ENERGY SAVING LIGHTING DESIGN FOR RETAIL SPACE

A Thesis Submitted Towards Partial Fulfilment of the Requirements for the Degree Of

MASTER OF ENGINEERING
IN
ILLUMINATION ENGINEERING

Submitted By

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CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a creditable study in the area of Illumination Engineering, carried out and presented by TANMAY KULOVI **(**Exam roll no.- M4ILN22007) in a manner satisfactory warrant its acceptance as a pre-requisite to the degree for which it has been submitted. It is notified to be understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn there in but approve the thesis only for purpose for which it has been submitted.

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DECLARATION OF ORIGINALITY AND OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of the thesis for the degree of **Master of Engineering in Illumination Engineering** studies during academic session 2020-22.

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

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

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ABSTRACT

The study of lighting design has important implication for consumer behavior and is an important aspect of consideration for the retail sector. It is important to understand perception of lighting design for retailers to understand how to use lighting as a benefit to provide consumers with a desirable shopping experience. This thesis insight the effect of lighting on product perception, provide a solution towards energy efficient lighting. For a new construction type retail space by analyzing the energy conservation to get better lighting solution without deviating the interior lighting design standard (IS-3646 part-2, 1992). All simulation are running by using lighting design software DIALUX EVO 10.1 & AUTOCAD electrical.[1]

The aim of thesis is lighting design retail shop with both conventional (CFL) and LED luminaire, comparison both design by installation cost as well as operating cost in two years, then draw most energy efficient retail lighting design with maintain all important retail lighting standard which provide by NATIONAL LIGHTING CODE-2010, IES, ECBC-2017, CIBSE. IS-3646 part 2,1992.

The result suggest that lighting design could affect price and quality perception with reference to store image and store atmosphere.

This study suggest that few particular lighting characteristics could be responsible for difference in product perception and impulse buying capacity.

LIST OF CONTENT

CHAPTER 1 INTRODUCTON

1.1 MOTIVATION

There is no doubt that energy efficiency is now an essential consideration for all lighting professional. To light up a lamp in any commercial place or residential area, electricity is necessary which is generated by burning coal or nuclear fuel or others source like hydroelectric, renewable source. Burning fossil fuels causes greenhouse gas (carbon di oxide) emission, which lead to climate change that could have dramatic environmental implication affecting the planet.

However, there is the substantial increase in energy cost particularly through the increase in the cost of oil and coal. It is estimated that electric lighting consume about 20% of the total electric load[1]. Reduce electric lighting consumption is one of the main responsibility of designer. Policy makers in countries are tackling this topic, they are looking at ways to help transform their markets to find cost-effective energy saving solution.

Lighting technology is changed over the past few years, lower efficacy incandescent lamp (15-20 lumen/watt) was replaced by CFL, which have efficiency 60-70 lumen/watts, now all are being replaced by white light emitting diode(white LED). LED based light source are much more efficient with luminous efficacy 100-130 lumen/watt, and higher life span. Sensor and automated protocol can be used with LEDs to save more energy in a space.[2]

In case of dynamic retail store energy efficiency is one of the most important needs today. Long opening hours and higher demands from the customers responding a unique shopping experience are some of the most challenging aspects of lighting system. Lighting truly makes an impact not only when it comes to the retail design and the inviting experience, but also on the energy usage.

To create energy saving and sustainable lighting retail environment light designer must keeping an eye on three points

- Addition of different light levels in the store
- Use of latest LED light inside space

- Implementation of the modern system of lighting system

A balance between the illuminance level and the thermal environment has to be maintained so as to achieve a satisfactory design solution

1.2 LITERATUER REVIEW

Color enhanced light emitting diode (LED) light with high gamut area for retail lighting[3] byXf feng, w. xu (fudan university, china, 16sept 2015)

Xf fend et. al investigated color appearance of objects which improve observer's preference with the help of high quality LED. Light quality is more important than Luminous efficacy like retail, restaurant like place, here LED's SPD (spectral power distribution) were optimized by changing color band gap to get desired CRI and high gamut area index(GAI is a characteristics of a source with good color discrimination and saturation of color and vividness). Author emphasized on the problem of CRI that is not alone enough to describe the subjective appreciation, introduced a new matric GAI can be a useful supplement to well established CRI to ensure saturation and satisfactory object perception. The gamut area of light source is commonly calculated as the area of the polygon defined by the chromaticity in the international commission of illumination (CIE) u v color space of the eight types of the color test samples when illuminated by a test light source.

