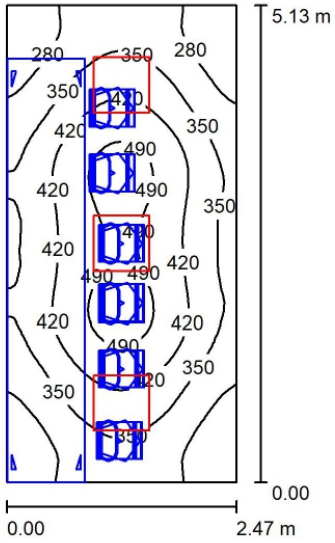
AUDIT & CASH / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:66

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	373	214	519	0.574
Floor	20	165	24	328	0.144
Ceiling	70	99	60	173	0.606
Walls (4)	50	173	21	440	/

Workplane:
Height: 0.760 m
Grid: 32 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.531, Ceiling / Working Plane: 0.264.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 9794	Total: 14640	187.5

Specific connected load: 14.78 W/m² = 3.96 W/m²/100 lx (Ground area: 12.68 m²)

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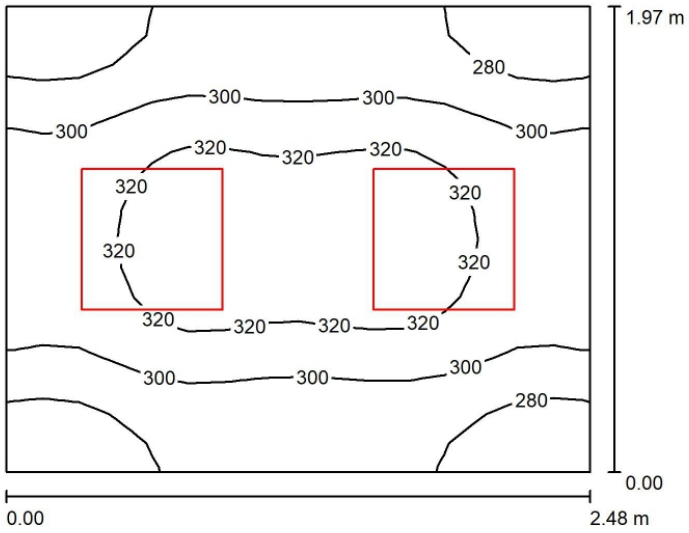
ROOM BESIDE AUDIT & CASH / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:26

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	302	257	332	0.852
Floor	20	302	253	331	0.839
Ceiling	70	128	84	206	0.653
Walls (4)	50	264	104	749	/

Workplane:
Height: 0.000 m
Grid: 16 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.874, Ceiling / Working Plane: 0.425.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 6529	Total: 9760	125.0

Specific connected load: 25.57 W/m² = 8.48 W/m²/100 lx (Ground area: 4.89 m²)

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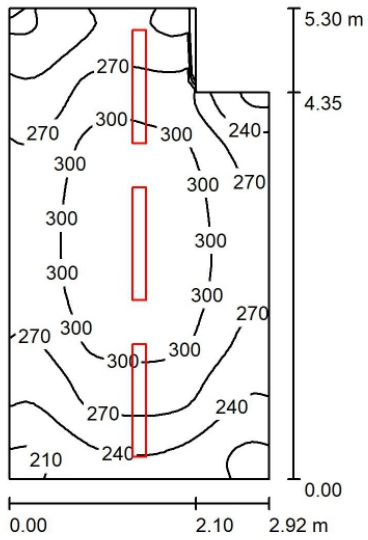
SPARE ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:69

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	275	195	329	0.708
Floor	20	275	197	328	0.714
Ceiling	70	183	101	551	0.551
Walls (6)	50	260	120	998	/

Workplane:
Height: 0.000 m
Grid: 64 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.941, Ceiling / Working Plane: 0.665.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. IPFC1124EB INDUSTRIAL LUMINARIE (1.000)	4684	6500	80.0
			Total: 14053	Total: 19500	240.0

Specific connected load: 16.31 W/m² = 5.93 W/m²/100 lx (Ground area: 14.72 m²)

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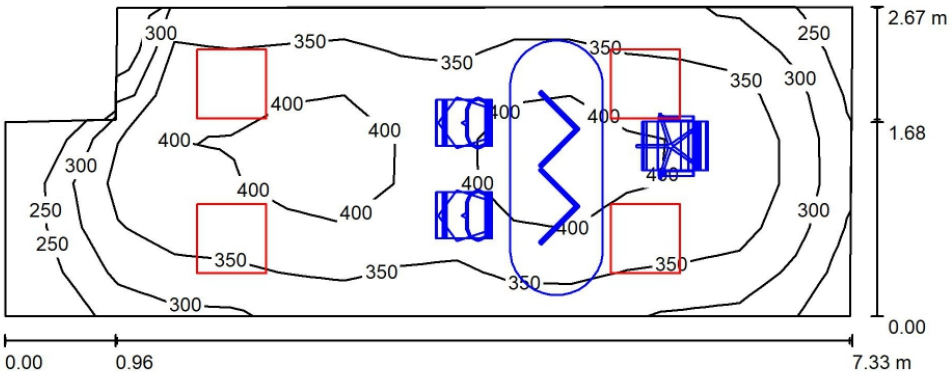
SUPERVISOR ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:53

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	357	203	429	0.568
Floor	20	229	35	353	0.154
Ceiling	70	90	43	189	0.479
Walls (6)	50	173	49	613	/

Workplane:

Height:	0.760 m
Grid:	15 x 7 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.515, Ceiling / Working Plane: 0.254.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 13058	Total: 19520	250.0

Specific connected load: 13.45 W/m² = 3.77 W/m²/100 lx (Ground area: 18.59 m²)

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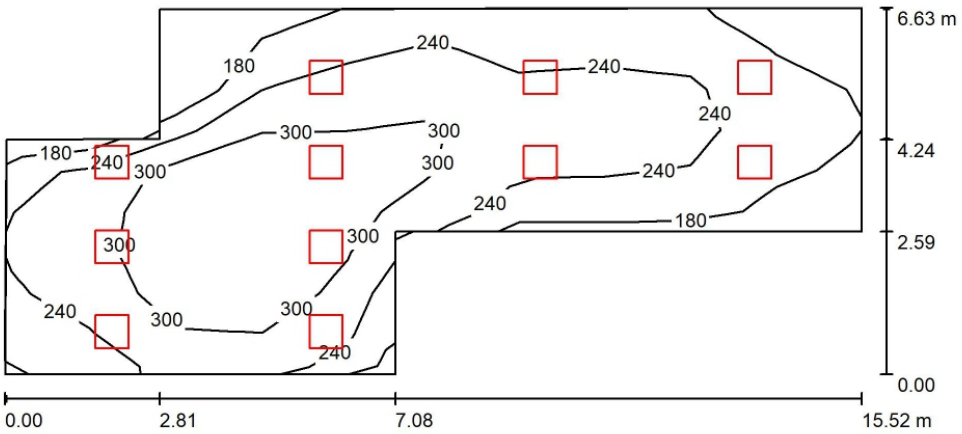
STATION ENTRANCES 2 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	253	143	403	0.564
Floor	20	253	103	406	0.407
Ceiling	70	60	35	229	0.578
Walls (8)	50	131	41	1431	/

Workplane:
Height: 0.000 m
Grid: 10 x 9 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.517, Ceiling / Working Plane: 0.236.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	11	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 35910	Total: 53680	687.5

Specific connected load: 9.26 W/m² = 3.66 W/m²/100 lx (Ground area: 74.23 m²)

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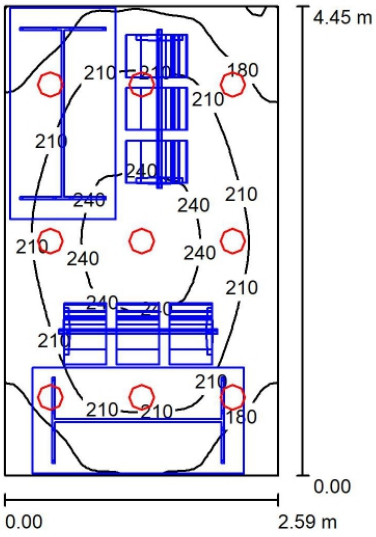
STAFF MESS ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:58

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	207	146	249	0.702
Floor	20	85	21	165	0.248
Ceiling	70	100	57	796	0.572
Walls (4)	50	126	19	346	/

Workplane:
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.736, Ceiling / Working Plane: 0.482.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	9	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 6023	Total: 10800	184.5

Specific connected load: 16.03 W/m² = 7.73 W/m²/100 lx (Ground area: 11.51 m²)

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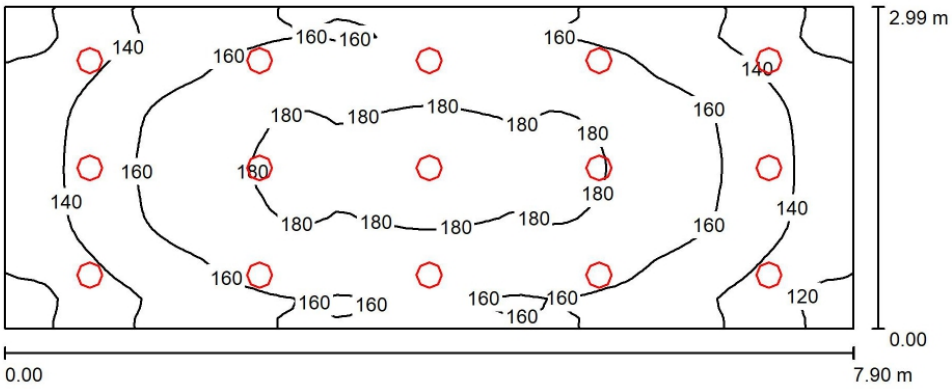
TOILET 1 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:57

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	158	111	184	0.707
Floor	20	158	113	184	0.718
Ceiling	70	75	46	800	0.606
Walls (4)	50	117	70	267	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.742, Ceiling / Working Plane: 0.478.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	15	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 10038	Total: 18000	307.5

Specific connected load: 13.00 W/m² = 8.25 W/m²/100 lx (Ground area: 23.66 m²)

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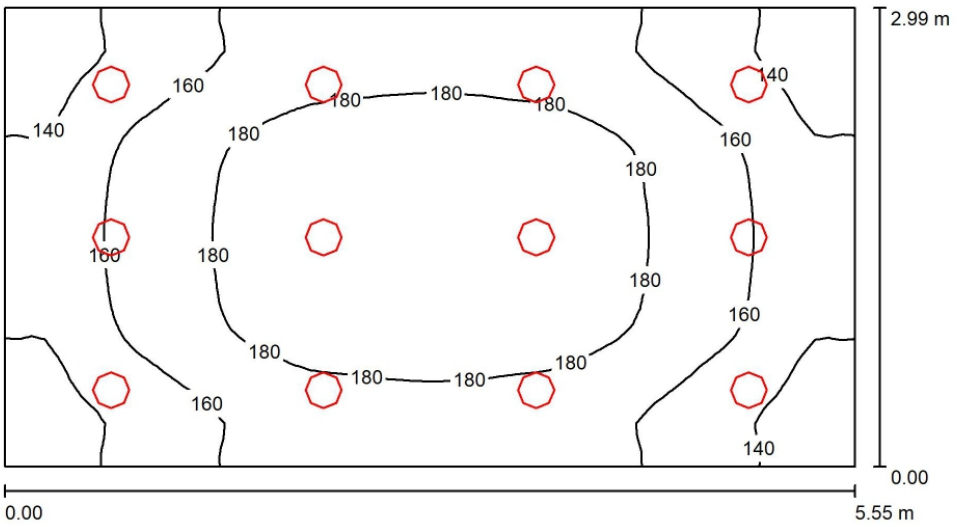
TOILET 2 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:40

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	166	121	195	0.728
Floor	20	167	125	195	0.750
Ceiling	70	85	51	812	0.605
Walls (4)	50	128	78	272	/

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

UGR (CIE, SHR = 0.25.)

	Lengthways-	Across
Left Wall	18	16
Lower Wall	17	16

to luminaire axis

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.766, Ceiling / Working Plane: 0.511.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	12	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 8030	Total: 14400	246.0

Specific connected load: 14.80 W/m² = 8.90 W/m²/100 lx (Ground area: 16.62 m²)

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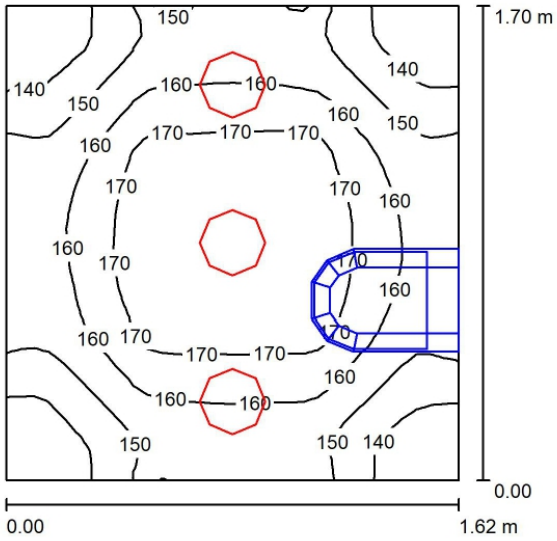
TOILET 3 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:22

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	158	131	180	0.832
Floor	20	94	31	108	0.333
Ceiling	70	113	52	797	0.462
Walls (4)	50	121	15	549	/

Workplane:
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.938, Ceiling / Working Plane: 0.718.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 2008	Total: 3600	61.5

Specific connected load: 22.26 W/m² = 14.11 W/m²/100 lx (Ground area: 2.76 m²)

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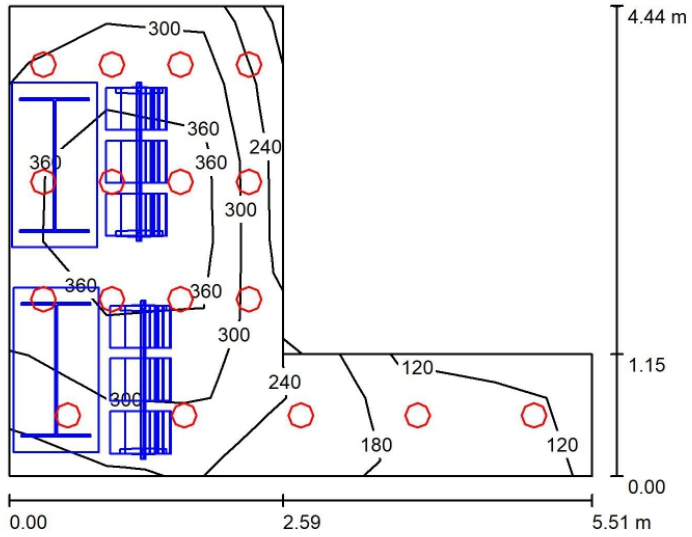
STAFF MESS ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:58

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	288	116	415	0.401
Floor	20	156	50	268	0.319
Ceiling	70	139	54	844	0.389
Walls (6)	50	171	42	509	/

Workplane:
Height: 0.760 m
Grid: 6 x 6 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.682, Ceiling / Working Plane: 0.469.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	17	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 11376	Total: 20400	348.5

Specific connected load: 23.43 W/m² = 8.13 W/m²/100 lx (Ground area: 14.88 m²)

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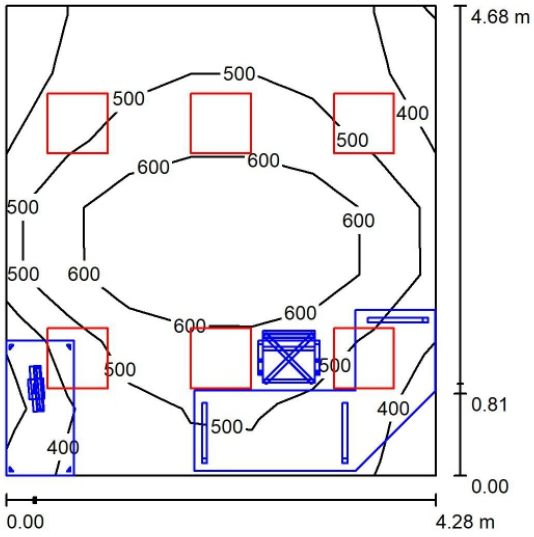
Station Control Room / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:61

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	519	284	776	0.547
Floor	20	368	74	563	0.201
Ceiling	70	118	87	198	0.737
Walls (4)	50	243	50	551	/

Workplane:
Height: 0.760 m
Grid: 7 x 7 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.512, Ceiling / Working Plane: 0.228.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 19587	Total: 29280	375.0

Specific connected load: 18.76 W/m² = 3.61 W/m²/100 lx (Ground area: 19.99 m²)

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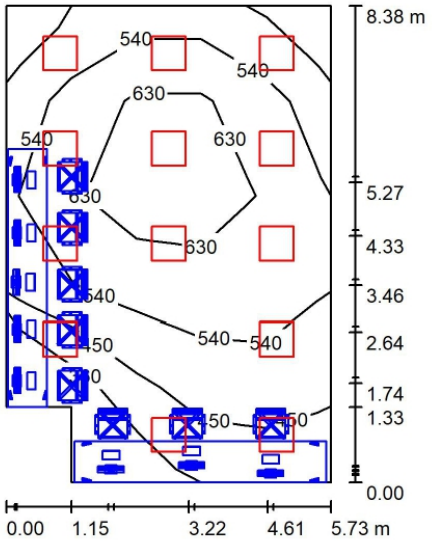
SMR Signal Relay Room / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:108

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	555	303	745	0.545
Floor	20	421	62	666	0.148
Ceiling	70	120	83	209	0.691
Walls (6)	50	238	51	494	/

Workplane:
Height: 0.760 m
Grid: 5 x 5 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.477, Ceiling / Working Plane: 0.221.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	13	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 42439	Total: 63440	812.5

Specific connected load: 17.49 W/m² = 3.15 W/m²/100 lx (Ground area: 46.46 m²)

13.06.2018

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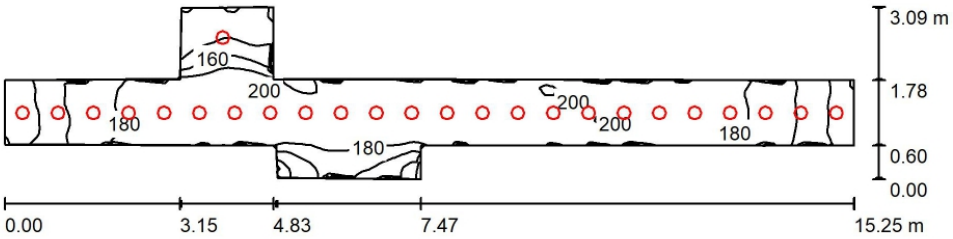
CORRIDOR NEAR TOILET / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.70 Values in Lux, Scale 1:110

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	177	118	205	0.667
Floor	20	178	116	202	0.654
Ceiling	70	125	50	846	0.401
Walls (12)	50	158	66	475	/

Workplane:
Height: 0.000 m
Grid: 128 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.884, Ceiling / Working Plane: 0.702.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	25	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 16730	Total: 30000	512.5

Specific connected load: 23.59 W/m² = 13.32 W/m²/100 lx (Ground area: 21.72 m²)

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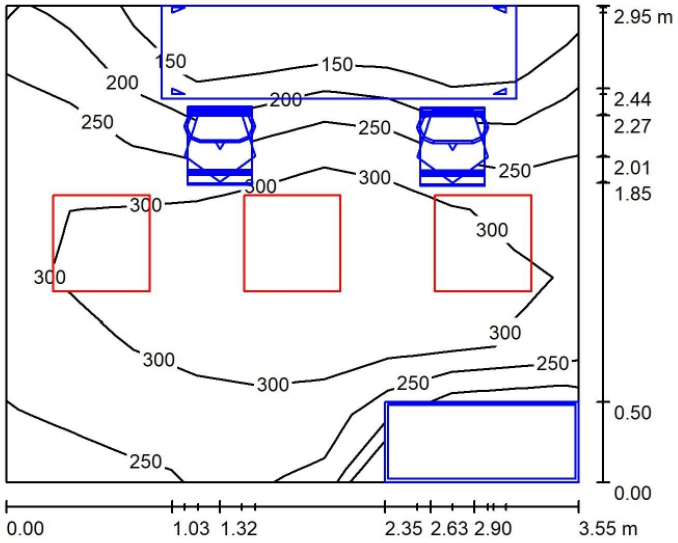
ENQUIRY ROOM / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:38

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	263	106	347	0.403
Floor	20	239	12	346	0.052
Ceiling	70	105	65	191	0.619
Walls (4)	50	188	1.98	773	/

Workplane:
Height: 0.760 m
Grid: 9 x 7 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.813, Ceiling / Working Plane: 0.400.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. T5CQ13414EBB COMMERCIAL LUMINAIRE (1.000)	3265	4880	62.5
			Total: 9794	Total: 14640	187.5

Specific connected load: 17.90 W/m² = 6.80 W/m²/100 lx (Ground area: 10.47 m²)

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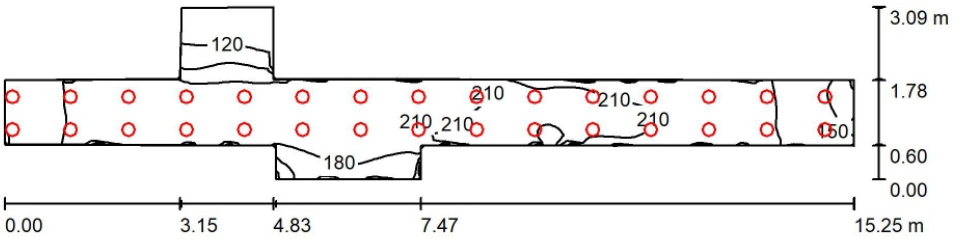
PASSAGE NEAR TOILET AREA / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:110

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	186	98	217	0.524
Floor	20	187	98	218	0.524
Ceiling	70	153	45	1049	0.294
Walls (12)	50	178	58	2418	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.960, Ceiling / Working Plane: 0.821.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	30	Crompton Greaves Ltd. DDSH118EB/G COMMERCIAL LUMINAIRE (1.000)	669	1200	20.5
			Total: 20076	Total: 36000	615.0

Specific connected load: 28.26 W/m² = 15.16 W/m²/100 lx (Ground area: 21.76 m²)

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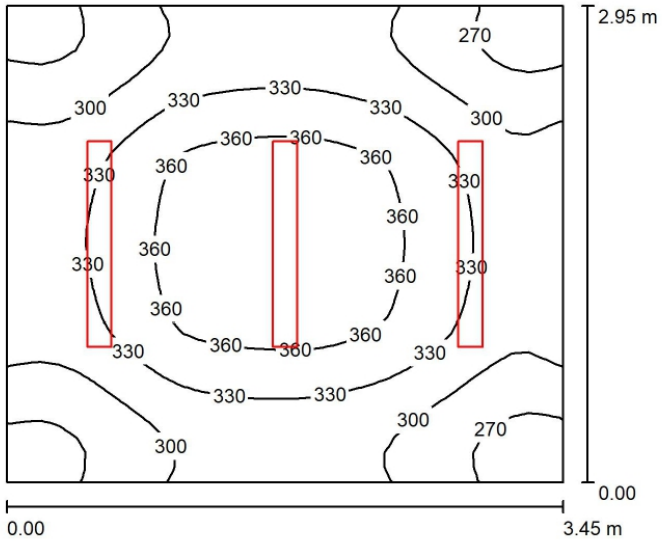
STORE ROOM / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:38

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	322	252	380	0.782
Floor	20	322	247	377	0.767
Ceiling	70	259	130	643	0.502
Walls (4)	50	333	161	1343	/

Workplane:
Height: 0.000 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.032, Ceiling / Working Plane: 0.804.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. IPFC1124EB INDUSTRIAL LUMINARIE (1.000)	4684	6500	80.0
			Total: 14053	Total: 19500	240.0

Specific connected load: 23.58 W/m² = 7.33 W/m²/100 lx (Ground area: 10.18 m²)

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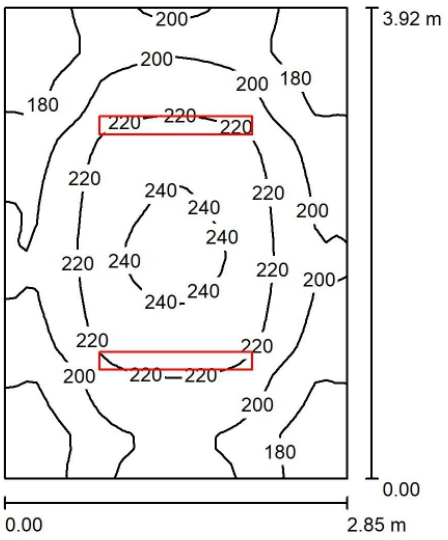
REFUSE STORE ROOM / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:51

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	205	157	244	0.766
Floor	20	205	154	243	0.747
Ceiling	70	157	83	526	0.529
Walls (4)	50	205	98	597	/

Workplane:
Height: 0.000 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.999, Ceiling / Working Plane: 0.763.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. IPFC1124EB INDUSTRIAL LUMINARIE (1.000)	4684	6500	80.0
			Total: 9369	Total: 13000	160.0

Specific connected load: 14.32 W/m² = 6.97 W/m²/100 lx (Ground area: 11.17 m²)

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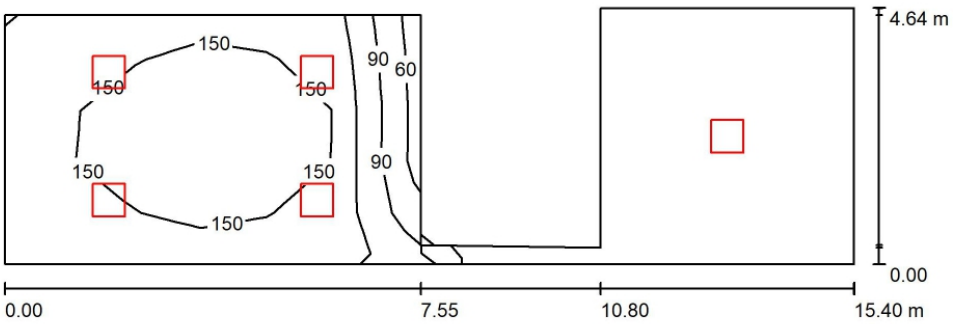
ROOM BELOW ESCALATOR -1 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	106	39	164	0.366
Floor	20	107	12	165	0.113
Ceiling	70	65	11	181	0.170
Walls (8)	50	103	5.48	442	/

Workplane:

Height:	0.000 m
Grid:	5 x 13 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.971, Ceiling / Working Plane: 0.609.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	5	Crompton Greaves Ltd. CRFW12336EB COMMERCIAL LUMINARIE (1.000)	6714	8700	112.3
			Total: 33572	Total: 43500	561.4

Specific connected load: 9.93 W/m² = 9.39 W/m²/100 lx (Ground area: 56.55 m²)

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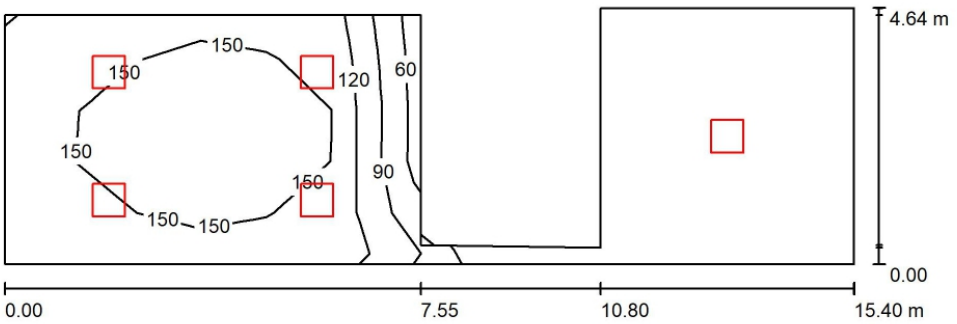
ROOM BELOW ESCALATOR -2 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	106	38	164	0.364
Floor	20	107	12	165	0.116
Ceiling	70	65	11	181	0.168
Walls (8)	50	103	5.42	442	/

Workplane:

Height:	0.000 m
Grid:	5 x 13 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.969, Ceiling / Working Plane: 0.607.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	5	Crompton Greaves Ltd. CRFW12336EB COMMERCIAL LUMINARIE (1.000)	6714	8700	112.3
			Total: 33572	Total: 43500	561.4

Specific connected load: 9.93 W/m² = 9.40 W/m²/100 lx (Ground area: 56.55 m²)

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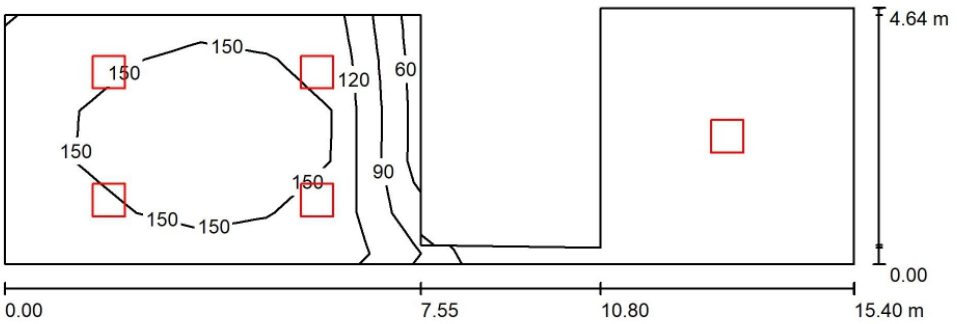
ROOM BELOW ESCALATOR -3 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	106	39	164	0.366
Floor	20	107	12	165	0.114
Ceiling	70	65	11	181	0.170
Walls (8)	50	104	5.78	442	/

Workplane:

Height:	0.000 m
Grid:	5 x 13 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.971, Ceiling / Working Plane: 0.608.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	5	Crompton Greaves Ltd. CRFW12336EB COMMERCIAL LUMINARIE (1.000)	6714	8700	112.3
			Total: 33572	Total: 43500	561.4

Specific connected load: 9.93 W/m² = 9.39 W/m²/100 lx (Ground area: 56.55 m²)

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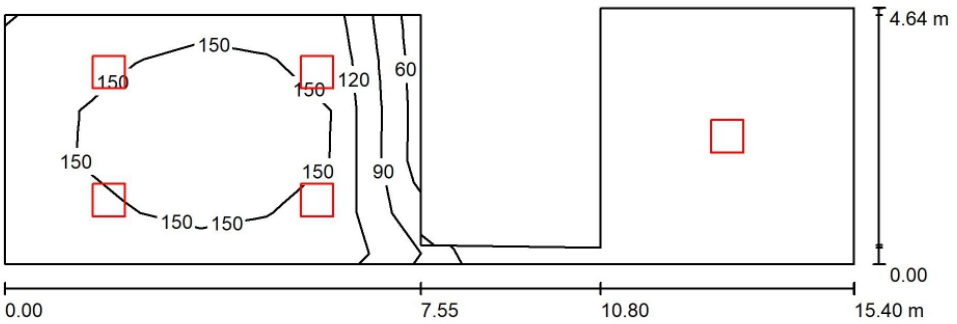
ROOM BELOW ESCALATOR -4 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.70 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	106	39	164	0.365
Floor	20	107	12	165	0.117
Ceiling	70	65	11	181	0.170
Walls (8)	50	103	5.09	442	/

Workplane:

Height:	0.000 m
Grid:	5 x 13 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.970, Ceiling / Working Plane: 0.608.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	5	Crompton Greaves Ltd. CRFW12336EB COMMERCIAL LUMINARIE (1.000)	6714	8700	112.3
			Total: 33572	Total: 43500	561.4

Specific connected load: 9.93 W/m² = 9.39 W/m²/100 lx (Ground area: 56.55 m²)

Annexure X
Case Study on Metro Railway Station by using LED Luminaire

CC METRO - PLATFORM AREA

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY

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Operator: Ankit Ghosh

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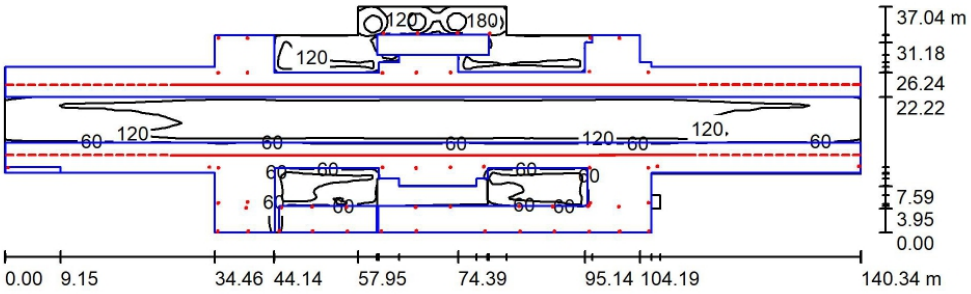
PLATFORM AREA / Summary



Height of Room: 8.500 m, Mounting Height: 5.500 m, Light loss factor: 0.80 Values in Lux, Scale 1:1004

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	74	0.62	276	0.008
Floor	20	54	0.68	217	0.013
Ceiling	70	56	5.02	96	0.089
Walls (36)	50	91	8.12	1963	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 1.328, Ceiling / Working Plane: 0.761.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	60	Crompton Greaves Ltd. 01 LPFC-36-CDL (1.000)	3568	3571	36.6
2	53	Crompton Greaves Ltd. 01 LSFN-72-CDL (1.000)	7086	7091	71.6
3	130	Crompton Greaves Ltd. IPFC112LT8-20(LT8-20-865-2) INDUSTRIAL LED LUMINAIRE (1.000)	3412	4200	40.0
			Total: 1033211	Total: 1136118	11190.8

Specific connected load: 3.15 W/m² = 4.25 W/m²/100 lx (Ground area: 3556.51 m²)

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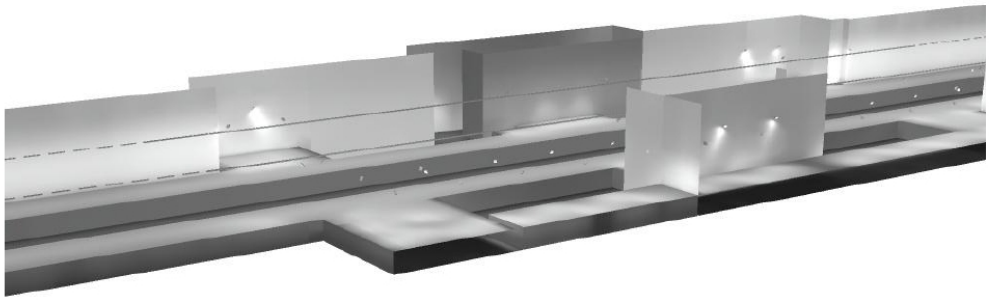
PLATFORM AREA / 3D Rendering



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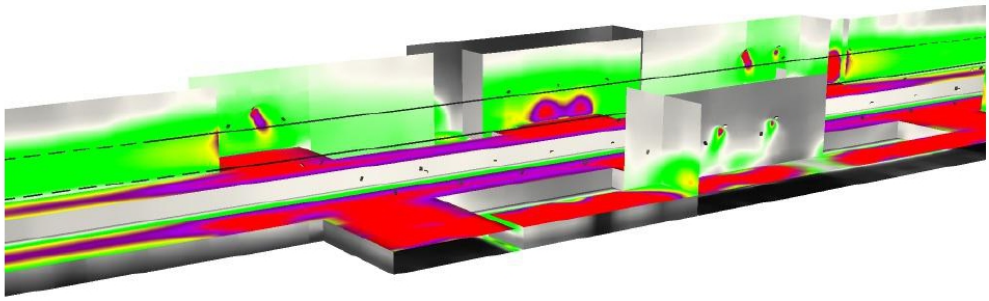
PLATFORM AREA / False Color Rendering



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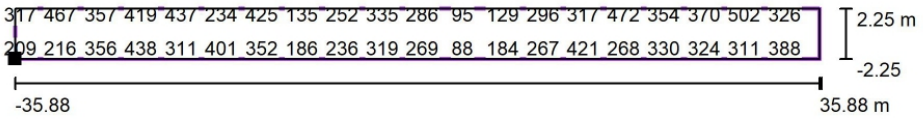
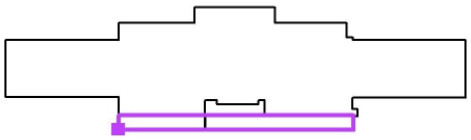
PLATFORM AREA / PASSAGE AREA / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 545

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (34.563 m, -9.300 m, 1.800 m)



Grid: 237 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
345	48	586	0.14	0.08

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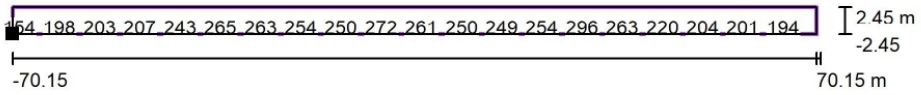
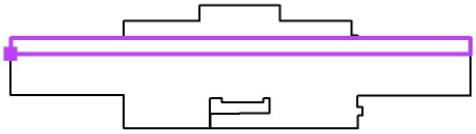
PLATFORM AREA / PLATFORM 1 - FRONT / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 1064

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (0.239 m, 13.245 m, 1.600 m)



Grid: 162 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
252	123	535	0.49	0.23

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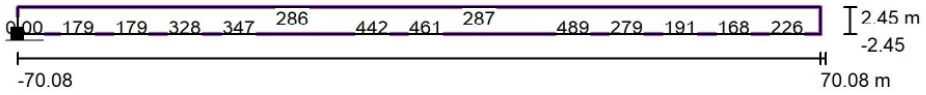
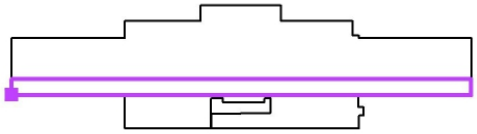
PLATFORM AREA / PLATFORM 2 - FRONT / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 1063

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (0.200 m, 0.800 m, 1.650 m)



Grid: 166 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
270	0.00	503	0.00	0.00

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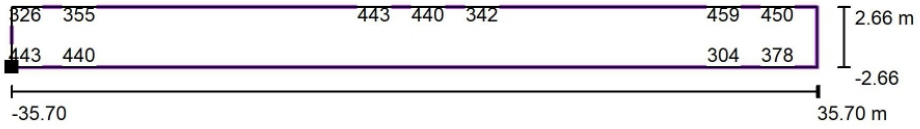
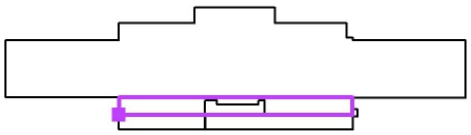
PLATFORM AREA / PLATFORM 2 - REAR / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 542

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (34.691 m, -4.629 m, 1.600 m)



Grid: 28 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
386	261	474	0.68	0.55

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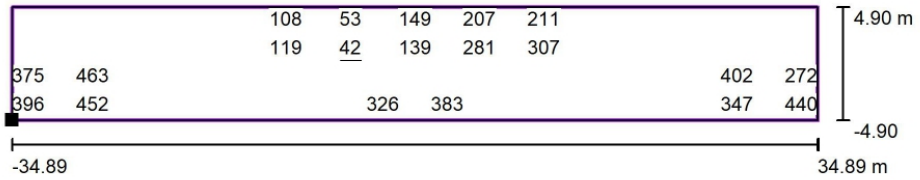
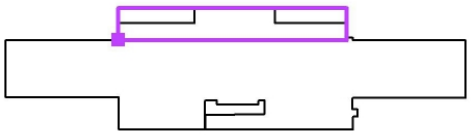
PLATFORM AREA / PLATFORM 1 - REAR / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 530

Not all calculated values could be displayed.

Position of surface in room:
Marked point: (34.500 m, 18.200 m, 1.650 m)



Grid: 33 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
276	42	557	0.15	0.08

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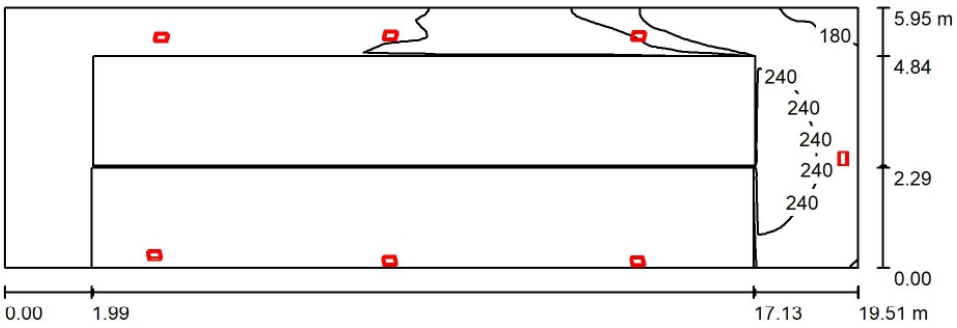
STAIRCASE - PLATFORM 1 LEFT / Summary



Height of Room: 10.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	107	3.98	277	0.037
Floors (10)	20	55	0.09	390	/
Ceiling	70	48	19	116	0.389
Walls (4)	50	85	1.44	1107	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.769, Ceiling / Working Plane: 0.459.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LSFN-72-CDL (1.000)	7086	7091	71.6
			Total: 49600	Total: 49638	501.2

Specific connected load: 4.32 W/m² = 4.04 W/m²/100 lx (Ground area: 116.01 m²)

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STAIRCASE - PLATFORM 1 LEFT / 3D Rendering

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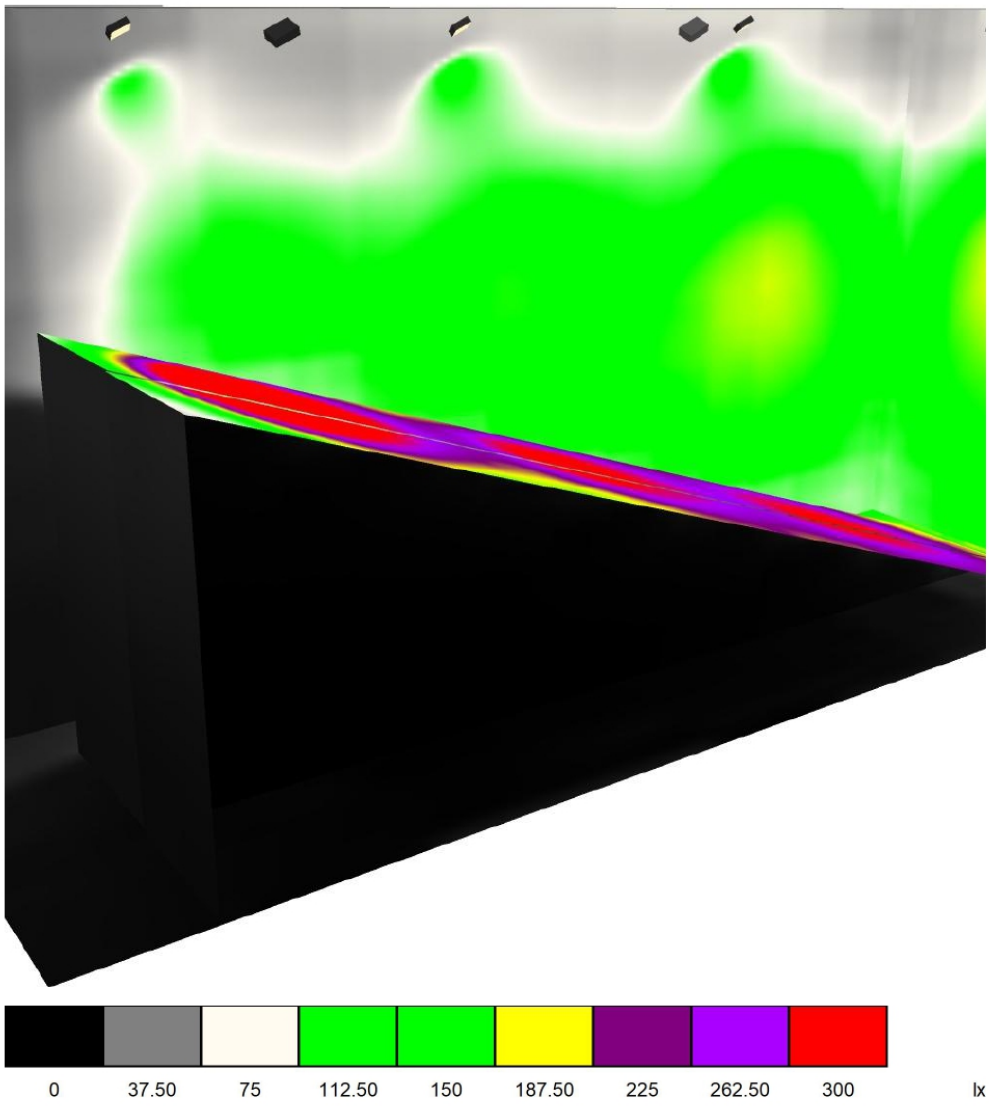
STAIRCASE - PLATFORM 1 LEFT / False Color Rendering



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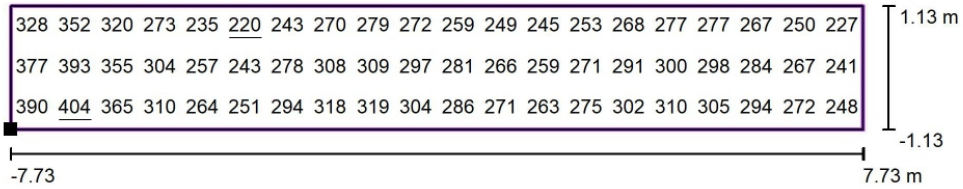
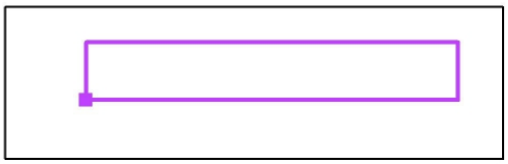
STAIRCASE - PLATFORM 1 LEFT / STAIRCASE / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 111

Position of surface in room:
Marked point: (44.872 m, 19.861 m, 5.836 m)



Grid: 20 x 3 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
288	220	404	0.76	0.55

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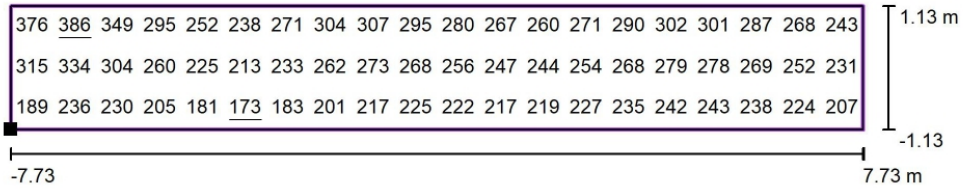
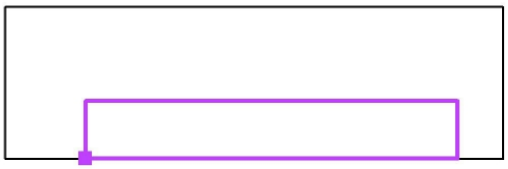
STAIRCASE - PLATFORM 1 LEFT / ESCALATOR / Value Chart (E, Perpendicular)



Values in Lux, Scale 1 : 111

Position of surface in room:
Marked point: (44.853 m, 17.572 m, 5.845 m)



Grid: 20 x 3 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
257	173	386	0.67	0.45

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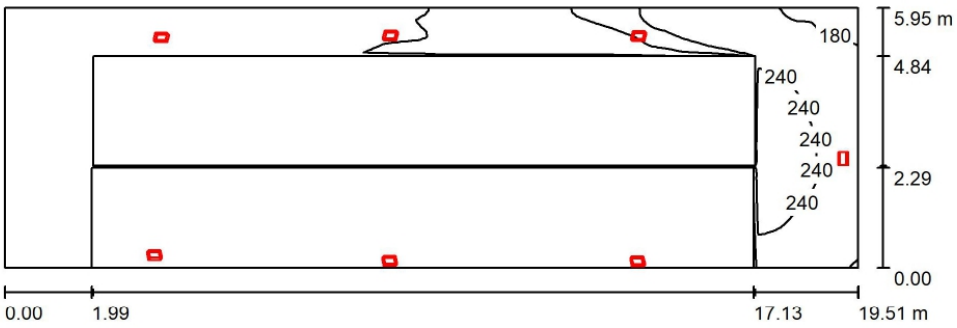
STAIRCASE - PLATFORM 1 RIGHT / Summary