The quality of different LED light on eight types of colored fabrics from a visual point of view was tested by the human factor only

The result show that addition of a narrow band RGB components, the light can increase the color appearance of the illuminated fabric significantly.

Effectiveness of retail lighting in terms of user satisfaction and quality[4] by izmir institute of technology published in GCRIS,2021,turkey**:-**

Purpose of the study of this paper is the interaction between psychology and light, better quality and comfortable lighting

spaces can be created for human beings with the lighting systems designed. The change in light color and proper standard maintained inside the space. The illumination of retail space depends on not only the level of illumination but also some factors like direction, shadow, contrast. The unbalanced use of these factors may create some problems in terms of visual comfort.
This paper covered lighting design effects customer satisfaction, and aims to determine the effective lighting design strategy in retail and to explore its effect on customers and quality of light inside retail environment.

Retail lighting and textiles: designing a lighting probe set[5] by b. bratati, E. karana, D. sekulovski, Deft university of technology, published in lighting research technology, 2017**:-**

This paper investigate interaction between retail lighting and textiles to object that can be used to test the visual effect of a lighting. In this experiment concerned photometric measurement of textiles in order to categorize the reflectance types, this paper study aims to provide understanding into the perceptual cues of apparel appearance and find a practical solution to help retail lighting designer visualize the effects of illumination of apparel.

Effect of surface reflectance on lighting effecting in interior lighting by Rohini singh, ranjan rawal,12th conference of international building performance, Sydney, 2011**:-**

This paper attempts to analyze the relationship between surface color reflectance and lighting power density for a given context. The study established itself on the premise that grey value of color can be presumed to calibrate the luminous character of light. It evaluates the impact of vertical an horizontal planer interior elements reflectance and its impact on LPD.
The study said to examine a rational method for assessing visual comfort and lighting efficiency of an interior portion, therefore, color choice for interior should also a higher range of understanding.

Smart retail lighting control using occupancy sensor[5] by xin wang Tjalling Tjakens, Jean-paul linnartz, netharland**:-**

Objective of the paper is to exploit the information contained in the estimated occupancy probability. To find the optimal dimming strategy given by the detected presence probability and to optimize the illuminance level in the retail so that the energy consumption is reduced gradually.
From the results we could see that when the probability of presence of occupancy is low, it is wise to completely turn off the light. When the probability exceeds a certain threshold.

Sustainable lighting in interior space[6] by khaleid alsaid ,Rodrigo muro , royal institute of technology**:-**

This paper emphasize on sustainable lighting design in interior space, by using SSL (solid state lighting) technology like LED, this study evaluates all aspects of an installation to determine the overall suitability of an LED product substitution, the power consumption per unit area was reduced up to 60% for LED lighting system comparing with fluorescent lighting.
In economic analysis, capital recovery ratio is around 0.40 and the rate of return was accumulated as 25.2% for LED lighting system.
In this study shows that co_2 emission factor of the LED lamps could be reduced in high rate compared to fluorescent lamps.

Retail design: lighting as an atmospheric tool, creating experience which influence consumers mood and behavior in commercial spaces[7] by katelijin qartier, hensi Christians, university of hasset,published in lighting research tecnolog, belgium,2008.

The aims of the study is that the conception on the influence of lighting on the physiology of the human being operating on mood and consumer behaviors through the perceptual system, beyond the conscious level.

bitner (researcher) analyzed how consumers respond to a retail environment and consumers can react to a retail store in a cognitive, emotional and biological way.