Height of Room: 10.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	107	3.98	277	0.037
Floors (10)	20	55	0.09	390	/
Ceiling	70	48	19	116	0.389
Walls (4)	50	85	1.44	1107	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.769, Ceiling / Working Plane: 0.459.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LSFN-72-CDL (1.000)	7086	7091	71.6
			Total: 49600	Total: 49638	501.2

Specific connected load: 4.32 W/m² = 4.04 W/m²/100 lx (Ground area: 116.01 m²)

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STAIRCASE - PLATFORM 1 RIGHT / 3D Rendering

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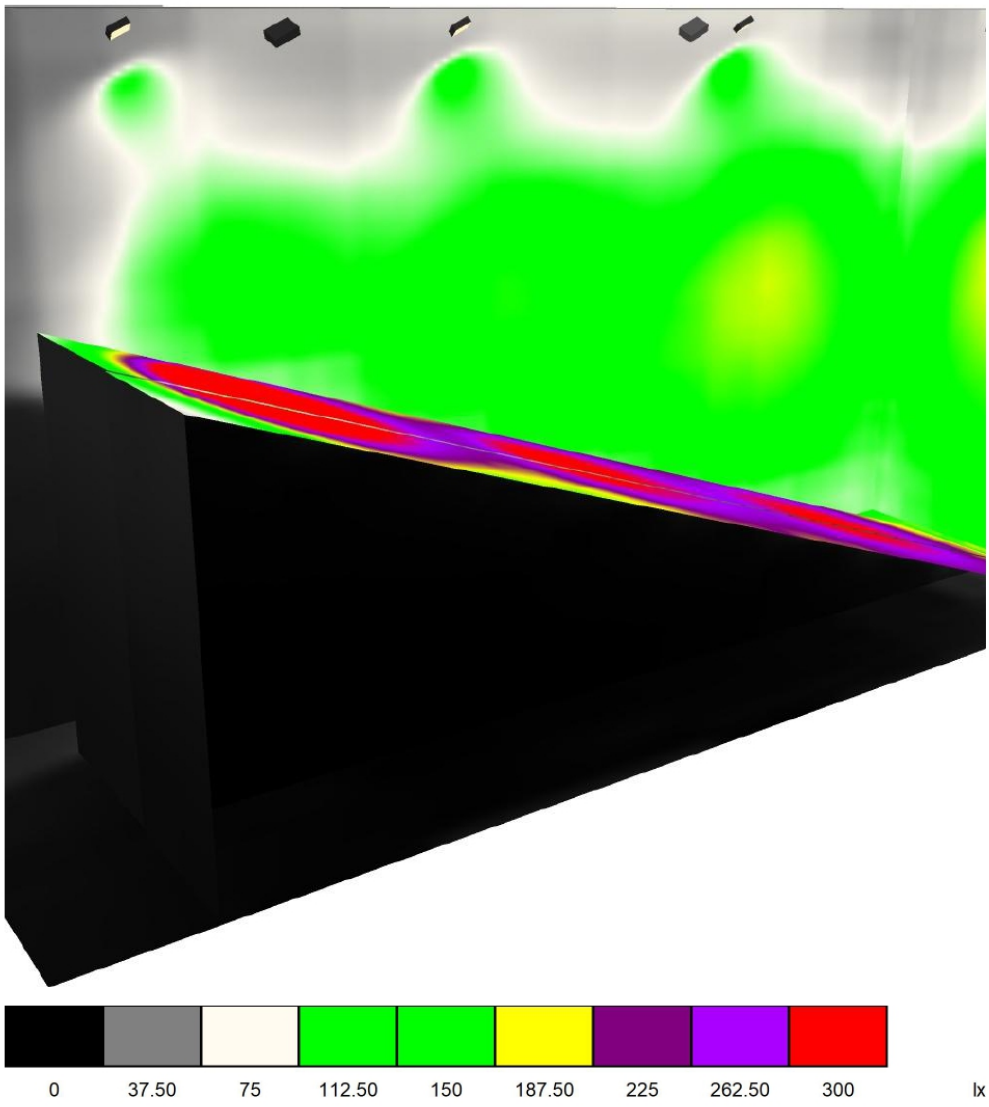
STAIRCASE - PLATFORM 1 RIGHT / False Color Rendering



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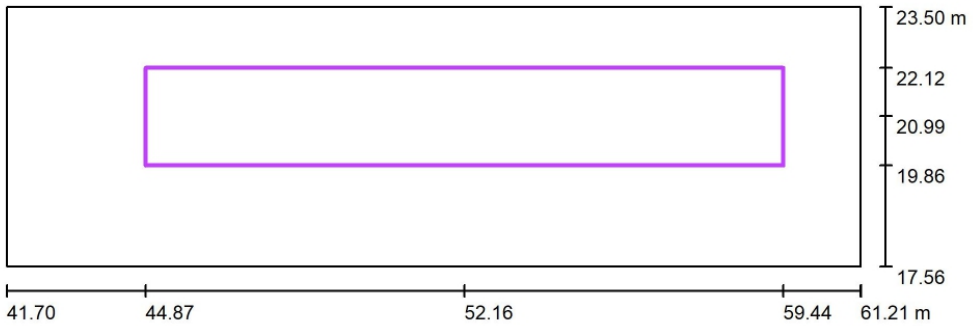
STAIRCASE - PLATFORM 1 RIGHT / STAIRCASE / Summary



Scale 1 : 140

Position: (52.155 m, 20.990 m, 3.257 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	288	220	404	0.76	0.55	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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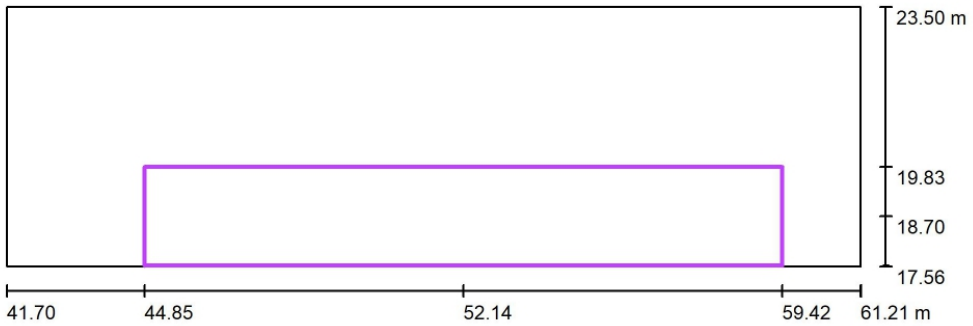
STAIRCASE - PLATFORM 1 RIGHT / ESCALATOR / Summary



Scale 1 : 140

Position: (52.137 m, 18.700 m, 3.266 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	257	173	386	0.67	0.45	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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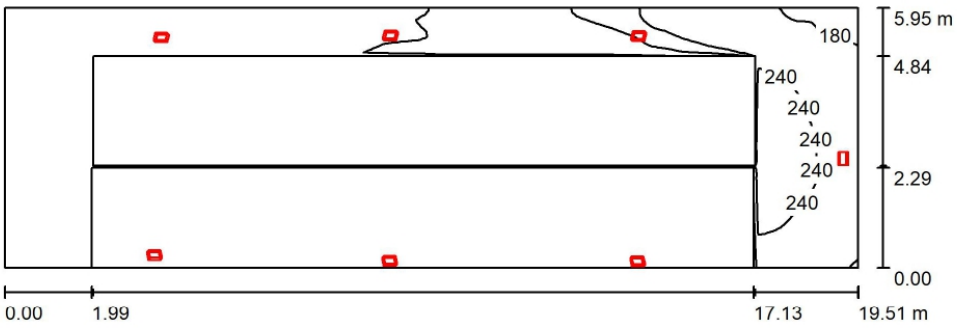
STAIRCASE - PLATFORM 2 LEFT / Summary



Height of Room: 10.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	107	3.98	277	0.037
Floors (10)	20	55	0.09	390	/
Ceiling	70	48	19	116	0.389
Walls (4)	50	85	1.44	1107	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.769, Ceiling / Working Plane: 0.459.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LSFN-72-CDL (1.000)	7086	7091	71.6
			Total: 49600	Total: 49638	501.2

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STAIRCASE - PLATFORM 2 LEFT / 3D Rendering

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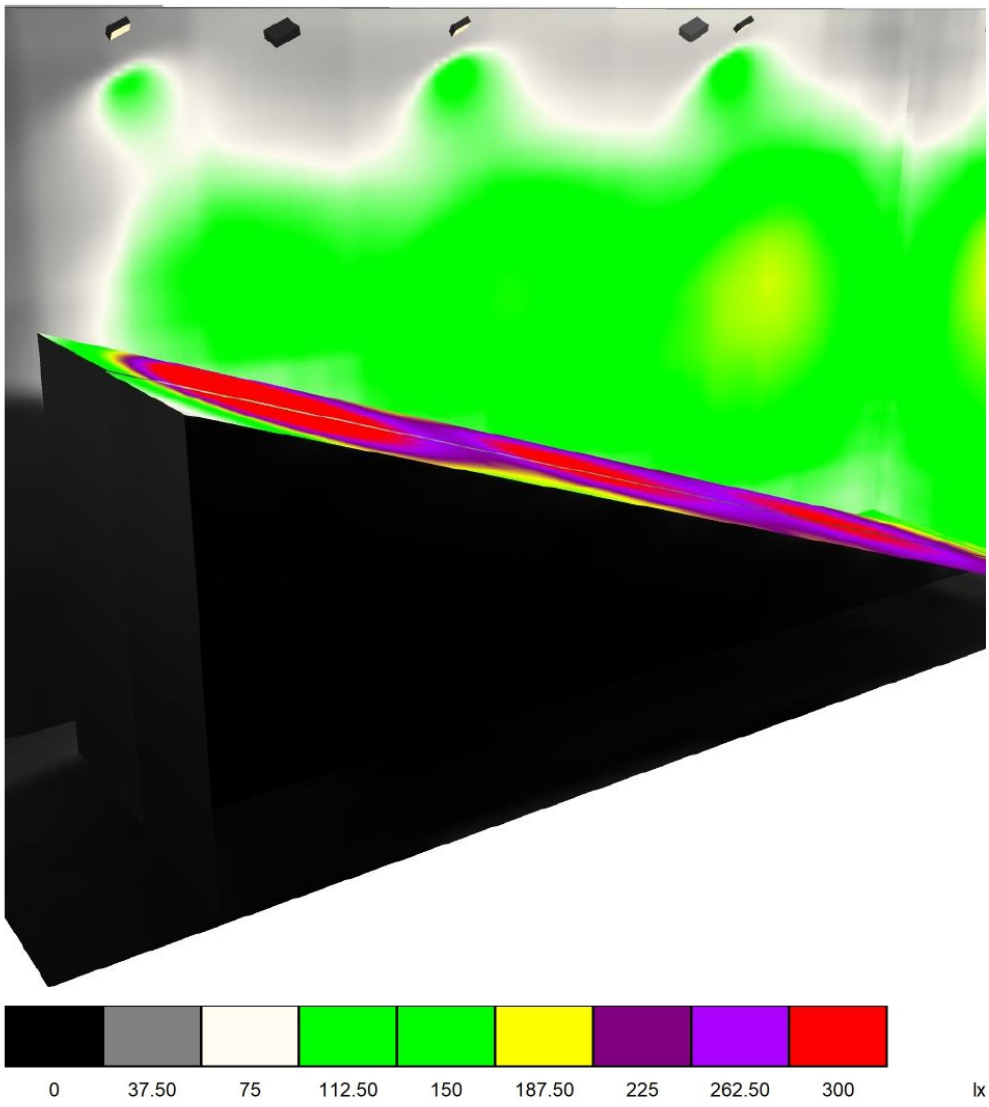
STAIRCASE - PLATFORM 2 LEFT / False Color Rendering



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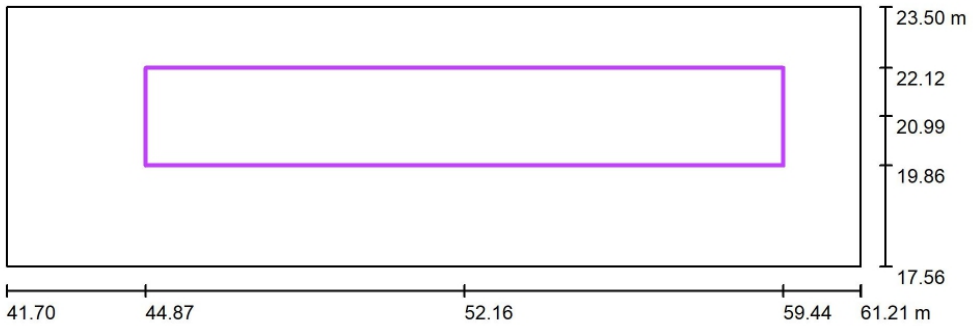
STAIRCASE - PLATFORM 2 LEFT / STAIRCASE / Summary



Scale 1 : 140

Position: (52.155 m, 20.990 m, 3.257 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	288	220	404	0.76	0.55	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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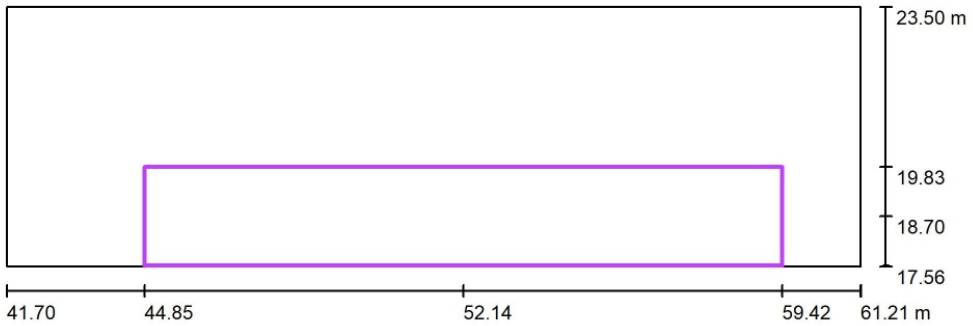
STAIRCASE - PLATFORM 2 LEFT / ESCALATOR / Summary



Scale 1 : 140

Position: (52.137 m, 18.700 m, 3.266 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	257	173	386	0.67	0.45	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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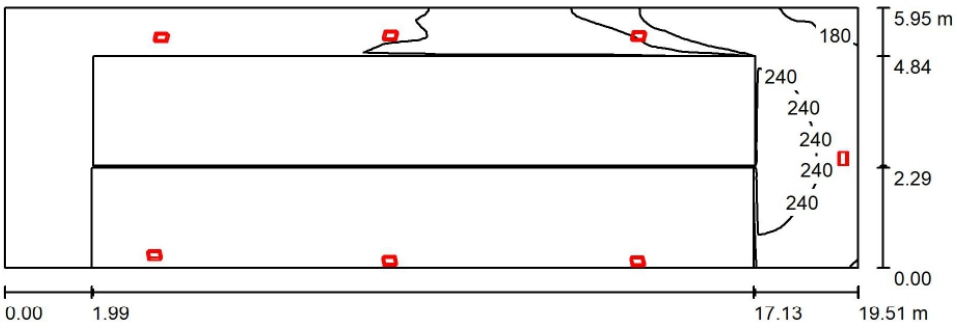
STAIRCASE - PLATFORM 2 RIGHT / Summary



Height of Room: 10.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:140

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	107	3.98	277	0.037
Floors (10)	20	55	0.09	390	/
Ceiling	70	48	19	116	0.389
Walls (4)	50	85	1.44	1107	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.769, Ceiling / Working Plane: 0.459.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LSFN-72-CDL (1.000)	7086	7091	71.6
			Total: 49600	Total: 49638	501.2

Specific connected load: 4.32 W/m² = 4.04 W/m²/100 lx (Ground area: 116.01 m²)

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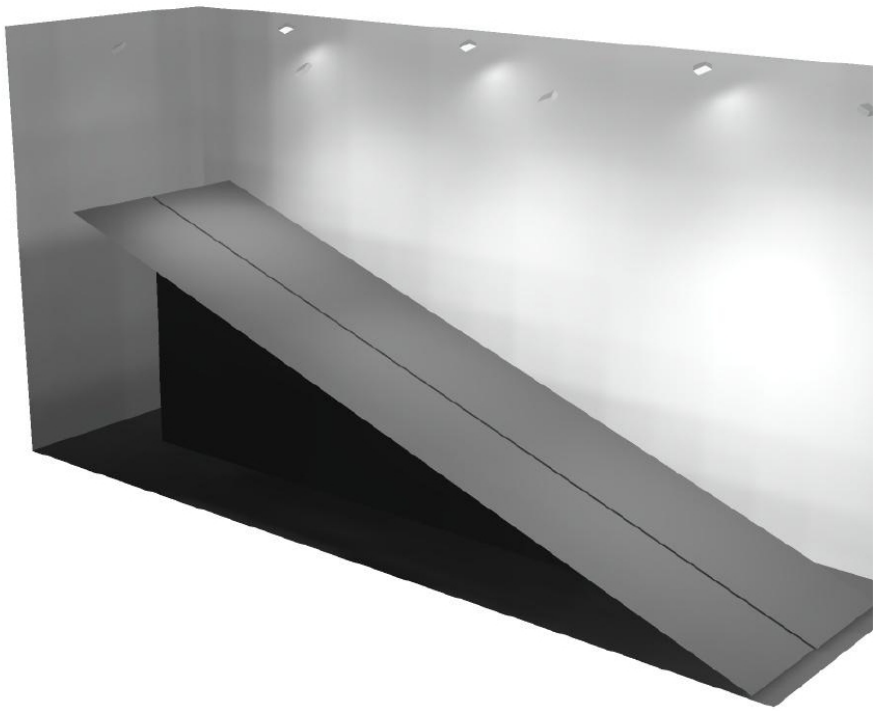
STAIRCASE - PLATFORM 2 RIGHT / 3D Rendering



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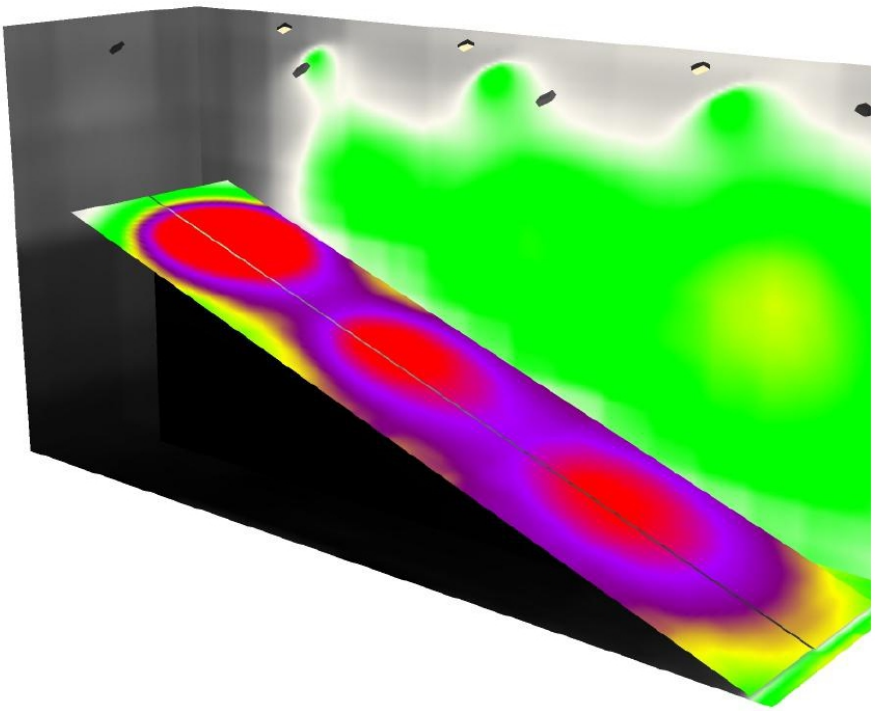
STAIRCASE - PLATFORM 2 RIGHT / False Color Rendering



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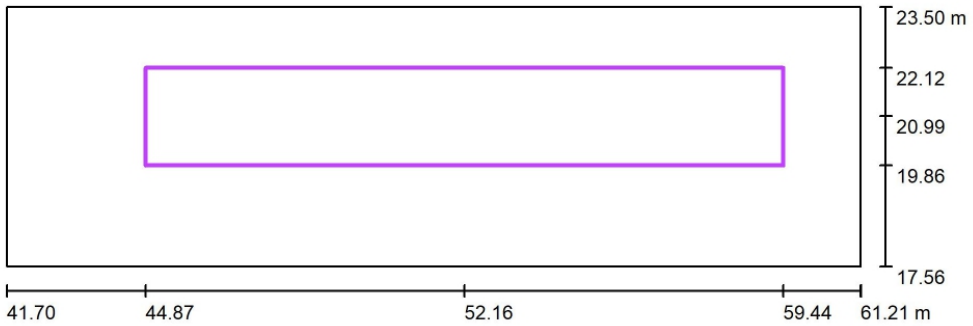
STAIRCASE - PLATFORM 2 RIGHT / STAIRCASE / Summary



Scale 1 : 140

Position: (52.155 m, 20.990 m, 3.257 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	288	220	404	0.76	0.55	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

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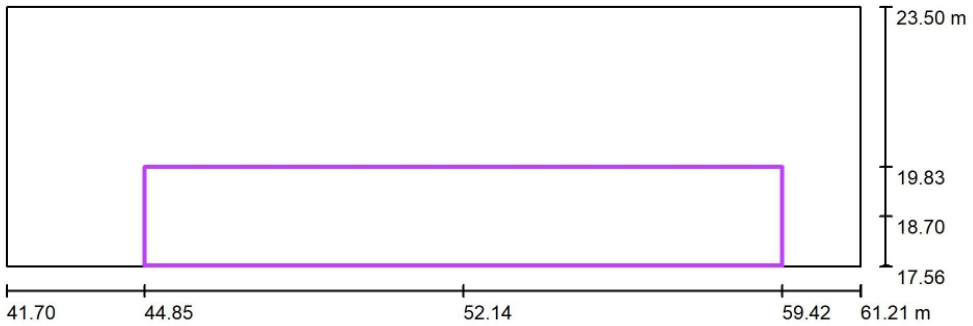
STAIRCASE - PLATFORM 2 RIGHT / ESCALATOR / Summary



Scale 1 : 140

Position: (52.137 m, 18.700 m, 3.266 m)
Size: (15.454 m, 2.257 m)
Rotation: (0.0°, 19.5°, 0.0°)
Type: Normal, Grid: 20 x 3 Points

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	257	173	386	0.67	0.45	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

City Centre Metro Concourse Area

ALL ILLUMINANCE VALUES ARE THE RESULT OF COMPUTER CALCULATIONS, BASED UPON PRECISELY POSITIONED LUMINAIRES IN A FIXED RELATIONSHIP TO EACH OTHER AND TO THE AREA UNDER EXAMINATION. IN PRACTICE THE VALUES MAY VARY DUE TO TOLARANCE OF LUMINAIRES, LUMINAIRE POSITIONING, REFLECTION PROPERTIES AND ELECTRICAL SUPPLY

Date: 13.06.2018
Operator: Ankit Ghosh

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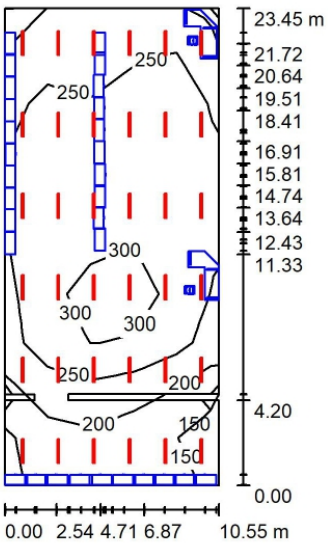
AUXILIARY SUBSTATION / Summary



Height of Room: 6.380 m, Mounting Height: 5.380 m, Light loss factor: 0.80 Values in Lux, Scale 1:302

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	255	128	330	0.504
Floor	20	213	26	307	0.122
Ceiling	70	88	52	113	0.590
Walls (12)	50	163	3.98	480	/

Workplane:
Height: 0.760 m
Grid: 10 x 5 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.681, Ceiling / Working Plane: 0.346.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	36	Crompton Greaves Ltd. 01 LPFC-36-CDL (1.000)	3568	3571	36.6
			Total: 128460	Total: 128570	1317.6

Specific connected load: 5.38 W/m² = 2.11 W/m²/100 lx (Ground area: 244.82 m²)

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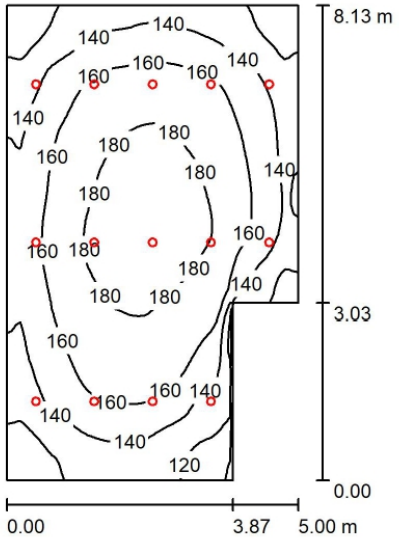
LOBBY AREA / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:105

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	154	92	191	0.599
Floor	20	154	98	191	0.638
Ceiling	70	45	34	105	0.746
Walls (6)	50	107	38	534	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.696, Ceiling / Working Plane: 0.294.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	14	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 11660	Total: 11691	173.6

Specific connected load: 4.66 W/m² = 3.03 W/m²/100 lx (Ground area: 37.22 m²)

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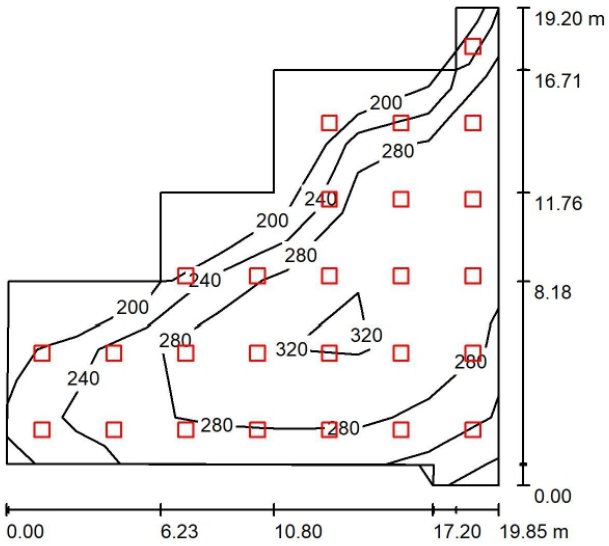
UNPAID AREA_ 1 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:247

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	270	163	326	0.604
Floor	20	268	92	343	0.343
Ceiling	70	59	38	113	0.638
Walls (12)	50	140	47	644	/

Workplane:
Height: 0.000 m
Grid: 7 x 7 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.526, Ceiling / Working Plane: 0.222.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	26	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 91644	Total: 91764	888.7

Specific connected load: 3.62 W/m² = 1.34 W/m²/100 lx (Ground area: 245.26 m²)

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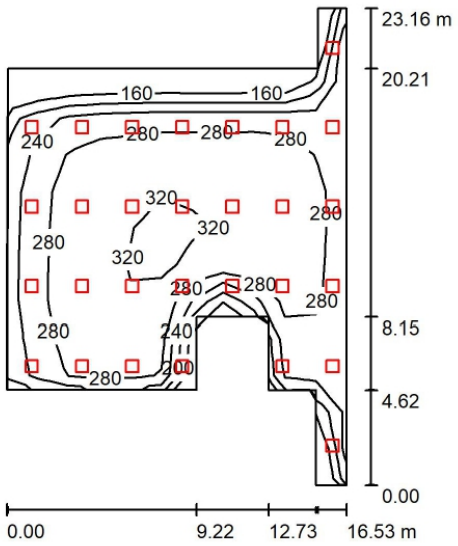
UNPAID AREA_ 2 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:298

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	279	152	342	0.544
Floor	20	273	109	346	0.397
Ceiling	70	64	44	156	0.682
Walls (12)	50	160	54	684	/

Workplane:
Height: 0.000 m
Grid: 13 x 11 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.594, Ceiling / Working Plane: 0.234.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	29	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 102218	Total: 102353	991.2

Specific connected load: 3.88 W/m² = 1.39 W/m²/100 lx (Ground area: 255.70 m²)

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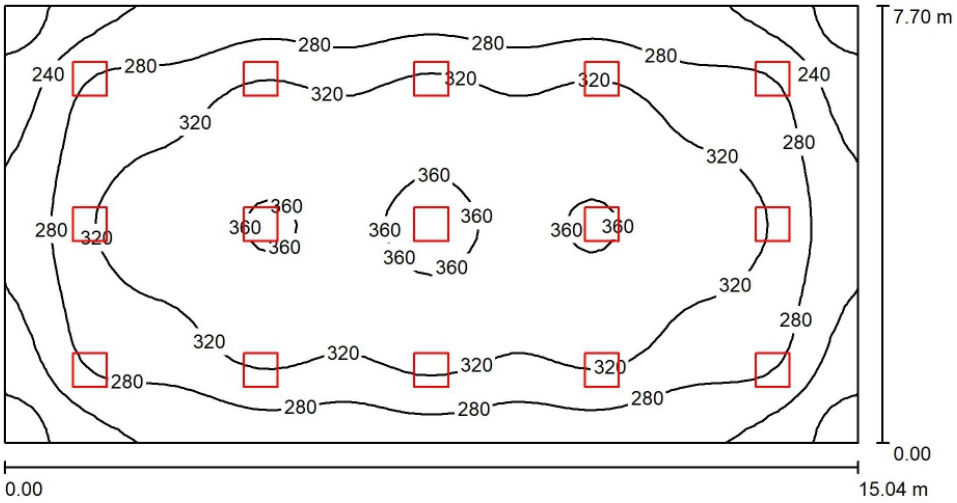
CONCOURSE PAID AREA_3M / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:108

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	302	177	371	0.586
Floor	20	302	175	371	0.580
Ceiling	70	70	52	90	0.742
Walls (4)	50	171	64	263	/

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

UGR Lengthways- Across to luminaire axis
Left Wall 19 19
Lower Wall 18 18
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.563, Ceiling / Working Plane: 0.233.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	15	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 52872	Total: 52941	512.7

Specific connected load: 4.43 W/m² = 1.47 W/m²/100 lx (Ground area: 115.79 m²)

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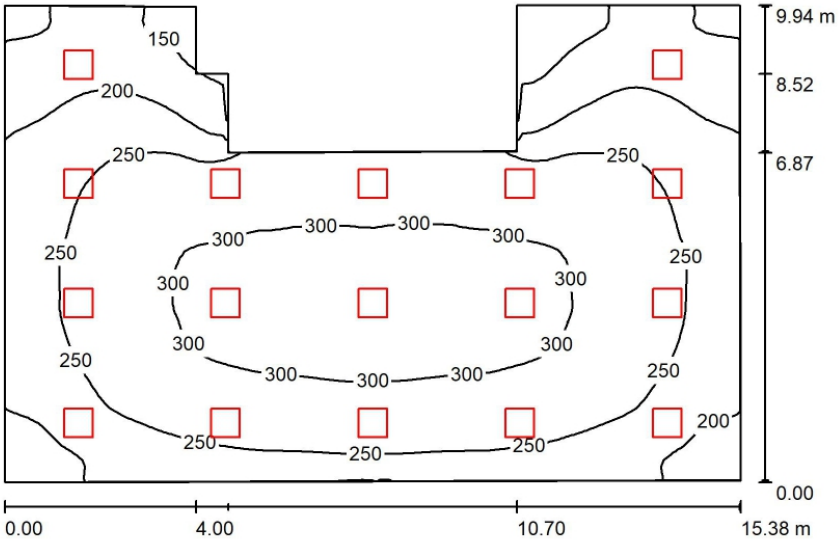
CONCOURSE PAID AREA_4.3M / Summary



Height of Room: 4.300 m, Mounting Height: 4.300 m, Light loss factor: 0.80 Values in Lux, Scale 1:128

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	251	103	325	0.412
Floor	20	251	99	323	0.396
Ceiling	70	66	40	120	0.606
Walls (10)	50	153	53	707	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.609, Ceiling / Working Plane: 0.261.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	17	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 59921	Total: 60000	581.1

Specific connected load: 4.37 W/m² = 1.74 W/m²/100 lx (Ground area: 133.00 m²)

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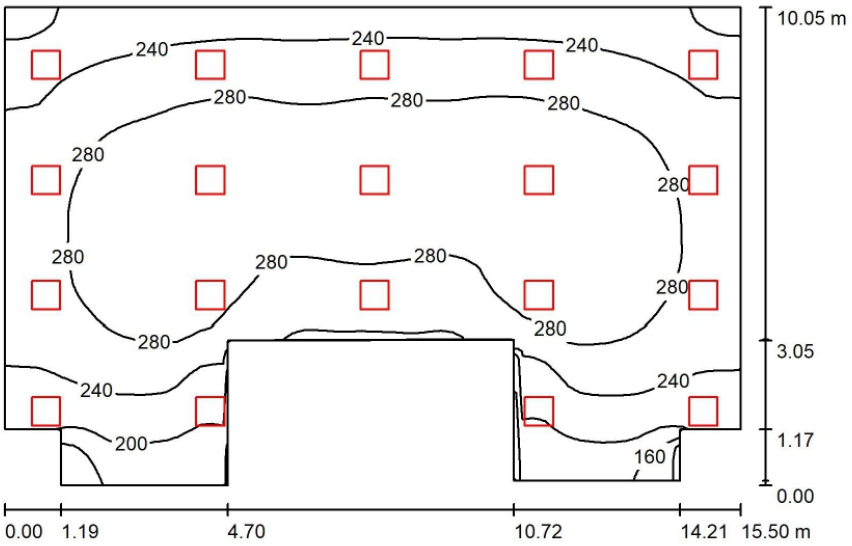
CONCOURSE PAID AREA_4.3M / Summary



Height of Room: 4.300 m, Mounting Height: 4.300 m, Light loss factor: 0.80 Values in Lux, Scale 1:129

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	262	113	311	0.431
Floor	20	262	120	310	0.457
Ceiling	70	76	48	361	0.630
Walls (12)	50	181	60	2095	/

Workplane:
Height: 0.000 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.691, Ceiling / Working Plane: 0.290.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	19	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 66971	Total: 67059	649.4

Specific connected load: 4.85 W/m² = 1.85 W/m²/100 lx (Ground area: 133.99 m²)

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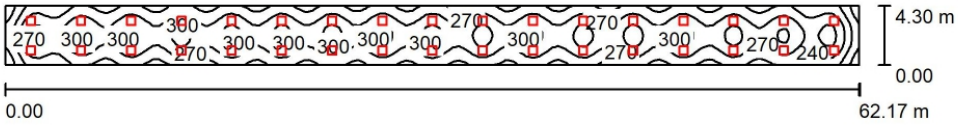
STATION ENTRANCES 1 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:445

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	268	171	313	0.637
Floor	20	268	157	315	0.588
Ceiling	70	67	55	94	0.828
Walls (4)	50	165	61	322	/

Workplane:
Height: 0.000 m
Grid: 128 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.629, Ceiling / Working Plane: 0.249.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	34	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 119842	Total: 120000	1162.1

Specific connected load: 4.35 W/m² = 1.63 W/m²/100 lx (Ground area: 267.21 m²)

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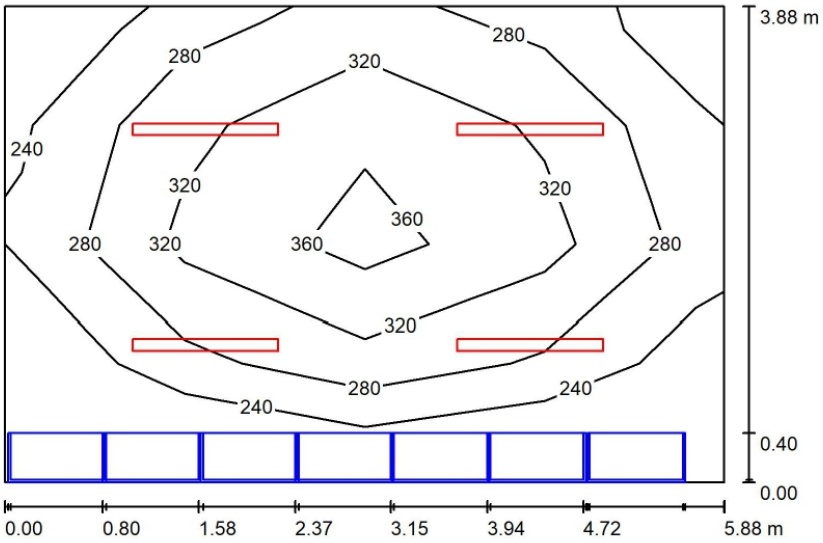
ELECTRICAL UPS / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 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	/	306	221	381	0.722
Floor	20	221	22	300	0.097
Ceiling	70	113	68	966	0.597
Walls (4)	50	143	1.12	371	/

Workplane:
Height: 0.760 m
Grid: 4 x 4 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.570, Ceiling / Working Plane: 0.406.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	Crompton Greaves Ltd. 01 LPFC-36-CDL (1.000)	3568	3571	36.6
			Total: 14273	Total: 14286	146.4

Specific connected load: 6.43 W/m² = 2.10 W/m²/100 lx (Ground area: 22.77 m²)

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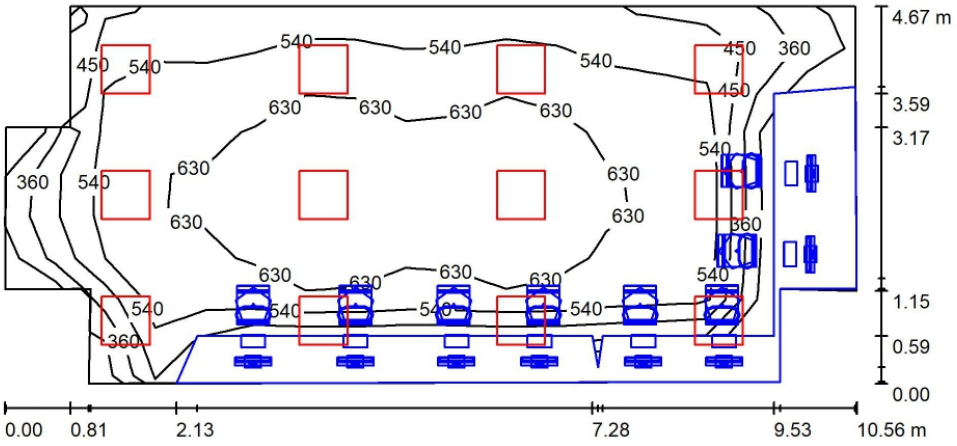
TER / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:76

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	571	261	704	0.457
Floor	20	415	57	594	0.138
Ceiling	70	128	87	245	0.678
Walls (10)	50	282	42	1607	/

Workplane:

Height:	0.760 m
Grid:	17 x 9 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.561, Ceiling / Working Plane: 0.224.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	12	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 42297	Total: 42353	410.2

Specific connected load: 8.98 W/m² = 1.57 W/m²/100 lx (Ground area: 45.66 m²)

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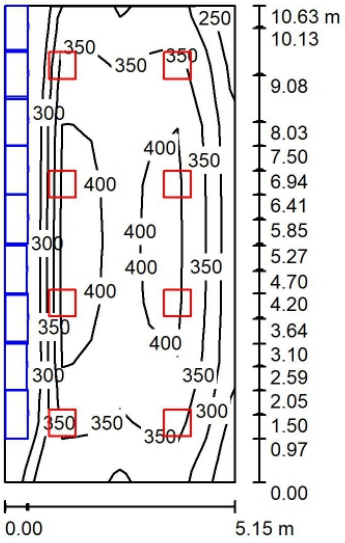
UPS / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:137

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	368	226	433	0.614
Floor	20	286	14	378	0.048
Ceiling	70	77	56	108	0.729
Walls (4)	50	132	1.89	268	/

Workplane:
Height: 0.760 m
Grid: 8 x 8 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.378, Ceiling / Working Plane: 0.212.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 28198	Total: 28235	273.4

Specific connected load: 5.00 W/m² = 1.36 W/m²/100 lx (Ground area: 54.72 m²)

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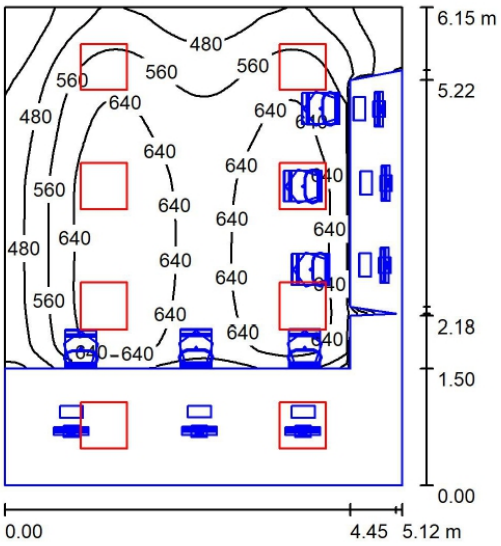
SER SIGNAL RELAY / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:79

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	590	306	703	0.519
Floor	20	330	24	580	0.074
Ceiling	70	129	90	170	0.698
Walls (4)	50	259	33	624	/

Workplane:
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.515, Ceiling / Working Plane: 0.219.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 28198	Total: 28235	273.4

Specific connected load: 8.68 W/m² = 1.47 W/m²/100 lx (Ground area: 31.52 m²)

Crompton Greaves Consumer Electricals Limited

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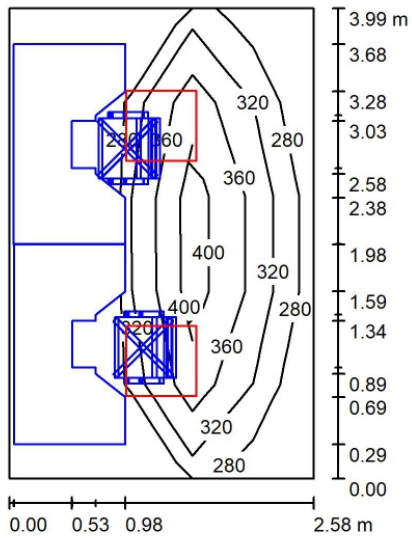
TICKET OFFICE MACHINE 1 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:52

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	362	252	451	0.697
Floor	20	174	29	296	0.164
Ceiling	70	84	57	95	0.678
Walls (4)	50	170	31	368	/

Workplane:

Height:	0.760 m
Grid:	5 x 5 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.579, Ceiling / Working Plane: 0.246.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 7050	Total: 7059	68.4

Specific connected load: 6.63 W/m² = 1.83 W/m²/100 lx (Ground area: 10.31 m²)

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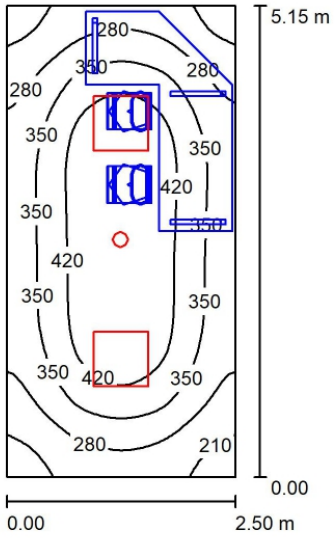
TICKET OFFICE MACHINE 2 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:67

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	351	181	490	0.514
Floor	20	210	23	345	0.112
Ceiling	70	84	52	103	0.621
Walls (4)	50	171	28	298	/

Workplane:
Height: 0.760 m
Grid: 32 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.541, Ceiling / Working Plane: 0.239.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
2	1	Crompton Greaves Ltd. 02 LCDE-12-CDL (1.000)	1339	1335	12.4
			Total: 8389	Total: 8394	80.7

Specific connected load: 6.27 W/m² = 1.79 W/m²/100 lx (Ground area: 12.88 m²)

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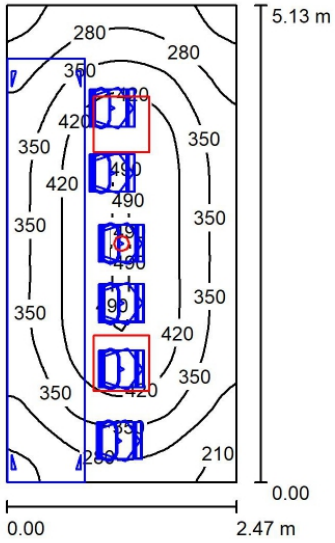
AUDIT & CASH / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:66

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	360	185	495	0.515
Floor	20	158	20	319	0.126
Ceiling	70	96	57	116	0.601
Walls (4)	50	173	16	312	/

Workplane:
Height: 0.760 m
Grid: 32 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.557, Ceiling / Working Plane: 0.266.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
2	1	Crompton Greaves Ltd. 02 LCDE-12-CDL (1.000)	1339	1335	12.4
			Total: 8389	Total: 8394	80.7

Specific connected load: 6.37 W/m² = 1.77 W/m²/100 lx (Ground area: 12.68 m²)

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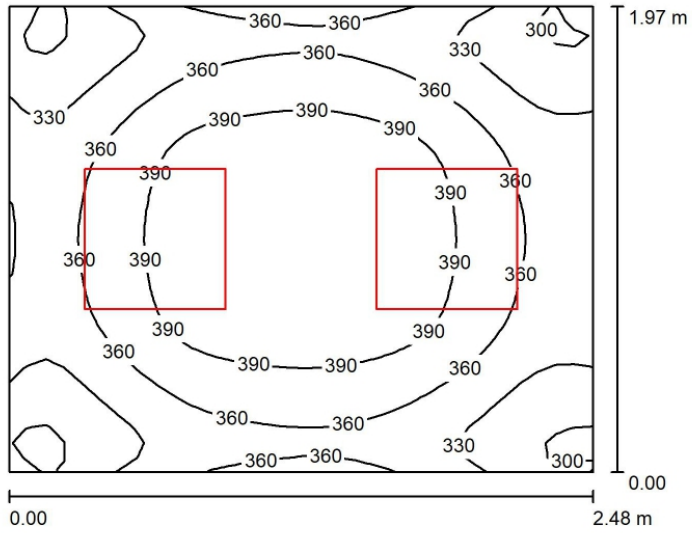
ROOM BESIDE AUDIT & CASH / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:26

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	364	281	421	0.773
Floor	20	364	282	420	0.774
Ceiling	70	161	115	188	0.718
Walls (4)	50	329	116	909	/

Workplane:
Height: 0.000 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.900, Ceiling / Working Plane: 0.441.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 7050	Total: 7059	68.4

Specific connected load: 13.98 W/m² = 3.84 W/m²/100 lx (Ground area: 4.89 m²)

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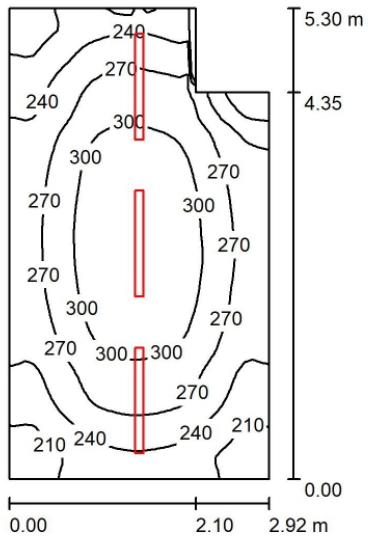
SPARE ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:69

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	267	185	327	0.696
Floor	20	267	179	326	0.672
Ceiling	70	133	76	490	0.576
Walls (6)	50	216	114	646	/

Workplane:
Height: 0.000 m
Grid: 64 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.809, Ceiling / Working Plane: 0.498.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. 01 LPFC-36-CDL (1.000)	3568	3571	36.6
			Total: 10705	Total: 10714	109.8

Specific connected load: 7.46 W/m² = 2.80 W/m²/100 lx (Ground area: 14.72 m²)