The main point of view is influence on buying behavior and sales number. Shop environments create ‘retail experiences’ that

strongly influence consumers purchase behavior. That is mean keeping shoppers longer in stores is result increased more browsing behaviors, which may cause to increase impulse purchasing.
Researcher concluded that the individual atmospheric variable have a demonstrable effect on the outcome of evaluations like store image, brand judgements.

Lighting impact on consumer's shopping behavior in retail cloth store[8] by j.deepika, t. neeraja (international journal of science and research)

Tullman et. al (2000) conducted a study to know whether the dynamic full spectrum digital lighting of retail displays affects customer behavior.
The study showed that more shoppers stopped to look at storefront displays and they spent more time in front of those displays looking at products. The customer inclination to purchase in the store are increased. Increase in customer mood rating of the quality of time spent in the store, the use of color within the store and overall impression of the store were found at the prototype location. The results of the study concluded from the standpoint of customer's behaviors and impressions that the prototype storefront had shown to be a more effective selling space as compared to the traditional storefront design

1.3 PROBLEM DEFINITION:

Low quality light inside the space may lead to down business of retailer as well as light with improper design may also lead to light loss, glare, distracting of color appearance of objects. Both can lead to mistakes at retail space and create low productivity.

Various studies suggest that proper lighting at retail space pays dividends in terms of impulse of selling objects.

1.4 Objective of the project:-

Objective of this project is to determine the energy saving lighting design concept and methodology of a retail shop indoor space,
The design must have to energy efficient and the result must meet the recommended values defined by the authority or client and

maintained all lighting standard. The entire project based on lighting design software simulation based.

1.5 Methodology:-

1) Study literatures related to this topic.
2) Creation of the floor plans of Retail Shop with the help of AutoCAD
3) Proposition of lighting design with the help of DIALux software.

1.6 Organization of thesis

This thesis consists of several chapters. In each chapter we have discussed about certain topics which lead to the completion of this thesis. The overview of each chapter given below,

Chapter 1: this chapter gives the introduction to the project. It consists of objectives, the execution process and the methodology of the project.

Chapter 2: This chapter comprise the theoretical background of the project. Here, layers of lighting and types of luminaire used in retail has been discussed.

Chapter 3: here retail lighting standard parameter and different section of retail light briefly discussed.

Chapter 4: it comprise the light source , CFL as well as LED light has been discussed. For smart energy saving lighting driver, sensor and automated protocol are important parts. Therefore all of these discussed in this chapter.

Chapter 5: it consists of brief discussion on entire project we have done. It also draw the conclusion of the project.

CHAPTER 2: THEORITICAL BACKGROND OF RETAIL LIGHTING

2.1 LAYERS OF LIGHT IN RETAIL SPACE

There is four layers of light commonly used in retail lighting. That is

- General lighting (ambient lighting)
- Accent lighting
- Task lighting
- Decorative lighting

Combining and adjusting these types of lighting gives noticeable interest to the retail premises and creates a more attractive, exciting and inviting environment

2.1.1 GENERAL LIGHTING

General lighting, also known as ambient lighting provides an area with non- specific illumination. General lighting is a main source of illumination in a retail space. Recommended light levels for general lighting is 300 – 500 lux.[9]General lighting helps the shopkeepers to do their regular works like re-stoking and cleaning, as well as guide the customer inside the space to examine the merchandise.

General light can achieve by even distribution of light using high bay light, fluorescent light, recessed light. By using cove light either ceiling or wall we can achieve dramatic general lighting effect can be achieved. General lighting provides better uniformity inside the shop.