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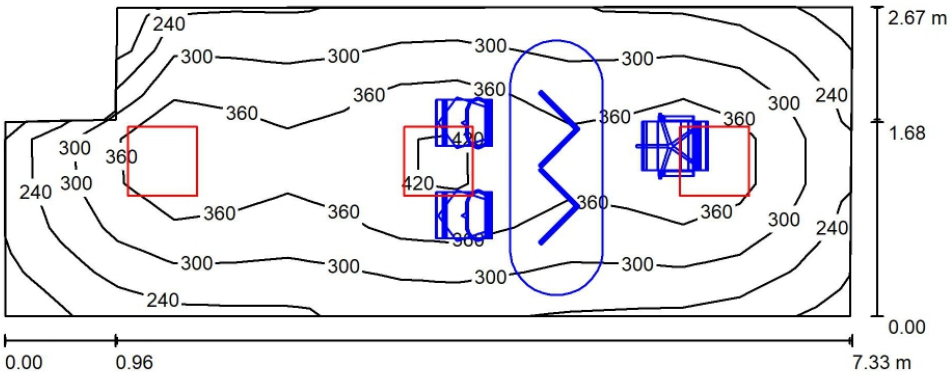
SUPERVISOR ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:53

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	319	173	448	0.543
Floor	20	206	27	304	0.132
Ceiling	70	80	48	110	0.605
Walls (6)	50	165	59	801	/

Workplane:
Height: 0.760 m
Grid: 15 x 7 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.556, Ceiling / Working Plane: 0.250.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 10574	Total: 10588	102.5

Specific connected load: 5.52 W/m² = 1.73 W/m²/100 lx (Ground area: 18.59 m²)

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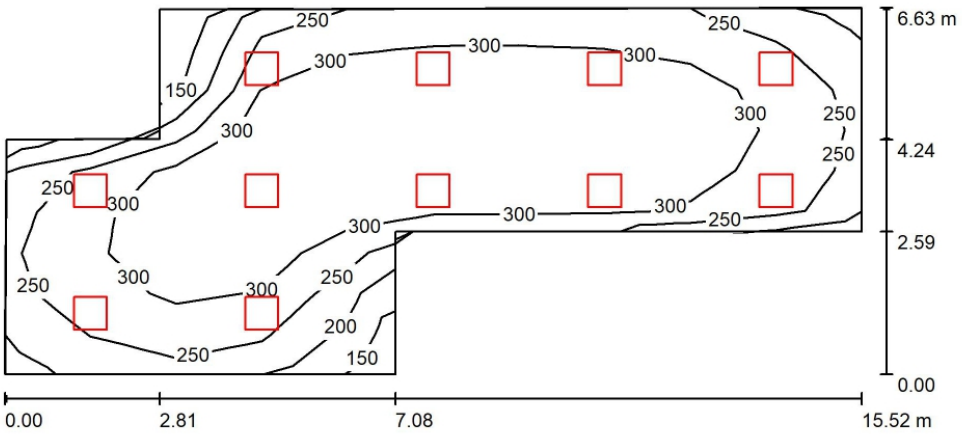
STATION ENTRANCES 2 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	289	131	351	0.454
Floor	20	292	124	364	0.426
Ceiling	70	76	51	109	0.675
Walls (8)	50	180	56	598	/

Workplane:
Height: 0.000 m
Grid: 10 x 9 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.612, Ceiling / Working Plane: 0.259.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	11	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 38772	Total: 38823	376.0

Specific connected load: 5.07 W/m² = 1.75 W/m²/100 lx (Ground area: 74.23 m²)

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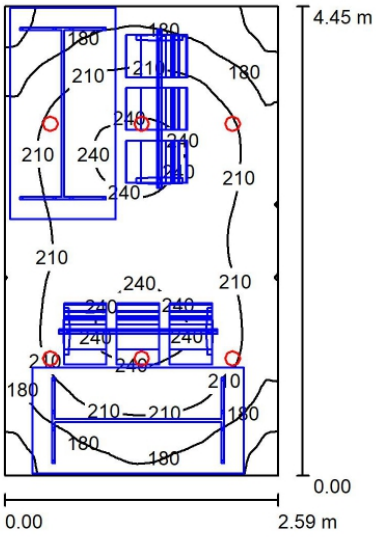
STAFF MESS ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:58

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	205	132	247	0.644
Floor	20	82	15	168	0.185
Ceiling	70	68	45	88	0.653
Walls (4)	50	123	14	440	/

Workplane:
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.728, Ceiling / Working Plane: 0.332.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 4997	Total: 5011	74.4

Specific connected load: 6.46 W/m² = 3.15 W/m²/100 lx (Ground area: 11.51 m²)

Crompton Greaves Consumer Electricals Limited

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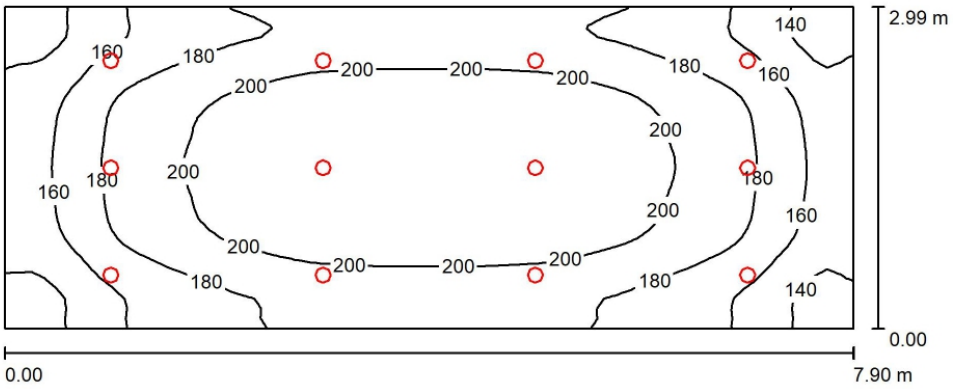
TOILET 1 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:57

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	185	126	219	0.683
Floor	20	185	124	220	0.667
Ceiling	70	60	48	79	0.808
Walls (4)	50	137	54	346	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.740, Ceiling / Working Plane: 0.322.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	12	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 9994	Total: 10021	148.8

Specific connected load: 6.29 W/m² = 3.40 W/m²/100 lx (Ground area: 23.66 m²)

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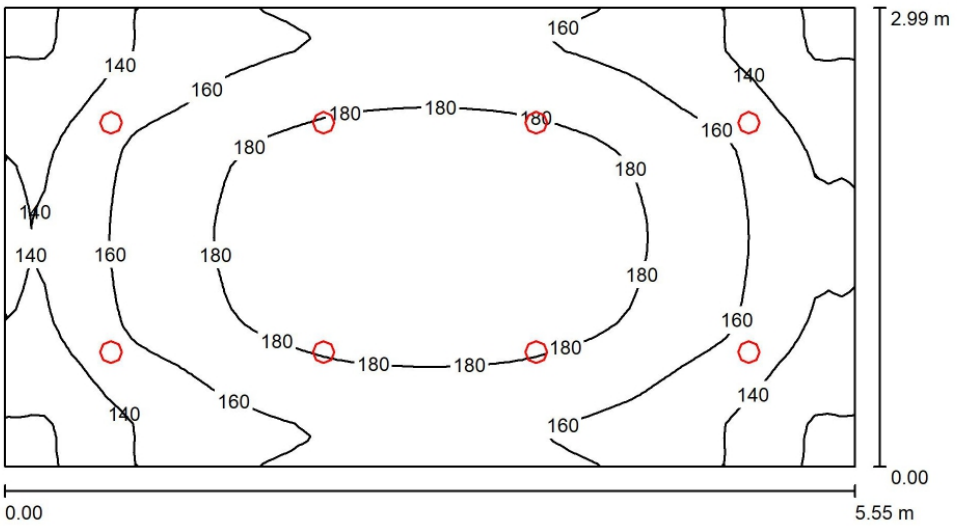
TOILET 2 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:40

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	163	114	196	0.699
Floor	20	163	111	195	0.681
Ceiling	70	54	46	66	0.837
Walls (4)	50	124	51	210	/

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

UGR (CIE, SHR = 0.25.)

	Lengthways-	Across
Left Wall	23	23
Lower Wall	22	22

to luminaire axis

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.765, Ceiling / Working Plane: 0.335.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	8	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 6663	Total: 6681	99.2

Specific connected load: 5.97 W/m² = 3.67 W/m²/100 lx (Ground area: 16.62 m²)

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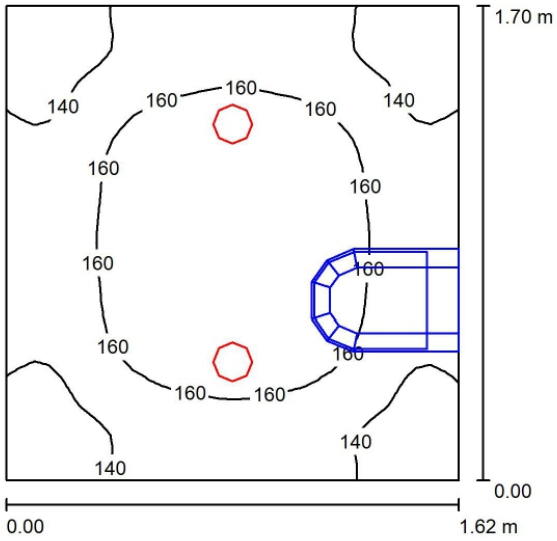
TOILET 3 / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:22

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	154	122	178	0.794
Floor	20	91	23	108	0.248
Ceiling	70	70	47	89	0.679
Walls (4)	50	118	10	446	/

Workplane:
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.945, Ceiling / Working Plane: 0.451.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 1666	Total: 1670	24.8

Specific connected load: 8.98 W/m² = 5.83 W/m²/100 lx (Ground area: 2.76 m²)

Crompton Greaves Consumer Electricals Limited

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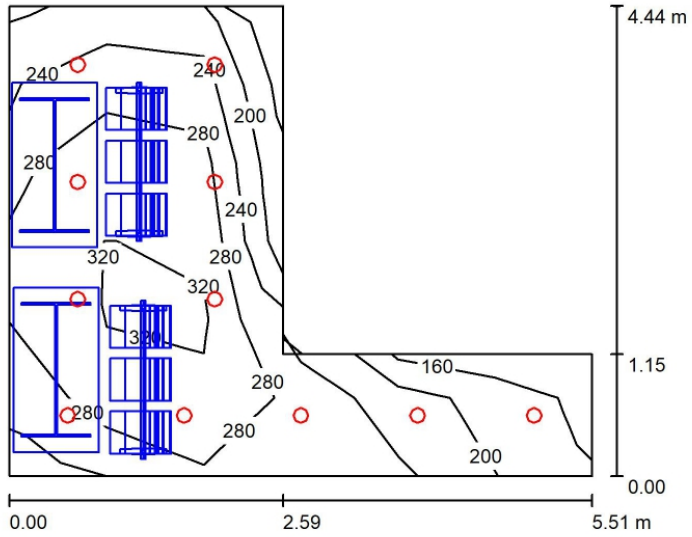
STAFF MESS ROOM / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:58

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	267	156	343	0.582
Floor	20	147	35	249	0.240
Ceiling	70	89	69	112	0.775
Walls (6)	50	167	30	339	/

Workplane:
Height: 0.760 m
Grid: 6 x 6 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.730, Ceiling / Working Plane: 0.328.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	11	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 9161	Total: 9186	136.4

Specific connected load: 9.17 W/m² = 3.43 W/m²/100 lx (Ground area: 14.88 m²)

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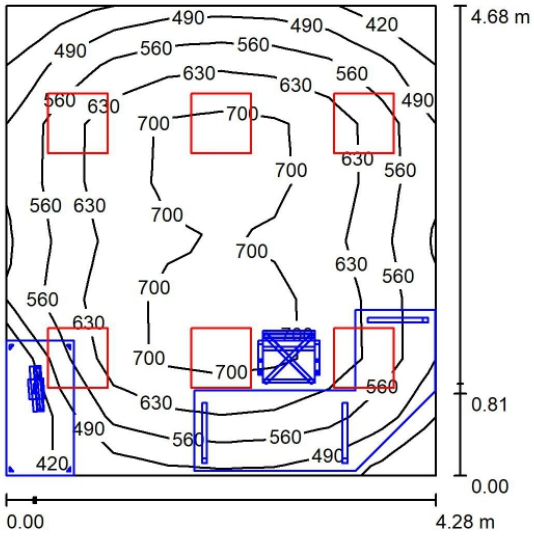
Station Control Room / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:61

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	625	410	755	0.657
Floor	20	426	76	597	0.178
Ceiling	70	149	104	177	0.701
Walls (4)	50	319	56	730	/

Workplane:
Height: 0.760 m
Grid: 8 x 8 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.594, Ceiling / Working Plane: 0.245.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	6	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 21149	Total: 21176	205.1

Specific connected load: 10.26 W/m² = 1.64 W/m²/100 lx (Ground area: 19.99 m²)

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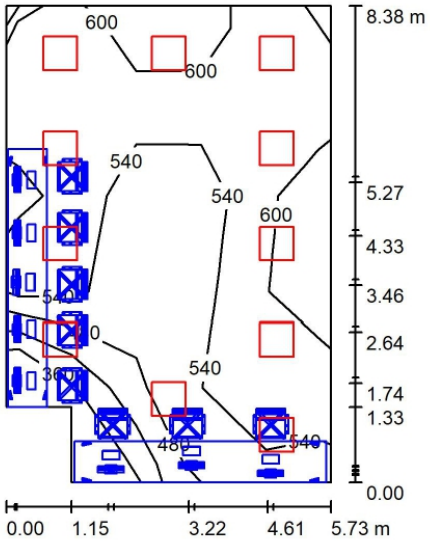
SMR Signal Relay Room / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:108

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	562	344	638	0.613
Floor	20	400	59	538	0.148
Ceiling	70	127	87	165	0.685
Walls (6)	50	285	54	559	/

Workplane:
Height: 0.760 m
Grid: 5 x 5 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.603, Ceiling / Working Plane: 0.238.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	11	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 38772	Total: 38823	376.0

Specific connected load: 8.09 W/m² = 1.44 W/m²/100 lx (Ground area: 46.46 m²)

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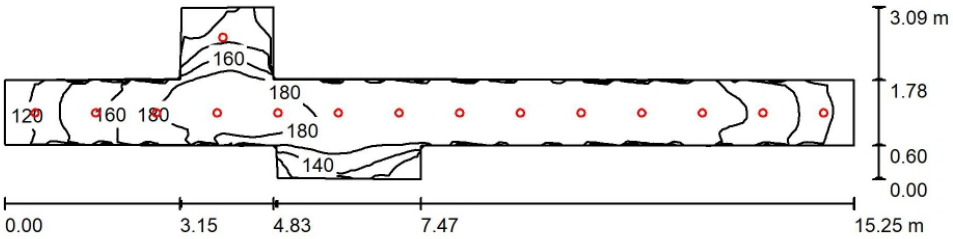
CORRIDOR NEAR TOILET / Summary



Height of Room: 2.700 m, Mounting Height: 2.700 m, Light loss factor: 0.80 Values in Lux, Scale 1:110

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	159	103	196	0.644
Floor	20	160	102	195	0.636
Ceiling	70	70	44	104	0.623
Walls (12)	50	138	52	313	/

Workplane:

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

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.860, Ceiling / Working Plane: 0.442.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	15	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 12492	Total: 12527	186.0

Specific connected load: 8.56 W/m² = 5.37 W/m²/100 lx (Ground area: 21.72 m²)

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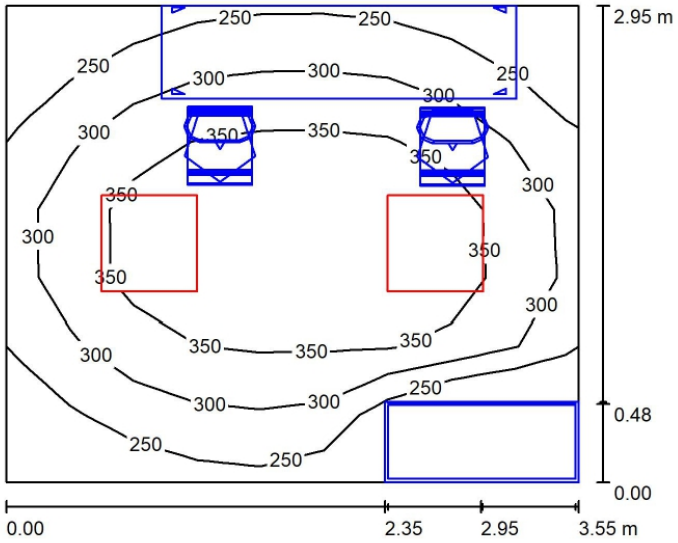
ENQUIRY ROOM / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:38

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	313	202	406	0.645
Floor	20	190	6.03	283	0.032
Ceiling	70	86	55	106	0.637
Walls (4)	50	160	0.68	444	/

Workplane:
Height: 0.760 m
Grid: 9 x 7 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.590, Ceiling / Working Plane: 0.273.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 01 LCTLRN-36-FO-CDL (1.000)	3525	3529	34.2
			Total: 7050	Total: 7059	68.4

Specific connected load: 6.53 W/m² = 2.09 W/m²/100 lx (Ground area: 10.47 m²)

13.06.2018

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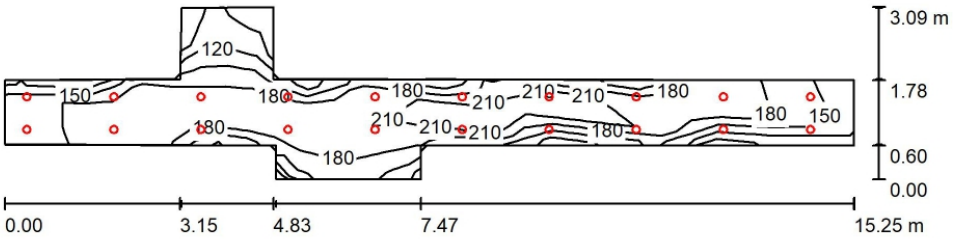
PASSAGE NEAR TOILET AREA / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:110

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	183	83	217	0.456
Floor	20	187	72	218	0.385
Ceiling	70	98	41	225	0.420
Walls (12)	50	172	49	1075	/

Workplane:

Height:	0.000 m
Grid:	31 x 7 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.933, Ceiling / Working Plane: 0.524.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	20	Crompton Greaves Ltd. 02 LCDSPLN-R-12-CDL (1.000)	833	835	12.4
			Total: 16656	Total: 16702	248.0

Specific connected load: 11.39 W/m² = 6.22 W/m²/100 lx (Ground area: 21.76 m²)

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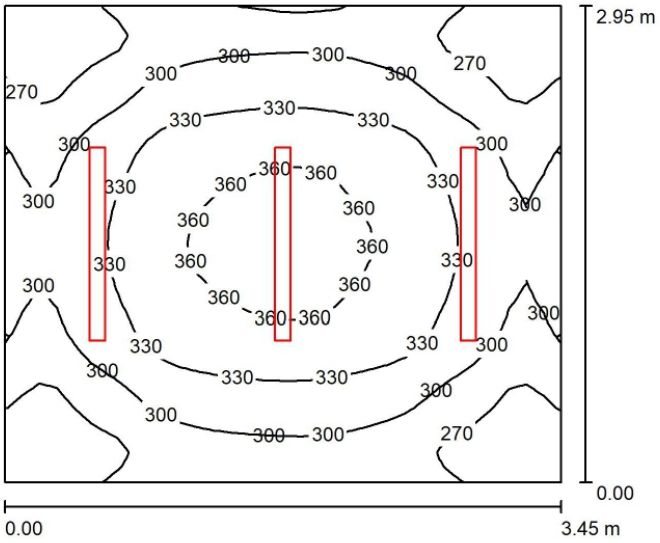
STORE ROOM / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:38

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	310	231	369	0.746
Floor	20	310	230	367	0.742
Ceiling	70	191	105	1124	0.552
Walls (4)	50	283	148	843	/

Workplane:
Height: 0.000 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.909, Ceiling / Working Plane: 0.616.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	Crompton Greaves Ltd. 01 LPFC-36-CDL (1.000)	3568	3571	36.6
			Total: 10705	Total: 10714	109.8

Specific connected load: 10.79 W/m² = 3.48 W/m²/100 lx (Ground area: 10.18 m²)

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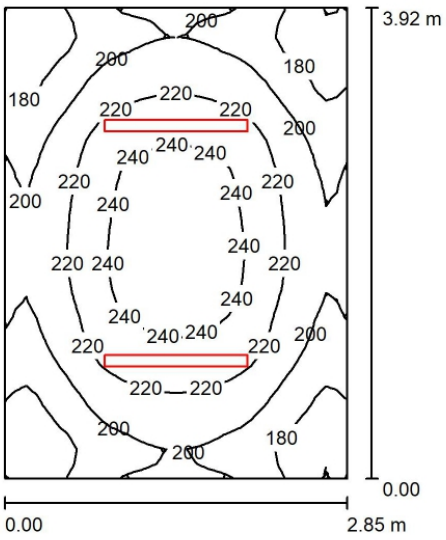
REFUSE STORE ROOM / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:51

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	209	155	249	0.741
Floor	20	209	150	247	0.718
Ceiling	70	119	73	436	0.616
Walls (4)	50	184	97	389	/

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

UGR Lengthways- Across to luminaire axis
Left Wall 18 18
Lower Wall 18 18
(CIE, SHR = 0.25.)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.881, Ceiling / Working Plane: 0.568.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	Crompton Greaves Ltd. 01 LPFC-36-CDL (1.000)	3568	3571	36.6
			Total: 7137	Total: 7143	73.2

Specific connected load: 6.55 W/m² = 3.13 W/m²/100 lx (Ground area: 11.17 m²)

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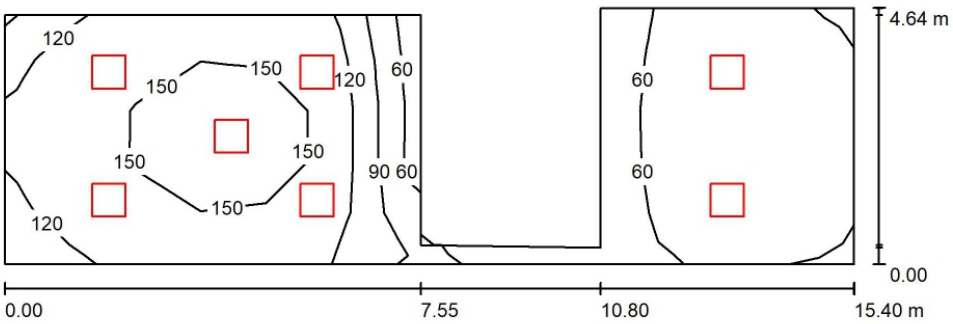
ROOM BELOW ESCALATOR -1 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	54	162	0.484
Floor	20	111	13	162	0.112
Ceiling	70	59	14	98	0.228
Walls (8)	50	98	5.40	401	/

Workplane:

Height:	0.000 m
Grid:	5 x 13 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.885, Ceiling / Working Plane: 0.534.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LCBOR-40-CDL (1.000)	4023	4027	39.7
			Total: 28164	Total: 28188	277.8

Specific connected load: 4.91 W/m² = 4.44 W/m²/100 lx (Ground area: 56.55 m²)

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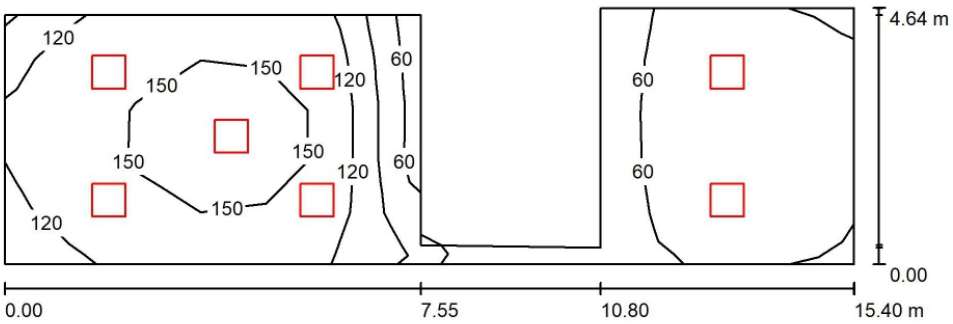
ROOM BELOW ESCALATOR -2 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	53	162	0.483
Floor	20	111	13	162	0.113
Ceiling	70	59	13	98	0.225
Walls (8)	50	98	5.18	401	/

Workplane:

Height:	0.000 m
Grid:	5 x 13 Points
Boundary Zone:	0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.883, Ceiling / Working Plane: 0.533.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LCBOR-40-CDL (1.000)	4023	4027	39.7
			Total: 28164	Total: 28188	277.8

Specific connected load: 4.91 W/m² = 4.44 W/m²/100 lx (Ground area: 56.55 m²)

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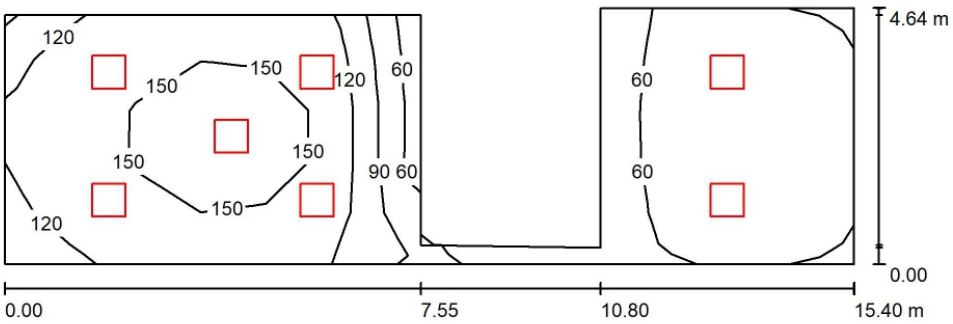
ROOM BELOW ESCALATOR -3 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	54	162	0.485
Floor	20	111	13	162	0.113
Ceiling	70	59	14	98	0.227
Walls (8)	50	98	5.65	402	/

Workplane:
Height: 0.000 m
Grid: 5 x 13 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.885, Ceiling / Working Plane: 0.534.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LCBOR-40-CDL (1.000)	4023	4027	39.7
			Total: 28164	Total: 28188	277.8

Specific connected load: 4.91 W/m² = 4.43 W/m²/100 lx (Ground area: 56.55 m²)

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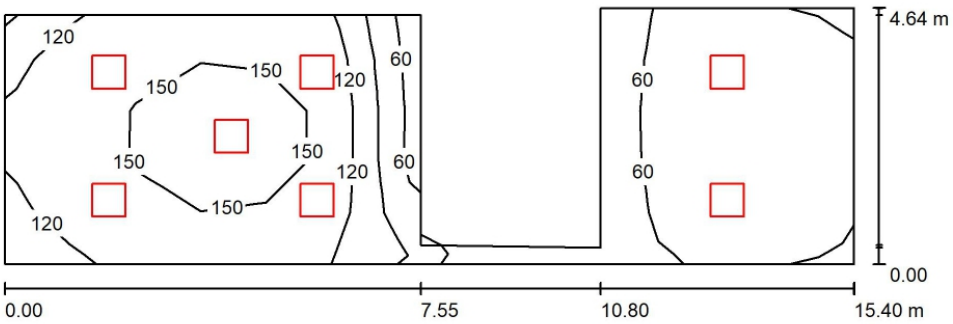
ROOM BELOW ESCALATOR -4 / Summary



Height of Room: 7.000 m, Mounting Height: 7.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:111

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	111	53	162	0.483
Floor	20	111	12	162	0.111
Ceiling	70	59	13	97	0.227
Walls (8)	50	98	4.88	401	/

Workplane:
Height: 0.000 m
Grid: 5 x 13 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.883, Ceiling / Working Plane: 0.533.