Fig. No. 1: image of general (ambient) lighting

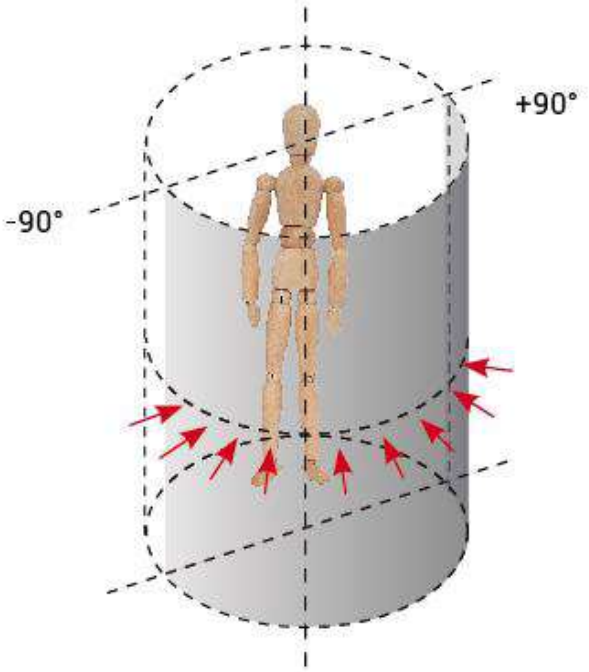
Sample image shows recessed downlights fitting. This is the easiest way of lighting for general lighting or ambient lighting to get better uniformity.

2.1.2 TASK LIGHTING

Task lighting refers to light that are focused on specific areas of the store that are required more lights and higher level of illumination. The common needs of task lighting are to detect and recognize very small parts of visual effects

Task lighting is different form of lighting from area and mood lighting, sometime creates particular desire effects. Task lighting is most effective when used as a supplement to general lighting in workspace conference areas and on counter tops. Effective task lighting should eliminate shadows on specific illuminated area. Task light is elucidate with four different aspects task illuminance–its level and distribution, contrast within the task, contrast between the task and its surroundings, absence of discomfort glare.

Task light also contribute a good cylindrical illuminance to show the friendly faces of the sales staff. This cylindrical illuminance will make the customers feel more comfortable.



Good visual communication and recognition needs a sufficient level of Brightness on objects, therefore the space in which people move to work have to be sufficiently illuminated .this can be achieved by ensuring better average cylindrical illuminance.

Fig. No. 2: cylindrical illuminance

Cylindrical illuminance defined by calculating the average vertical illuminance. IES recommends that cylindrical illuminance should not under 150 lux in open space. [10]

2.1.3 ACCENT LIGHTING

Accent lighting called as highlighting, creates dramatic emphasize on merchandise to draw attention to part of the field of view.

It adds depth contrast and creates a focal point for merchandise to be displayed, highlight texture shape design and color merchandise drawing customer to it. The key point is to make precise illumination and provide higher level of luminous intensity than the surrounding ambient lighting. Point source are ideal for accent lighting because

Accent lighting have good color rendering. Accent lighting can achieve with using of spotlights, pendant lights, track lights.
Advantage of accent lighting for retail 1) directing attention on to a product is a way to increase sales.2) In a hurry customer easily find out the latest range products.3) By adding accent lighting we can improve our customer mood and create relaxed environment.

Division of accent lighting:-

Key or hard accent lighting: hard accent light is used to create shadows and determine contrast and focal point. In such type accent lighting case distracting reflection from glass should be avoid.

Fill lighting: when accent lighting used as fill lighting mode, wider distribution of light is angled to soften shadow.

High lighting: wide accent is used to highlight shape and texture in product.

Back lighting: for back accent lighting, lighting from behind accentuates size and shape.

Up lighting: lighting from below creates unnatural ghost like shadows, therefore it should be used selectively. Where the most dramatic effect is needed, Such as store front window to displays or to create a transition between department.

2.1.4 DECORATIVE LIGHTING

- Decorative lighting is fourth layer of lighting in retail space, in one words it is jewelry of the room. Decorative lights contain the comfort of ambience lighting, the efficiency of task lighting, impact of accent lighting.

- Decorative lighting serves a dual purpose, not only to contribute to the lighting layers in retail environment but also to enhance the look of the space as a design element.
- Decorative lighting does not require any lux or glare restriction.
- Decorative lighting may perform as general lighting or accent lighting in the retail space. By adding beauty and style decorative Lighting intensify the brand store image.
- By adding décor, beauty and style, decorative lighting is also an important communication of a store's brand image.

Example of decorative lights.

- Ceiling decorative lights (ceiling cove lights)
- Chandeliers lights
- Pendent lights
- Decorative lights for store brand image

2.1.5 PERIMETER LIGHTING

Perimeter lighting is an important consideration for proper illumination of a merchandise space because vertical surface brightness have a significant role in the shopper's impression of the store. Perimeter lighting is an asset to a store environment, contribute to perception of brightness and sense of pleasantness.

Perimeter wall lighting can be achieved by various techniques using either linear or point sources to create continuous form of lights. Architectural cornice, soffits or valances with concealed fluorescent, linear socket strip luminaire using ceramic metal halide PAR lamps can be employed, as well as properly spaced wall-wash luminaire that provide a continuous pattern of light. but now days LED replaced all above lights for enhancing energy efficiency of building.

2.2 TYPES OF LUMINAIRES FOR RETAIL SHOP

Luminaire type for retail shop should properly selected. Wrong selection of luminaire will lead to incorrect design. CRI, CCT, beam angle, aiming, mounting, maintenance, and other standards are some of the consideration when selecting the proper luminaires for a retail shop design.

The selection of luminaire depends on the budget inside the store. As an example, Designer cannot use pendants or suspended tracks in a low ceiling shop.

Luminaire also depends on the ceiling layout. Cove light and other ceiling decoration must match with the light fittings to be used. So, it is important to check the ceiling design before selecting the luminaire types

The most common types of luminaires use in the retail shops are:

1. Track Lights
2. Downlights (recessed type)
3. Wall Washers
4. Shelf Lights
5. Pendant Lights
6. Cove Lights
7. Back Lit Lights
8. Vertical LED case Lights

2.2.1 Track Lights

Track lights can be mounted recessed, surface or suspended. This is the most flexible type of luminaire in retail shops. Gondolas and shelves are sometimes moved from one place to another, and using track lighting is the best solution for these changes. Track lights produce aim flexibly, can rotate 340 degrees, they are also easy to install and maintain.

This is the most flexible type of luminaire in retail shops. Track lights can not only be aimed flexibly, they are also easy to install and maintain, as shown in Fig.3.

The rule of using track lights is to focus the beam onto the merchandise from the viewer's point of view. Incorrect use of track lights may cause glare, which is main standard parameter in a retail shop lighting [11]

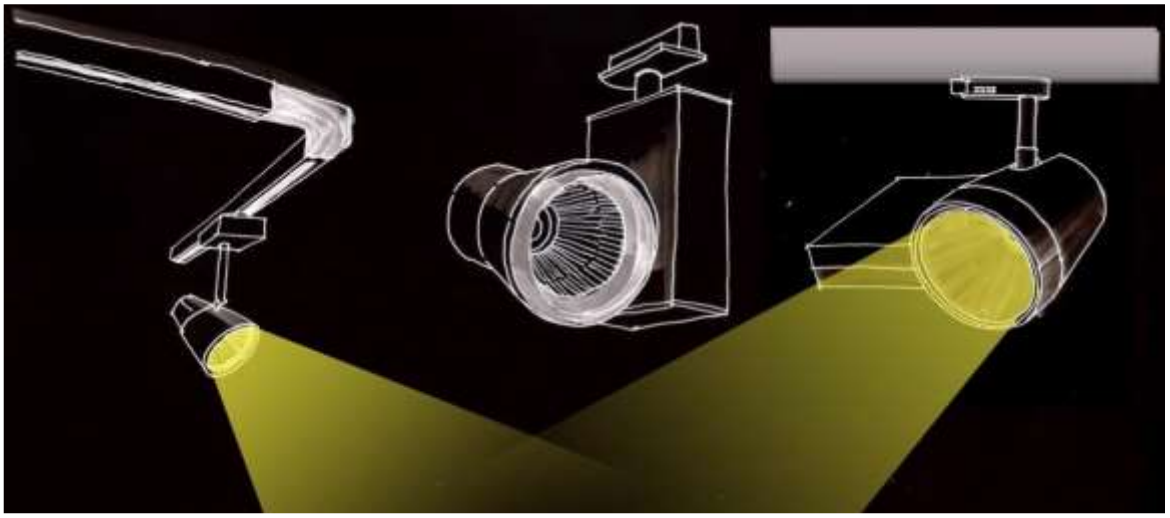


Figure No. 3: Track luminaire (adjustable)