Luminaire Parts List

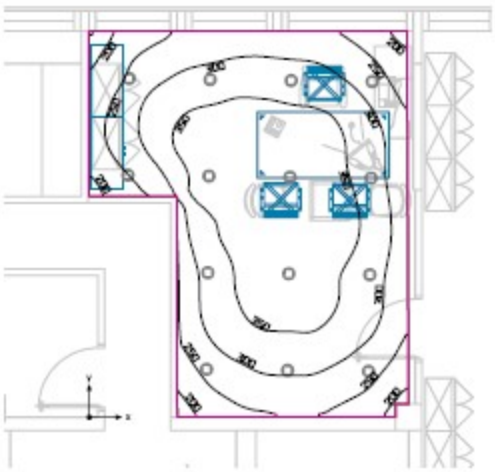
No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	7	Crompton Greaves Ltd. 01 LCBOR-40-CDL (1.000)	4023	4027	39.7
			Total: 28164	Total: 28188	277.8

Specific connected load: 4.91 W/m² = 4.44 W/m²/100 lx (Ground area: 56.55 m²)

Annexure XI
Case Study on Office Building by using Conventional Luminaire

Crompton

Head of Section HS 02



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	312 (≥ 300)	174	399	0.56	0.44

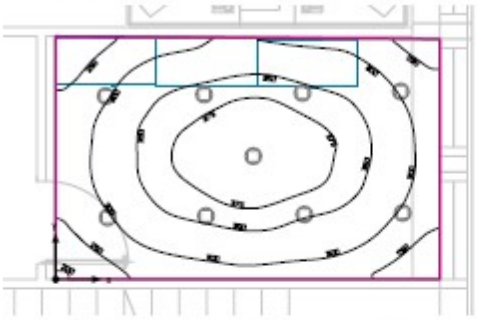
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
14	Crompton Greaves Ltd. - DDLHF213EBGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	15862	476.0	33.3

Lighting power density: 20.00 W/m² = 6.40 W/m²/100 lx (Floor area of room 23.80 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1300 kWh/a of maximum 850 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Existing IT Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	320 (≥ 300)	196	397	0.61	0.49

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
9	Crompton Greaves Ltd. - DOLHFQ13EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	10197	306.0	33.3

Lighting power density: 27.66 W/m² = 8.64 W/m²/100 lx (Floor area of room 11.06 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 840 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

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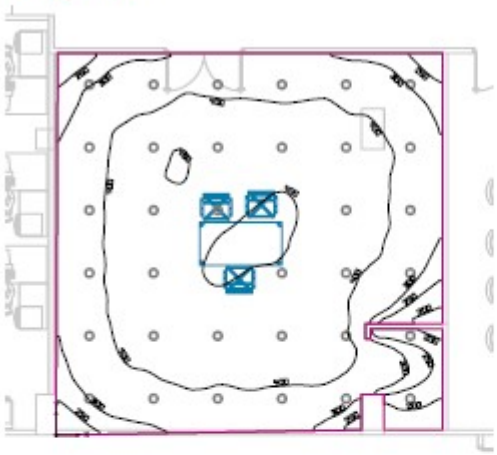
Exixting IT Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	374 (≥ 300)	156	456	0.42	0.34

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
34	Crompton Greaves Ltd. - DDLHR213EB9GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	38522	1156.0	33.3

Lighting power density: 20.43 W/m² = 5.47 W/m²/100 lx (Floor area of room 56.59 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 3200 kWh/a of maximum 2000 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

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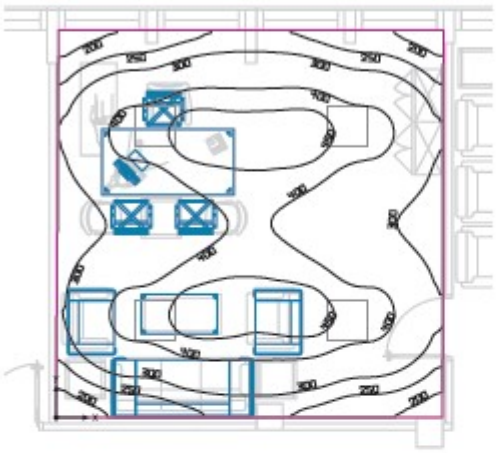
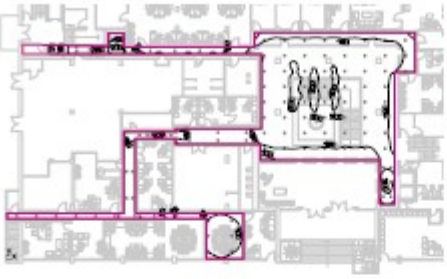
Director's Office



Crompton

Coridoor



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	160 (≥ 150)	6.37	224	0.04	0.03

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
116	Crompton Greaves Ltd. - DDLHP213EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	131428	3944.0	33.3

Lighting power density: 11.15 W/m² = 6.96 W/m²/100 lx (Floor area of room 353.68 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 10850 kWh/a of maximum 12400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

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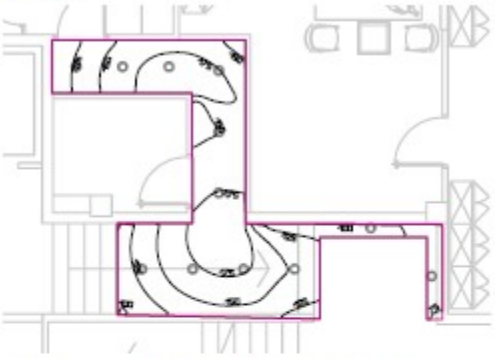
Corridor 1



Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 0.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	151 (≥ 150)	72.4	193	0.48	0.38

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - DDLHF213EBGIS COMMERCIAL LUMINIARE	1133	34.0	33.3
	Total via all luminaires	13596	408.0	33.3

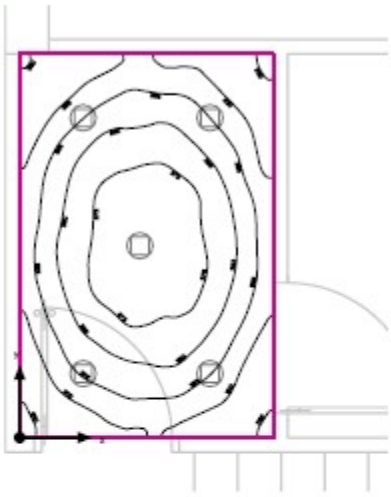
Lighting power density: 29.54 W/m² = 19.53 W/m²/100 lx (Floor area of room: 13.81 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1100 kWh/a of maximum 500 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Electric Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	332 (≥ 300)	236	394	0.71	0.60

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
5	Crompton Greaves Ltd. - DOLHR213EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	5665	170.0	33.3

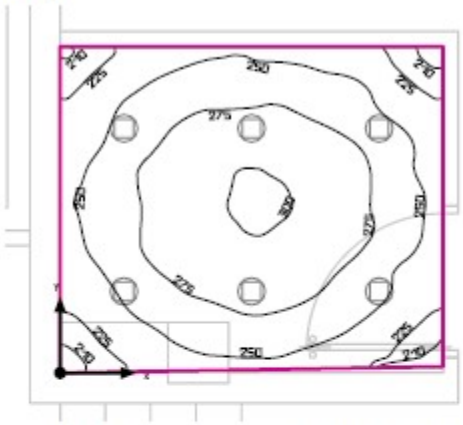
Lighting power density: 36.63 W/m² = 11.04 W/m²/100 lx (Floor area of room 4.64 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 470 kWh/a of maximum 200 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Pantry 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	261 (≥ 250)	203	304	0.78	0.67

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - DDLHP213EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	6798	204.0	33.3

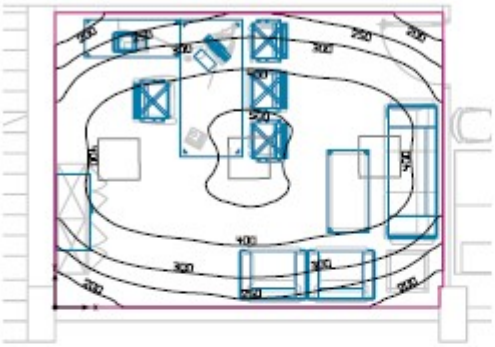
Lighting power density: 37.95 W/m² = 14.53 W/m²/100 lx (Floor area of room 5.38 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 550 kWh/a of maximum 200 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Officer's Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	367 (≥ 300)	152	523	0.41	0.29

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - CRFQ11336EBPS COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	14730	354.0	41.6

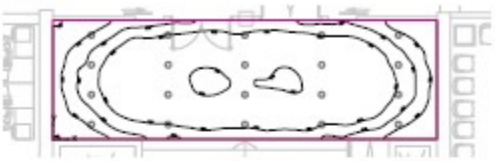
Lighting power density: 14.58 W/m² = 3.97 W/m²/100 lx (Floor area of room 24.28 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 970 kWh/a of maximum 900 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Entrance



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular Illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	251 (≥ 200)	146	307	0.58	0.48

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
20	Crompton Greaves Ltd. - DDLHR213ESIGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	22660	680.0	33.3

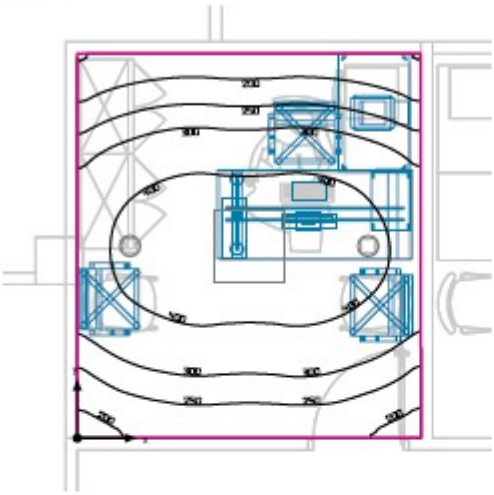
Lighting power density: 17.48 W/m² = 6.97 W/m²/100 lx (Floor area of room 38.91 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1850 kWh/a of maximum 1400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 09



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	329 (≥ 300)	148	489	0.45	0.30

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
2	Crompton Greaves Ltd. - DDLHR213EB/GI/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	7176	186.0	38.6

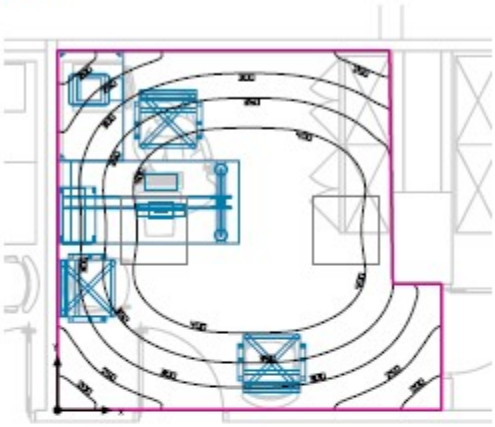
Lighting power density: 19.74 W/m² = 5.99 W/m²/100 lx (Floor area of room 9.42 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 510 kWh/a of maximum 350 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 08



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	350 (≥ 300)	168	449	0.48	0.37

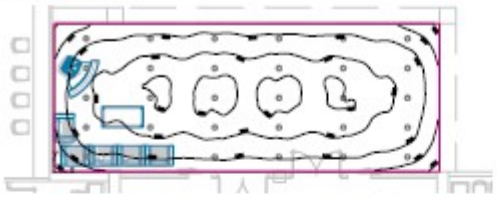
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EBPS COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	9820	236.0	41.6

Lighting power density: 22.84 W/m² = 6.52 W/m²/100 lx (Floor area of room: 10.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Reception Area



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	276 (≥ 250)	137	334	0.50	0.41

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
30	Crompton Greaves Ltd. - DDLHF213EBGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	33990	1020.0	33.3

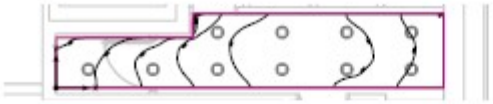
Lighting power density: 14.31 W/m² = 5.18 W/m²/100 lx (Floor area of room 71.27 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 2800 kWh/a of maximum 2500 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Pantry



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	308 (≥ 250)	140	386	0.45	0.36

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
10	Crompton Greaves Ltd. - ODLHFC13EBKGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	11330	340.0	33.3

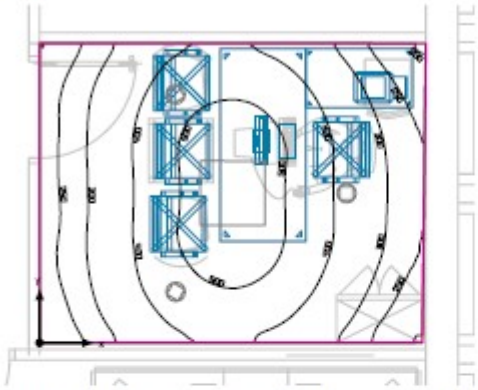
Lighting power density: 59.75 W/m² = 19.39 W/m²/100 lx (Floor area of room 5.69 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 940 kWh/a of maximum 250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 01



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	379 (≥ 300)	196	553	0.52	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Crompton Greaves Ltd. - CRFQ11336EB/PS COMMERCIAL LUMINAIRE	4910	118.0	41.6
3	Crompton Greaves Ltd. - DOLHR213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	8309	220.0	37.8

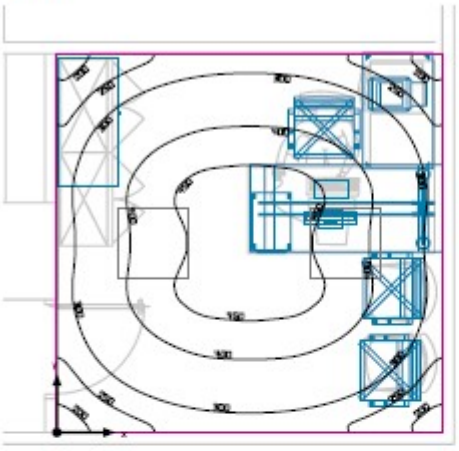
Lighting power density: 21.94 W/m² = 5.79 W/m²/100 lx (Floor area of room: 10.03 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 600 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 07



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	354 (≥ 300)	176	464	0.50	0.38

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	9820	236.0	41.6

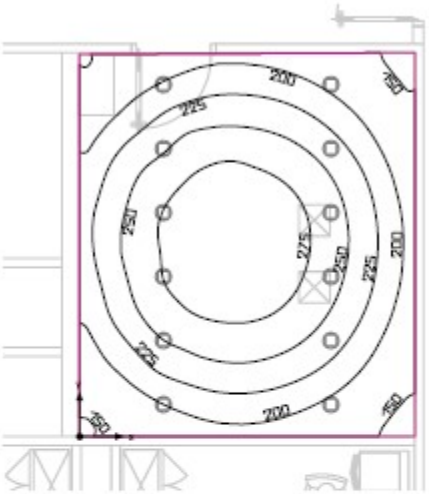
Lighting power density: 21.97 W/m² = 6.20 W/m²/100 lx (Floor area of room 10.74 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Services



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	229 (≥ 200)	133	295	0.58	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - DDLHF213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	13596	408.0	33.3

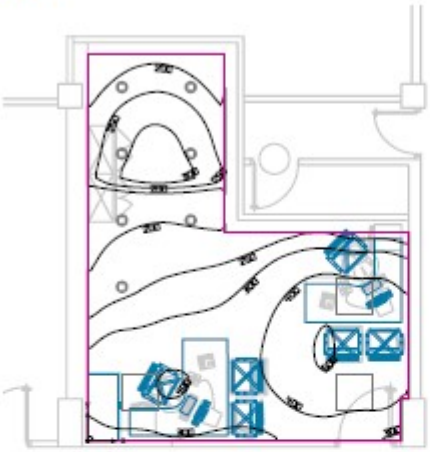
Lighting power density: 25.24 W/m² = 11.03 W/m²/100 lx (Floor area of room 16.16 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1100 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 11



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	319 (≥ 300)	131	505	0.41	0.26

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
7	Crompton Greaves Ltd. - DOLHFQ13EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	22661	592.0	38.3

Lighting power density: 23.37 W/m² = 7.32 W/m²/100 lx (Floor area of room 25.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1650 kWh/a of maximum 900 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Security Check and Exit Lobby

Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	346 (≥ 300)	139	530	0.40	0.26

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
17	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
12	Crompton Greaves Ltd. - DDLHR213EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	97066	2414.0	40.2

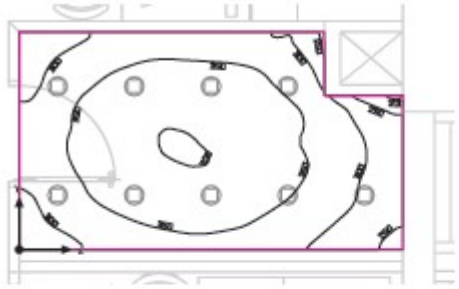
Lighting power density: 13.60 W/m² = 3.93 W/m²/100 lx (Floor area of room 177.46 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 6650 kWh/a of maximum 6250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Photocopier Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	339 (≥ 300)	193	404	0.57	0.48

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
9	Crompton Greaves Ltd. - DDLHR213EB/GIS COMMERCIAL LUMINIARE	1133	34.0	33.3
	Total via all luminaires	10197	306.0	33.3

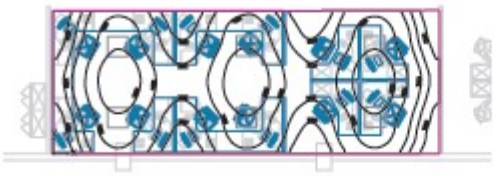
Lighting power density: 44.06 W/m² = 13.00 W/m²/100 lx (Floor area of room 6.95 m²)

The energy consumption quantities refer to the lights planned for the room **without** taking into account light scenes and their dimming levels.
Consumption: 840 kWh/a of maximum 250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 12



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	383 (≥ 300)	148	581	0.40	0.25

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - CRFQ11338EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	29460	708.0	41.6

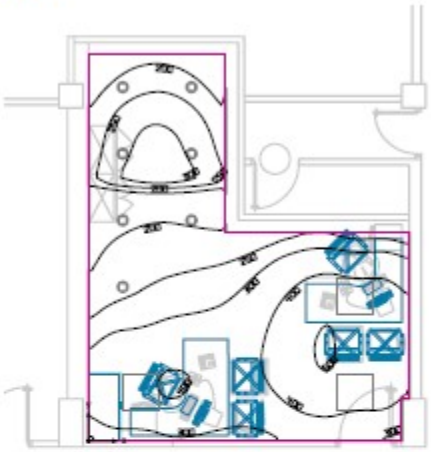
Lighting power density: 14.38 W/m² = 3.96 W/m²/100 lx (Floor area of room 49.24 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1950 kWh/a of maximum 1750 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 11



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	319 (≥ 300)	131	505	0.41	0.26

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
7	Crompton Greaves Ltd. - DDLHF213EB/GI/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	22661	592.0	38.3

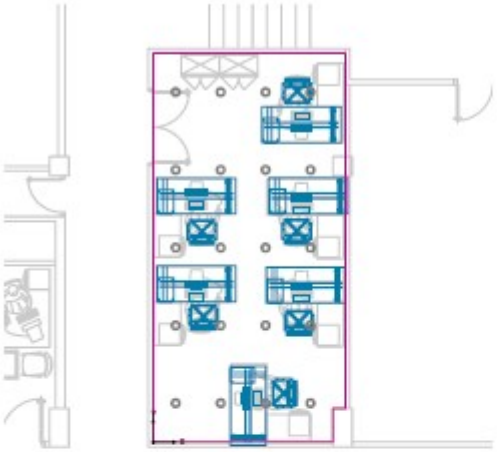
Lighting power density: 23.37 W/m² = 7.32 W/m²/100 lx (Floor area of room 25.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1650 kWh/a of maximum 900 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 10



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.850 m, Wall zone: 0.000 m	367 (≥ 300)	179	483	0.49	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
20	Crompton Greaves Ltd. - DDLHR213EBGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	22660	680.0	33.3

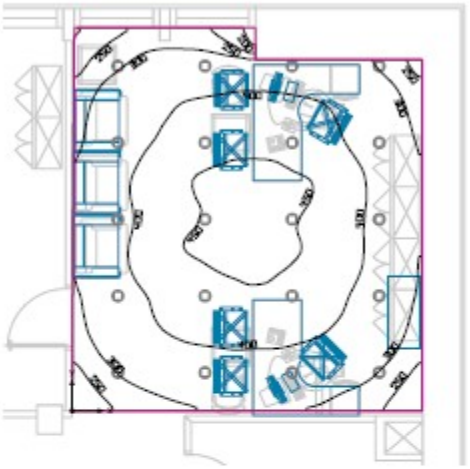
Lighting power density: 21.10 W/m² = 5.76 W/m²/100 lx (Floor area of room 32.22 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1850 kWh/a of maximum 1150 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Secretary SE 01



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	371 (≥ 300)	174	464	0.47	0.38

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
20	Crompton Greaves Ltd. - DDLHR213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	22660	680.0	33.3

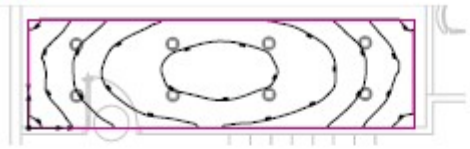
Lighting power density: 21.91 W/m² = 5.90 W/m²/100 lx (Floor area of room 31.04 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1850 kWh/a of maximum 1100 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Pantry 2



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	241 (≥ 200)	164	286	0.68	0.57

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
8	Crompton Greaves Ltd. - DOLHF213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	9064	272.0	33.3

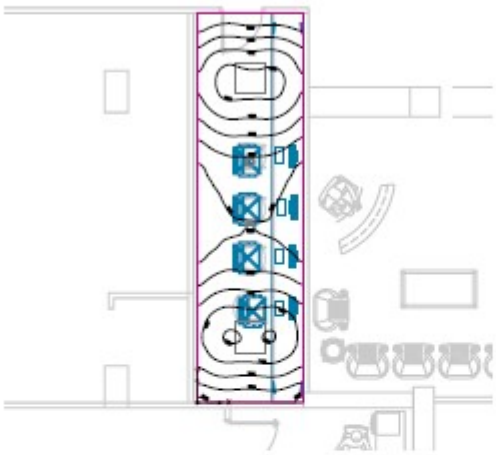
Lighting power density: 31.32 W/m² = 12.98 W/m²/100 lx (Floor area of room 8.69 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 750 kWh/a of maximum 350 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 16



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	338 (≥ 300)	212	468	0.63	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
2	Crompton Greaves Ltd. - DOLHR213EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	12086	304.0	39.8

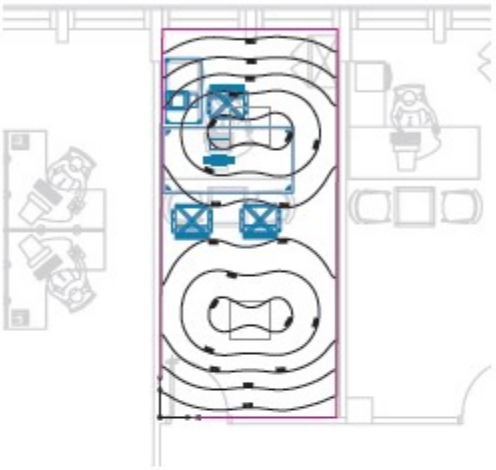
Lighting power density: 20.12 W/m² = 5.95 W/m²/100 lx (Floor area of room 15.11 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 640 kWh/a of maximum 550 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 21



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	311 (≥ 300)	164	414	0.53	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	9820	236.0	41.6

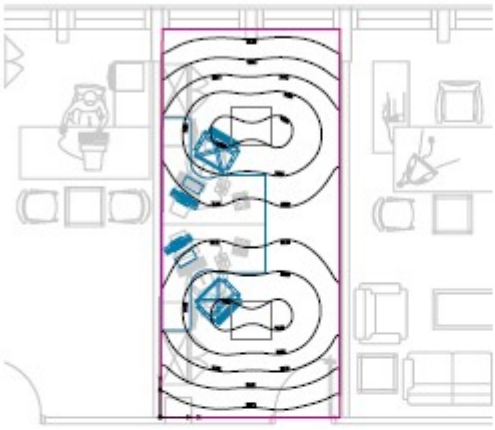
Lighting power density: 14.65 W/m² = 4.71 W/m²/100 lx (Floor area of room 16.11 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 18



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	310 (≥ 300)	163	411	0.53	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EBP5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	9820	236.0	41.6

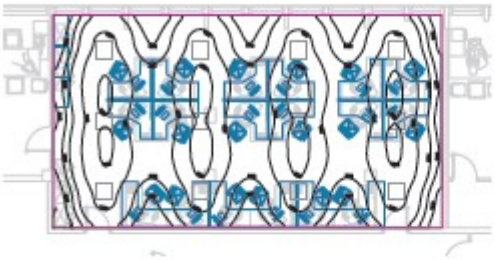
Lighting power density: 14.46 W/m² = 4.67 W/m²/100 lx (Floor area of room 16.32 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 22



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	386 (≥ 300)	134	529	0.37	0.25

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - CRFQ11338EB/PS COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	58920	1416.0	41.6

Lighting power density: 12.89 W/m² = 3.52 W/m²/100 lx (Floor area of room: 109.85 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 3900 kWh/a of maximum 3850 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 19

Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	310 (≥ 300)	160	412	0.52	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CFFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	9820	236.0	41.6

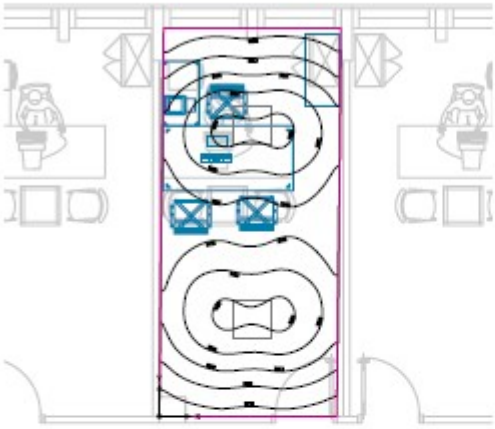
Lighting power density: 14.45 W/m² = 4.67 W/m²/100 lx (Floor area of room 16.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 20



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	310 (≥ 300)	162	412	0.52	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	9820	236.0	41.6

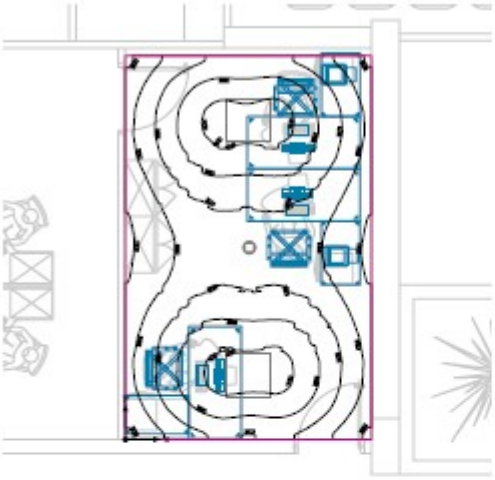
Lighting power density: 14.53 W/m² = 4.69 W/m²/100 lx (Floor area of room 16.24 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 800 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 15



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	306 (≥ 300)	191	420	0.62	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Crompton Greaves Ltd. - CRFQ11336EB/PS COMMERCIAL LUMINAIRE	4910	118.0	41.6
1	Crompton Greaves Ltd. - DDLHR213EB/G/S COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	10953	270.0	40.6

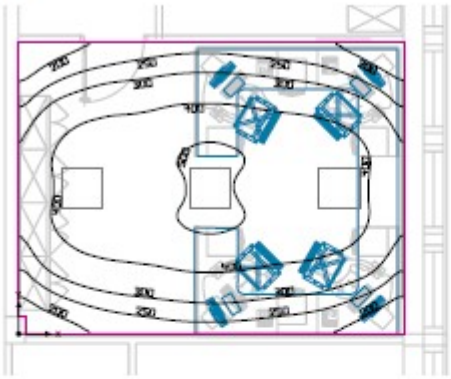
Lighting power density: 14.15 W/m² = 4.63 W/m²/100 lx (Floor area of room: 19.09 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 740 kWh/a of maximum 700 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 17



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	359 (≥ 300)	144	520	0.40	0.28

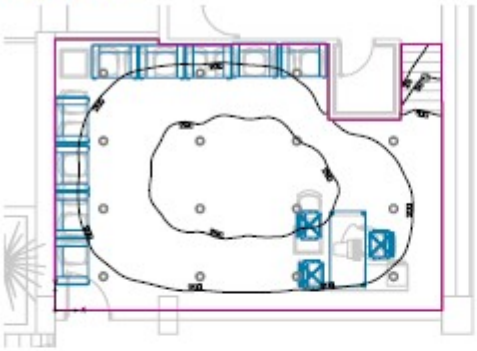
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - CRFQ11336EB/P5 COMMERCIAL LUMINAIRE	4910	118.0	41.6
	Total via all luminaires	14730	354.0	41.6

Lighting power density: 14.11 W/m² = 3.93 W/m²/100 lx (Floor area of room 25.09 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 970 kWh/a of maximum 900 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Visitor's Lounge



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	209 (≥ 200)	15.2	264	0.07	0.06

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
16	Crompton Greaves Ltd. - ODLHF213EBSGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	18128	544.0	33.3

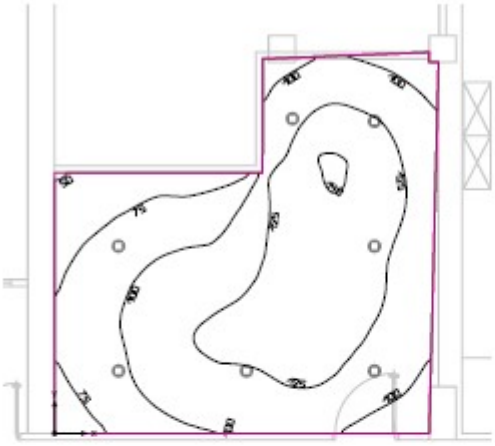
Lighting power density: 12.34 W/m² = 5.89 W/m²/100 lx (Floor area of room 44.09 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1500 kWh/a of maximum 1550 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Store



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	110 (≥ 100)	48.7	141	0.44	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
7	Crompton Greaves Ltd. - DOLHFI213EBIGIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	7931	238.0	33.3

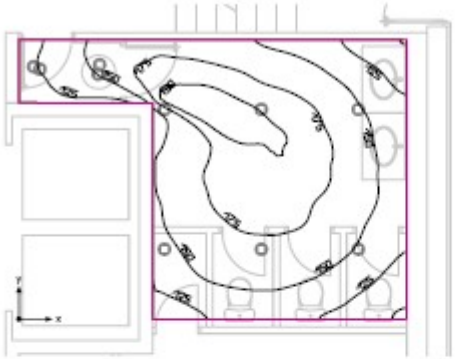
Lighting power density: 8.95 W/m² = 8.15 W/m²/100 lx (Floor area of room 26.59 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 650 kWh/a of maximum 950 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet 3



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular Illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	157 (≥ 150)	95.8	198	0.61	0.48

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
10	Crompton Greaves Ltd. - DDLHR213EB/GIS COMMERCIAL LUMINIARE	1133	34.0	33.3
	Total via all luminaires	11330	340.0	33.3

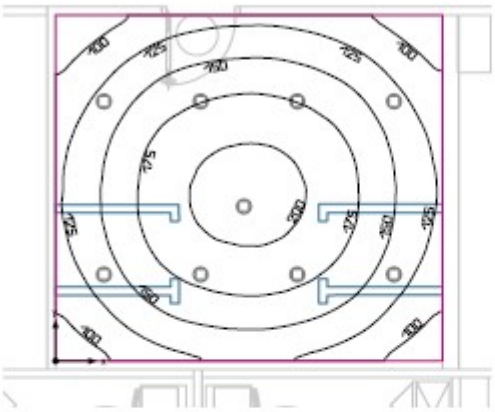
Lighting power density: 19.12 W/m² = 12.20 W/m²/100 lx (Floor area of room 17.79 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 940 kWh/a of maximum 650 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	151 (≥ 150)	75.9	208	0.50	0.36

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
9	Crompton Greaves Ltd. - DOLHF213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	10197	306.0	33.3

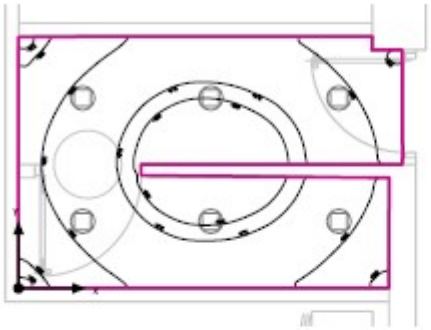
Lighting power density: 15.49 W/m² = 10.28 W/m²/100 lx (Floor area of room 19.75 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 840 kWh/a of maximum 700 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet 2



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	161 (≥ 150)	123	189	0.76	0.65

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - DDLHF213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	6798	204.0	33.3

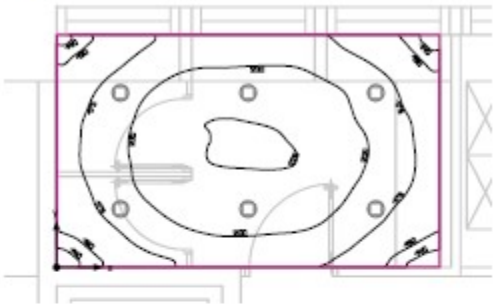
Lighting power density: 40.37 W/m² = 25.04 W/m²/100 lx (Floor area of room 5.05 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 550 kWh/a of maximum 200 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.70

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	190 (≥ 150)	133	230	0.70	0.58

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - DDLHR213EB/GIS COMMERCIAL LUMINAIRE	1133	34.0	33.3
	Total via all luminaires	6798	204.0	33.3

Lighting power density: 19.61 W/m² = 10.30 W/m²/100 lx (Floor area of room 10.40 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 560 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

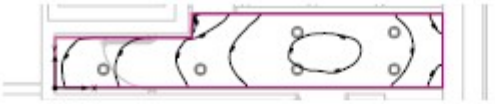
Annexure XII
Case Study on Office Building by using LED Luminaire

TCS Sabina Park 08-Jan-19

Crompton

Site 1 / Building 1 / Storey 2 / Pantry / Room summary

Pantry



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	282 (≥ 250)	134	361	0.48	0.37

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	8040	74.4	108.1

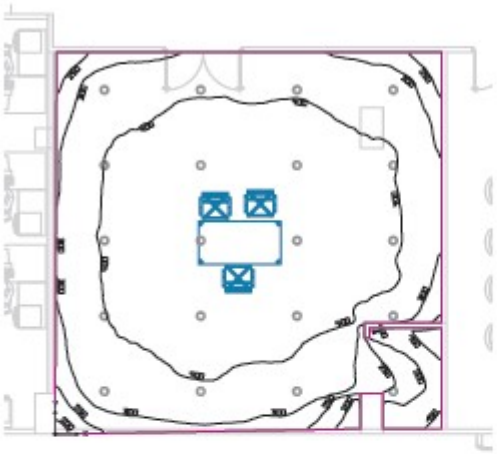
Lighting power density: 13.08 W/m² = 4.64 W/m²/100 lx (Floor area of room 5.69 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 200 kWh/a of maximum 250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Exixting IT Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	376 (≥ 300)	155	473	0.41	0.33

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
20	Crompton Greaves Ltd. - 03 LCDE-15-CDL	1625	15.9	101.9
	Total via all luminaires	32500	318.0	102.2

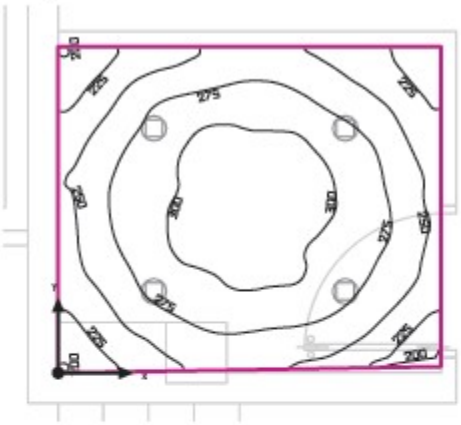
Lighting power density: 5.62 W/m² = 1.49 W/m²/100 lx (Floor area of room 56.59 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 880 kWh/a of maximum 2000 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Pantry 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	270 (≥ 250)	199	319	0.74	0.62

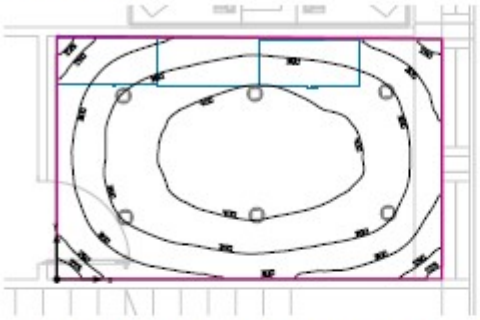
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	5360	49.6	108.1

Lighting power density: 9.23 W/m² = 3.42 W/m²/100 lx (Floor area of room 5.38 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 140 kWh/a of maximum 200 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Existing IT Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	353 (≥ 300)	201	433	0.57	0.46

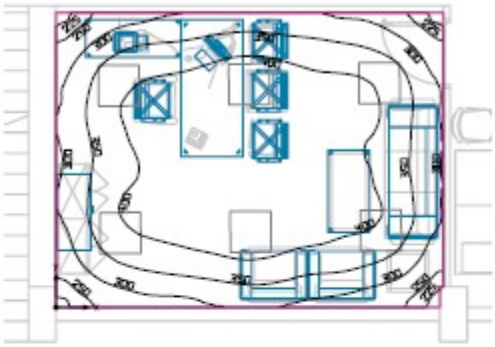
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	8040	74.4	108.1

Lighting power density: 6.72 W/m² = 1.91 W/m²/100 lx (Floor area of room 11.06 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 200 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Officer's Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	368 (≥ 300)	210	447	0.57	0.47

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	15480	148.8	104.0

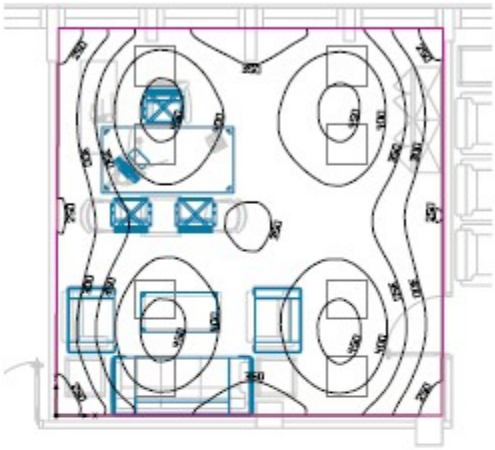
Lighting power density: 6.13 W/m² = 1.66 W/m²/100 lx (Floor area of room 24.28 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 410 kWh/a of maximum 900 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Director's Office



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	368 (≥ 300)	217	465	0.59	0.47

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
8	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	20640	198.4	104.0

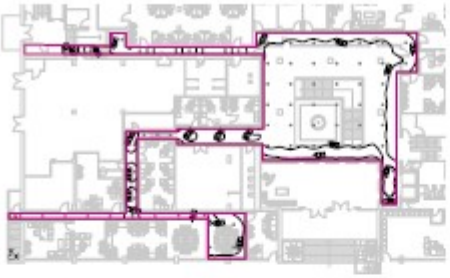
Lighting power density: 5.79 W/m² = 1.57 W/m²/100 lx (Floor area of room 34.28 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 540 kWh/a of maximum 1250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Coridoor



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	157 (≥ 150)	3.86	232	0.02	0.02

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
80	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	107200	992.0	108.1

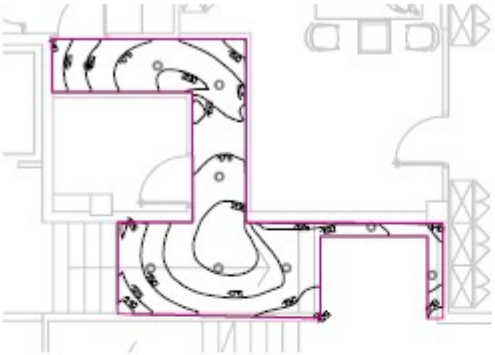
Lighting power density: 2.80 W/m² = 1.78 W/m²/100 lx (Floor area of room 353.68 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 2700 kWh/a of maximum 12400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Corridor 1



Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 0.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	169 (≥ 150)	101	212	0.60	0.48

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
9	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	12060	111.6	108.1

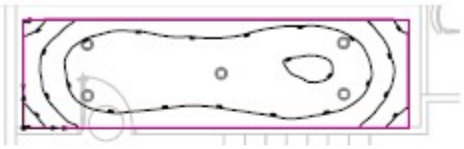
Lighting power density: 8.08 W/m² = 4.79 W/m²/100 lx (Floor area of room 13.81 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 310 kWh/a of maximum 500 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Pantry 2



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	224 (≥ 200)	159	253	0.71	0.63

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
5	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	6700	62.0	108.1

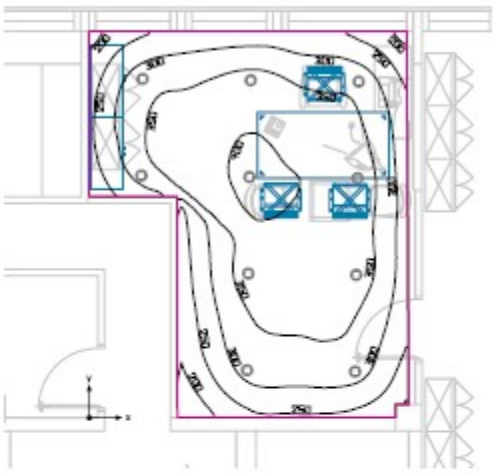
Lighting power density: 7.14 W/m² = 3.19 W/m²/100 lx (Floor area of room 8.69 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 170 kWh/a of maximum 350 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Head of Section HS 02



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	327 (≥ 300)	156	412	0.48	0.38

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
10	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	13400	124.0	108.1

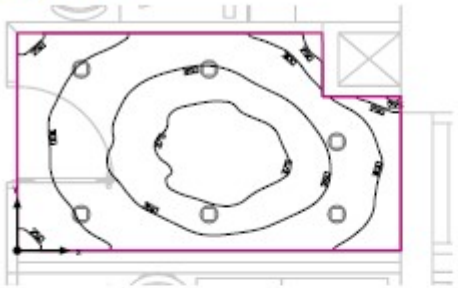
Lighting power density: 5.21 W/m² = 1.60 W/m²/100 lx (Floor area of room 23.80 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 340 kWh/a of maximum 850 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Photocopier Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	330 (≥ 300)	221	392	0.67	0.56

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	8040	74.4	108.1

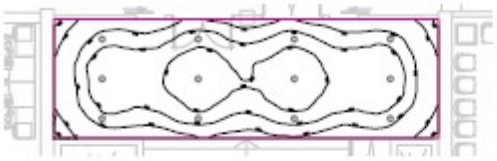
Lighting power density: 10.71 W/m² = 3.24 W/m²/100 lx (Floor area of room 6.95 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 200 kWh/a of maximum 250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Entrance



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	219 (≥ 200)	120	273	0.55	0.44

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	16080	148.8	108.1

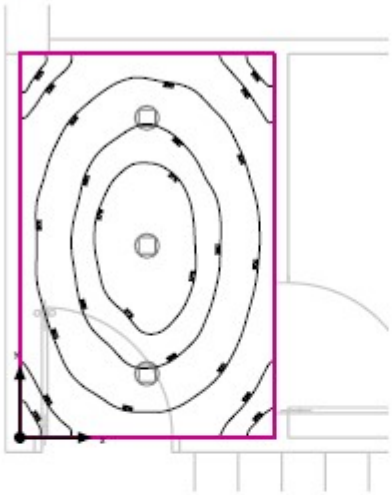
Lighting power density: 3.82 W/m² = 1.74 W/m²/100 lx (Floor area of room 38.91 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 410 kWh/a of maximum 1400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Electric Room



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	317 (≥ 300)	206	400	0.65	0.52

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	4020	37.2	108.1

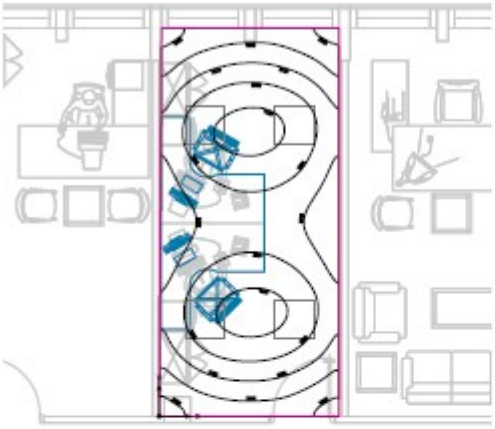
Lighting power density: 8.02 W/m² = 2.53 W/m²/100 lx (Floor area of room 4.64 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 100 kWh/a of maximum 200 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 18



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	321 (≥ 300)	179	417	0.56	0.43

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 01 LCTLR9-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	10320	99.2	104.0