2.2.2 DOWN LIGHTS

It is called a downlight because the light shines down from the ceiling, When the light is produced from an LED, as opposed to another light source. Downlights are a versatile light fitting excellent for a multitude of uses throughout the retail space. These downlights are sometimes called recessed light or pot light or can light. LED downlights can come as either a fixed downlights or directional version. Some are also available with different beam widths like narrow, medium or wide.

Figure 4 shows downlights, which are not flexible, but they are manageable. we can aim them towards merchandise, but they may be limited as far as spacing between them. The shape of downlights varies from round to square. Round shapes are easy to lay-out, because we don't need to align the luminaire from edge to edge compare with square or rectangular.

Fig.no 4: Down light (recessed type)

2.2.3 WALL WASHERS LIGHTS

Wall washers light illuminate vertical surface with uniform brightness. Wall washers type of light "washes" the wall or an area of the wall with illumination. Wall Washers are the best solution for vertical illuminance. Having a bright wall will make the retail shop seem wider and bigger. Bright walls will also encourage customers to enter the shop. Paint wall with white color or light color for greatest efficiency of reflection of light.

Wall washer are slim lights with different wattages, beam angles and color temperatures. Wattage start from 6W to maximum of 48W.[12]

Fig. no.5: Wall Washer luminaire

Wall washers light create light scallop and grazing on the wall.

Light scallop: light scallop is an effect created when recessed fixture is placed closer to wall resulting in a more concentrated and tighter scallop. Scallop light effects are a part of the lighting, which add more drama inside space. They can be created if fixture placement is not properly calculated.

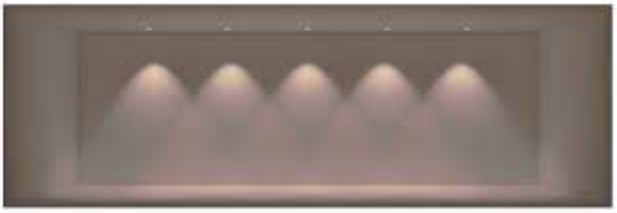


Fig.no 6: wall scallop lighting (type wall washer)

Wall grazing: For dramatic effect on texture surface such as stone, bricks ,place fixture 6 to 12 inches away from the wall.[13] Grazing is not recommended on smooth surface. Below pic shows wall grazing scenario, which place from wall with short distance.

Fig.no 7: Wall grazing(type wall washer)

2.2.4 SHELF LIGHTS

Shelf lights are usually integrated into shelves. They are used to highlight the merchandise closely. The most common shelf lights are strip LEDs or small pin lights

Some furniture manufacturers include them in their modules. But most retail lighting manufacturers have their owned range of products for this lighting solution which shown in fig no 7.

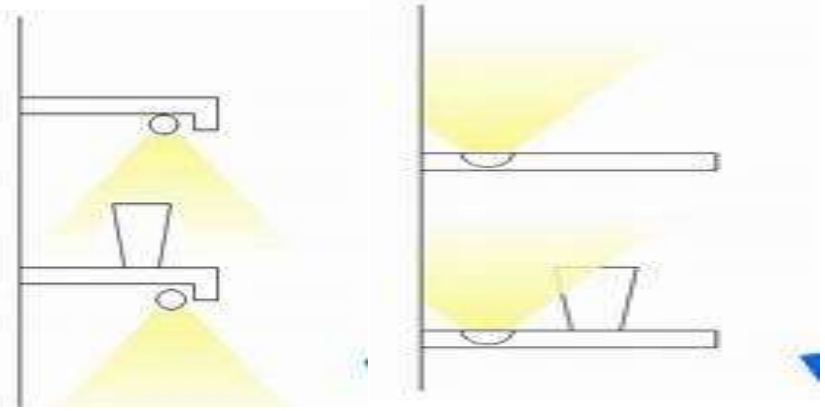


Fig. no. 7: shelf lights (LED strip)

LED shelf lighting can be efficient and highly effective way to highlights retail space, create sooth ness and highlights decorative display.