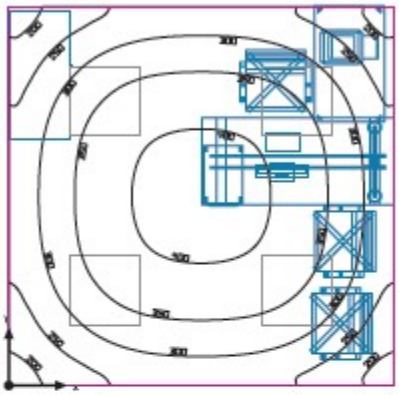
Lighting power density: 6.08 W/m² = 1.89 W/m²/100 lx (Floor area of room 16.32 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 270 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

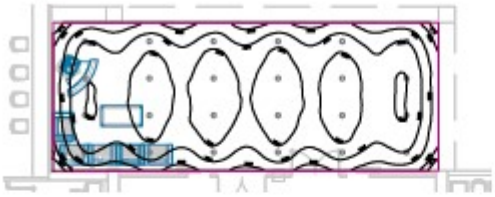
Crompton

ST 07


300
300
300

Crompton

Reception Area



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	316 (≥ 250)	154	394	0.49	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
24	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	32160	297.6	108.1

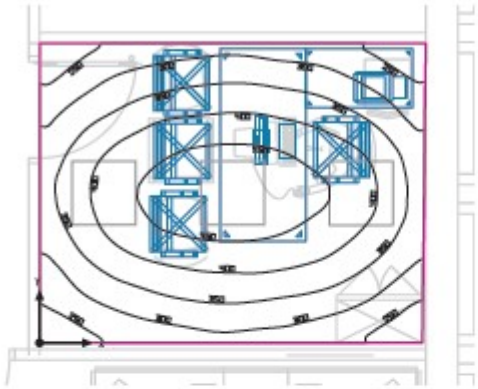
Lighting power density: 4.18 W/m² = 1.32 W/m²/100 lx (Floor area of room 71.27 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 820 kWh/a of maximum 2500 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 01



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	380 (≥ 300)	205	483	0.57	0.42

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	7740	74.4	104.0

Lighting power density: 7.42 W/m² = 2.06 W/m²/100 lx (Floor area of room 10.03 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 200 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 11

Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.85

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	389 (≥ 300)	160	508	0.41	0.31

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
7	Crompton Greaves Ltd. - 01 LCSRR-4-CDL	211	3.5	60.3
8	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	22117	222.9	99.2

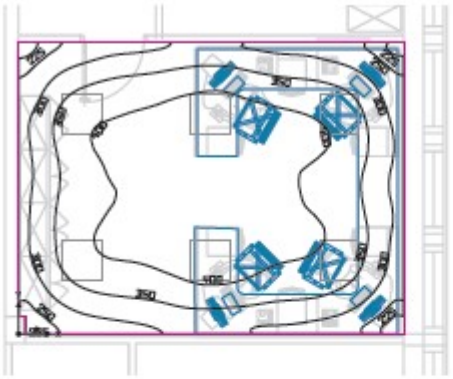
Lighting power density: 8.80 W/m² = 2.26 W/m²/100 lx (Floor area of room 25.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 610 kWh/a of maximum 900 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 17


350
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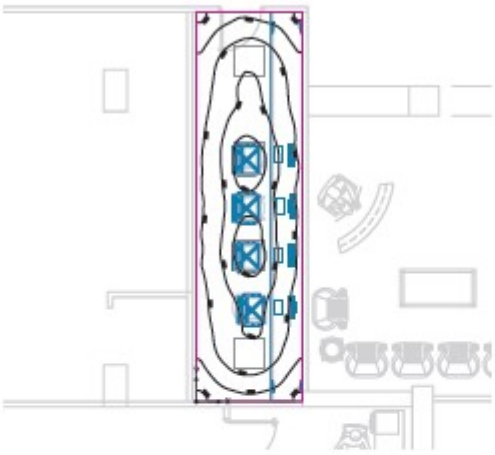
Crompton

ST 16



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	317 (≥ 300)	185	387	0.58	0.48

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	10320	99.2	104.0

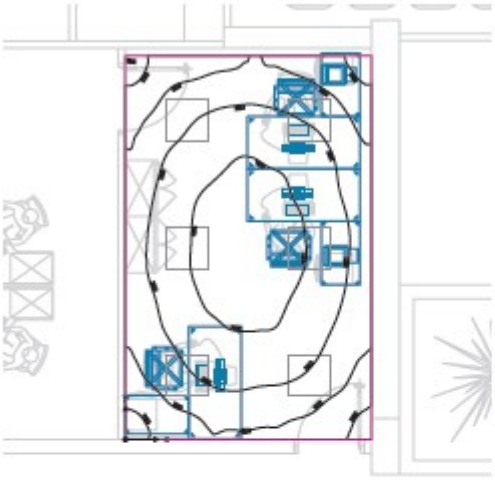
Lighting power density: 6.56 W/m² = 2.07 W/m²/100 lx (Floor area of room 15.11 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 270 kWh/a of maximum 550 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 15



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: **0.800** m, Wall zone: 0.000 m	347 (≥ 300)	225	423	0.65	0.53

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	15480	148.8	104.0

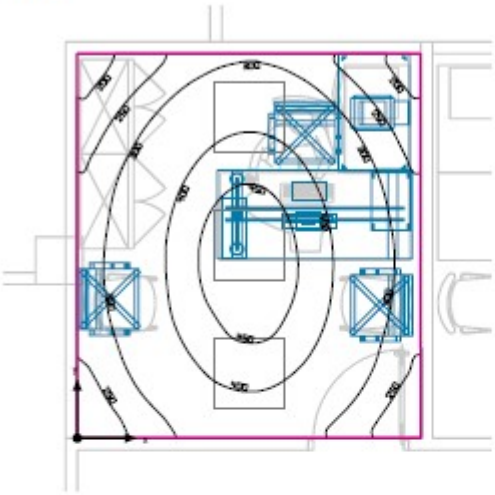
Lighting power density: 7.80 W/m² = 2.24 W/m²/100 lx (Floor area of room 19.09 m²)

The energy consumption quantities refer to the lights planned for the room **without** taking into account light scenes and their dimming levels.
Consumption: 410 kWh/a of maximum 700 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 09



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	342 (≥ 300)	174	482	0.51	0.36

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Crompton Greaves Ltd. - 01 LCTLR9-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	7740	74.4	104.0

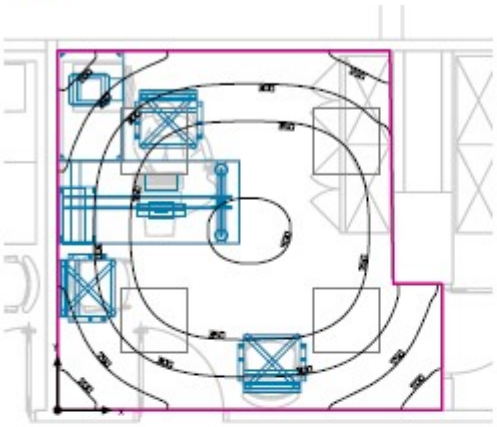
Lighting power density: 7.90 W/m² = 2.31 W/m²/100 lx (Floor area of room 9.42 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 200 kWh/a of maximum 350 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 08



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	318 (≥ 300)	171	403	0.54	0.42

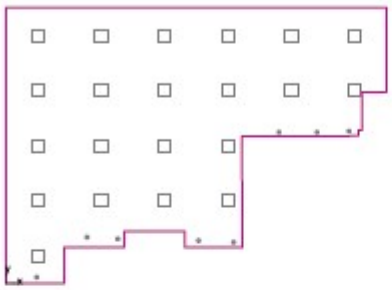
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - D1 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	10320	99.2	104.0

Lighting power density: 9.60 W/m² = 3.02 W/m²/100 lx (Floor area of room 10.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 270 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Security Check and Exit Lobby



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	335 (≥ 300)	144	473	0.43	0.30

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
21	Crompton Greaves Ltd. - 01 LCTLR9-36-FO-CDL	3525	34.2	103.1
8	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	84745	817.4	103.7

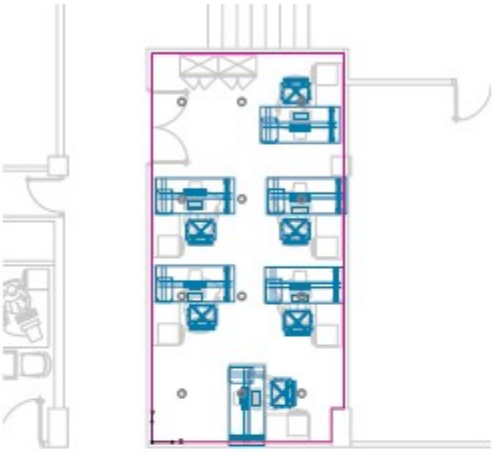
Lighting power density: 4.61 W/m² = 1.37 W/m²/100 lx (Floor area of room 177.46 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 2250 kWh/a of maximum 6250 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 10



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular Illuminance (adaptive) [lx] Height: 0.850 m, Wall zone: 0.000 m	369 (≥ 300)	183	463	0.50	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - 03 LCDE-15-CDL	1625	15.9	101.9
	Total via all luminaires	19500	190.8	102.2

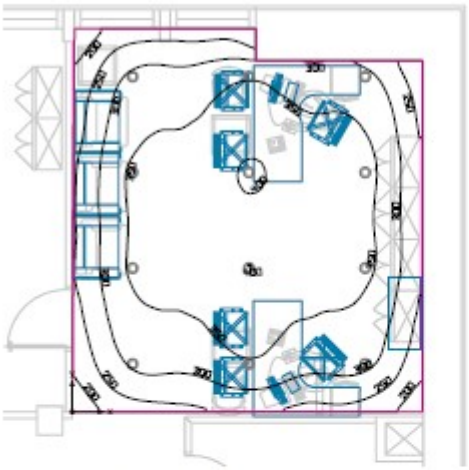
Lighting power density: 5.92 W/m² = 1.61 W/m²/100 lx (Floor area of room 32.22 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 530 kWh/a of maximum 1150 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Secretary SE 01



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	325 (≥ 300)	163	404	0.50	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	16080	148.8	108.1

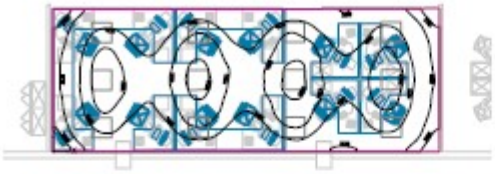
Lighting power density: 4.79 W/m² = 1.48 W/m²/100 lx (Floor area of room 31.04 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 410 kWh/a of maximum 1100 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 12



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	396 (≥ 300)	208	516	0.53	0.40

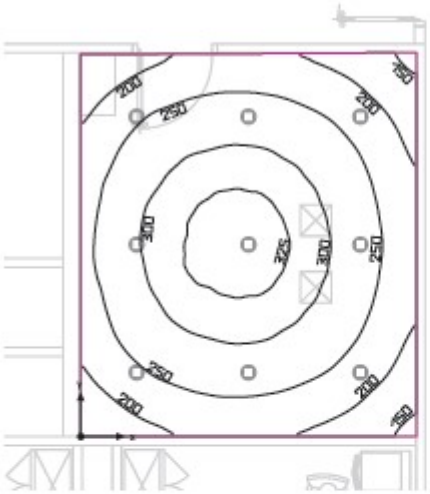
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - 01 LCTL/RI-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	30960	297.6	104.0

Lighting power density: 6.04 W/m² = 1.52 W/m²/100 lx (Floor area of room 49.24 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 820 kWh/a of maximum 1750 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Services



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	258 (≥ 200)	137	338	0.53	0.41

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
9	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	12060	111.6	108.1

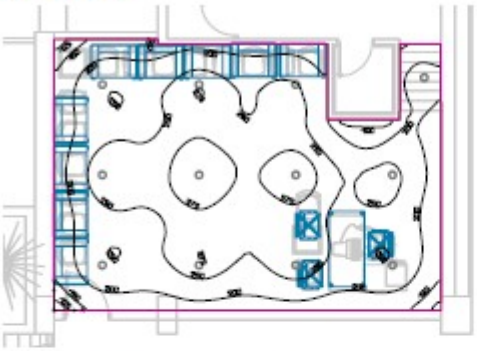
Lighting power density: 6.90 W/m² = 2.68 W/m²/100 lx (Floor area of room 16.16 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 310 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Visitor's Lounge



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	232 (≥ 200)	116	299	0.50	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
12	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	16080	148.8	108.1

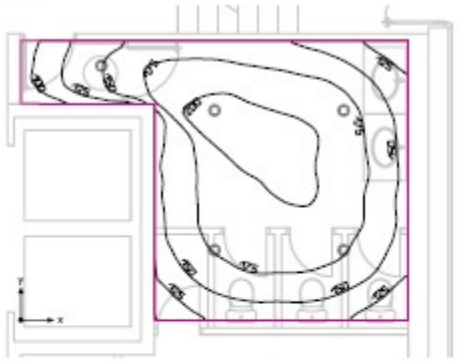
Lighting power density: 3.37 W/m² = 1.46 W/m²/100 lx (Floor area of room 44.09 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 410 kWh/a of maximum 1550 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet 3



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.85

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	157 (≥ 150)	80.4	210	0.48	0.38

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
5	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	6700	62.0	108.1

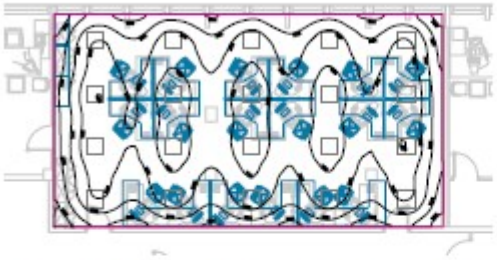
Lighting power density: 3.49 W/m² = 2.09 W/m²/100 lx (Floor area of room 17.79 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 170 kWh/a of maximum 650 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 22



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	344 (≥ 300)	162	436	0.47	0.37

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
20	Crompton Greaves Ltd. - 01 LCTL/RN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	51600	496.0	104.0

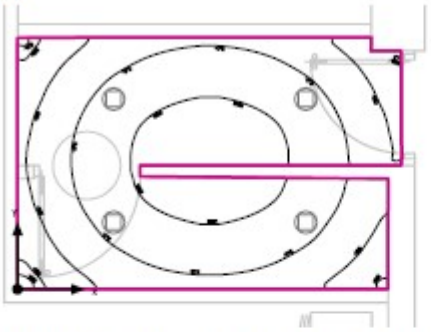
Lighting power density: 4.52 W/m² = 1.31 W/m²/100 lx (Floor area of room 109.85 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 1350 kWh/a of maximum 3850 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet 2



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	175 (≥ 150)	121	213	0.69	0.57

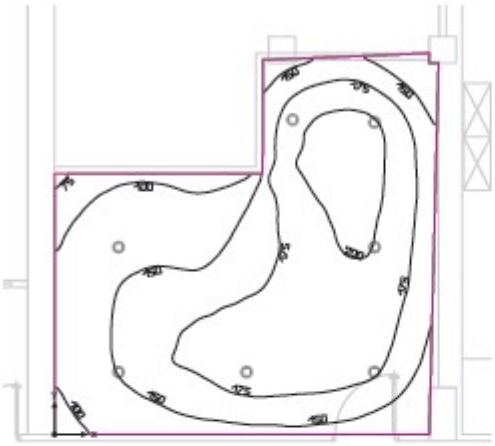
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	5360	49.6	108.1

Lighting power density: 9.82 W/m² = 5.59 W/m²/100 lx (Floor area of room 5.05 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 140 kWh/a of maximum 200 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Store



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	161 (≥ 100)	71.4	215	0.44	0.33

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
7	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	9380	86.8	108.1

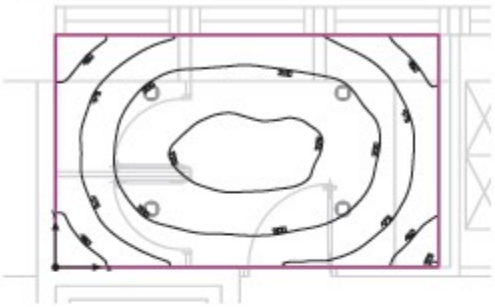
Lighting power density: 3.26 W/m² = 2.02 W/m²/100 lx (Floor area of room 26.59 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 240 kWh/a of maximum 950 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	192 (≥ 150)	124	231	0.65	0.54

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	5360	49.6	108.1

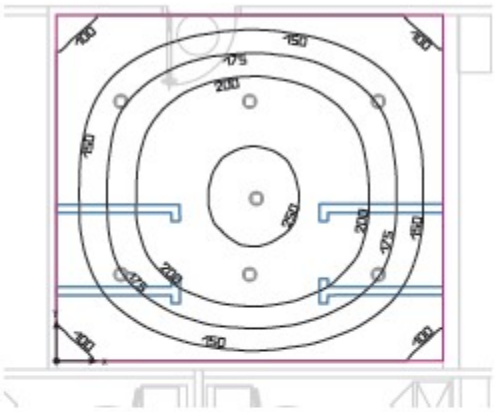
Lighting power density: 4.77 W/m² = 2.48 W/m²/100 lx (Floor area of room 10.40 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 140 kWh/a of maximum 400 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

Toilet



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.000 m, Wall zone: 0.000 m	178 (≥ 150)	82.4	263	0.46	0.31

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
7	Crompton Greaves Ltd. - 02 LCDE-12-CDL	1340	12.4	108.2
	Total via all luminaires	9380	86.8	108.1

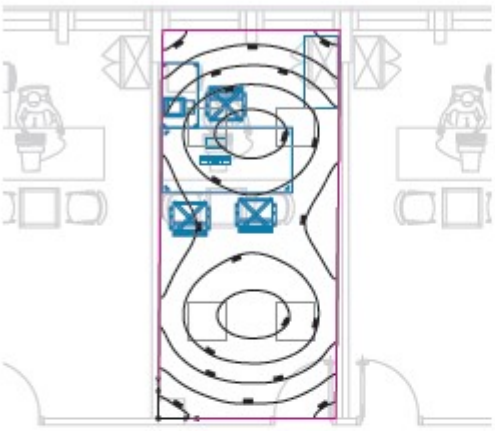
Lighting power density: 4.40 W/m² = 2.47 W/m²/100 lx (Floor area of room 19.75 m²)

The energy consumption quantities refer to the lights planned for the room **without** taking into account light scenes and their dimming levels.
Consumption: 240 kWh/a of maximum 700 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 20



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	321 (≥ 300)	177	417	0.55	0.42

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	10320	99.2	104.0

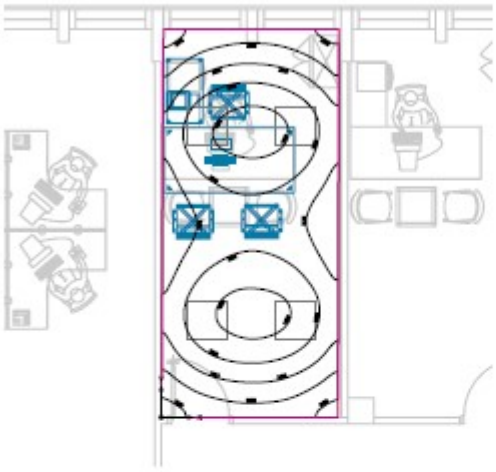
Lighting power density: 6.11 W/m² = 1.90 W/m²/100 lx (Floor area of room 16.24 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 270 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Crompton

ST 21



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	323 (≥ 300)	179	420	0.55	0.43

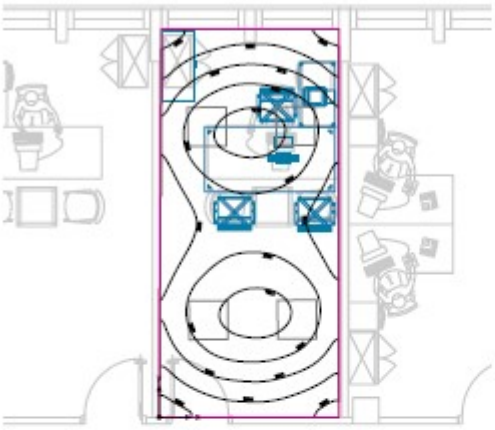
#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	10320	99.2	104.0

Lighting power density: 6.16 W/m² = 1.91 W/m²/100 lx (Floor area of room 16.11 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 270 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

ST 19



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Light loss factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	321 (≥ 300)	176	418	0.55	0.42

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Crompton Greaves Ltd. - 01 LCTLRN-24-FO-CDL	2580	24.8	104.3
	Total via all luminaires	10320	99.2	104.0

Lighting power density: 6.07 W/m² = 1.89 W/m²/100 lx (Floor area of room 16.33 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 270 kWh/a of maximum 600 kWh/a

The results were calculated without consideration of objects and furniture. No results were determined on their surfaces.

Annexure XIII
Installation Pictures

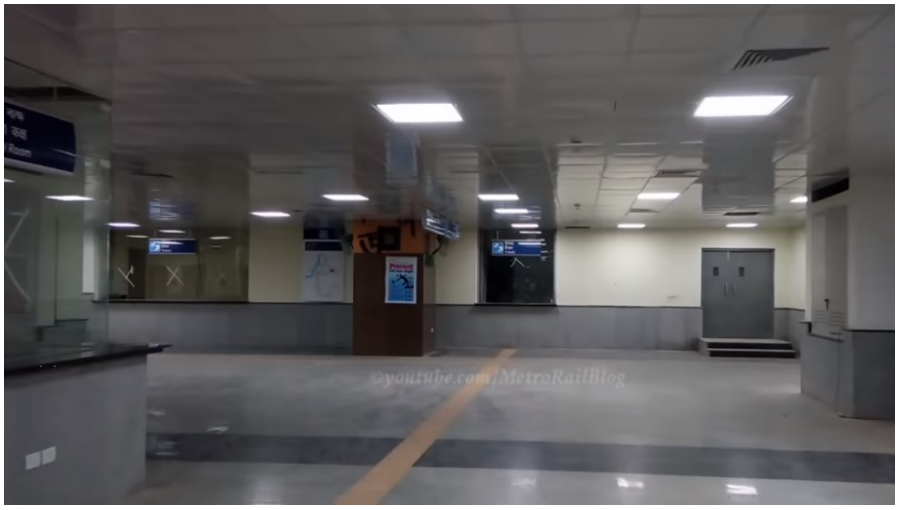
Electrification of Muchipara to Durgapur Barrage Road, Durgapur

NTPC Nabinagar Thermal Power Plant

City Centre Metro Unpaid Area

City Centre Metro Platform Area

City Centre Metro Unpaid Area 4.3 M



City Centre Metro Ticket and Enquiry Counter

City Centre Metro Exit Area

Annexure XII
Internship Details

Company Name: Crompton Greaves Consumer Electricals Limited
Branch: Kolkata (Head Office.)
Duration: 10 months (1st June 2017 to 31st March 2018)
Reporting Head: Mr. Pinaki Chowdhury, Sr. Manager- Business Development

Work Summary:

- Worked as Business Development Trainee in Kolkata Branch.
- The major Task was to demand generate by active engagement with specifiers segment Consultants, Architects, Government, Industry and Commercial Segment.
- Brand quality enhancement through seminars, workshops, presentations on new trends/ products to customers/ specifiers.
- Technical Support for projects to Sales Team and Provide high quality sales leads to sales team early in sales process on new projects/expansions/tenders.
- Furnished designs in software for various Indoor and Outdoor areas using LED, CFL, FTL, MHL, HPSV following IS 3646, IS 6665 and IS 1944 guidelines.
- Prepared Bill of Quantity (BOQ), Load calculation, Lux report, Luminaire Placement Layout for each area, Payback Calculation and Return of Investment (ROI) chart for LED vs. Conventional Fixtures as per the requirement.
- Conducted pre-installation and post-installation Lux Audit.

Design Domain:

1. Metro Railway
2. Indoor Sports Lighting
3. Industry Sheds
4. Streets, Highways and Flyover.
5. Hospital and Academic Building
6. Government offices
7. Indoor and Outdoor Car parking
8. Thermal Power Plant Lighting
9. Oil Refinery Lighting
10. Façade Lighting
11. Auditorium Lighting
12. Architechtural Landscape Lighting
13. High mast Lighting