The increasing popularity of LED shelf lighting across both the retail and non-retail area because of

- Cost and energy efficiency advantage :

A retail store environment needs good energy efficient light capable of withstanding high crowd. Without glass LED shelf light is resistant to breakage or damage. shelf light requires almost zero maintenance cost.

- Greater control and illumination for highlighting visual merchandise:

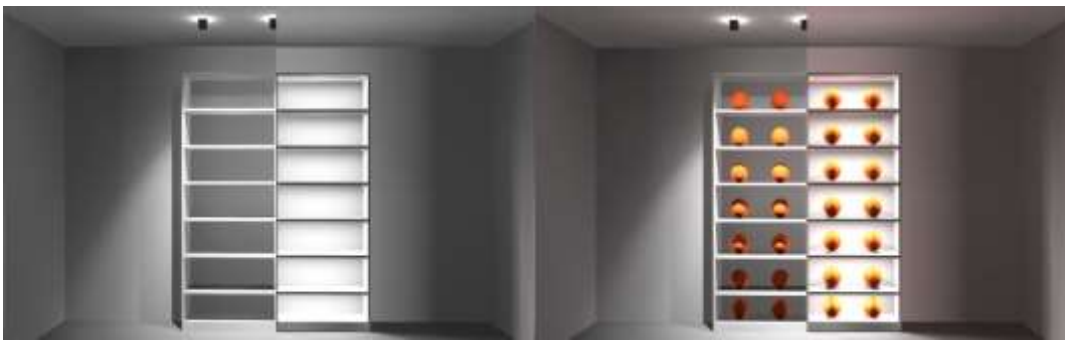


Fig.no 8:-shelf lighting comparison pic

fig no 8, introducing a shelf lighting pictures where self are illuminated with track mounted spotlight (left side) and LED strip shelf light (right side). The left side shelf is illuminated by overhead track mounted with aiming angle roughly 20°-30°. There are insufficient light in the lower part of shelf. With track light, it can be difficult to achieve proper illumination on the shelf. LED shelf lights

Works here efficiently by ensuring uniform light distribution through out shelves.

- Greater control of dimming capabilities:
  The degree of control of LED shelf light is high, allowing dimming to as low as 10%.shelf light can dim with methods such as DALI, Network based lighting control (POE).[14]

2.2.5 PENDANT LIGHTS

Pendant lights used as a task lighting in retail space. Pendant lights can be used for general lighting or functional lighting. High ceiling retail shops prefer to use industrial design suspended luminaires. Open ceiling retail shops prefer to use them as well. For exclusive or high activity zone like cash counter, we must use suspended pendant light.

There are seven types of pendant lights in the market- 1) drum pendant 2) globe pendant 3) bowl pendant 4) exposed bulb pendant 5) multiple pendant 6) mini pendant 7) abstract pendant

2.2.6 UNDER CABINET FIXTURE LIGHT

These are designated for either task, decorative or accent lighting, it depends on where designer placed.
There are four types of under cabinet fixture:

- **Pucks Lights:** hockey puck shaped fixture, do not necessarily require to be plugged in or connected to the main wiring. They can be battery operated, with LED bulbs.
- **LED strips:** the only advantage of LED strip is that it have a longer life span and do not over heat. Light colour varies to be sure to test or find out the exact range of colour temperature.
- **LED tape:** it is an extremely thin fixtures that make it discrete from others. It can be installed any desired surface with the provided sticky tape. Presently architectural lighting designer use LED tape immensely at commercial retail space.

Fig.no 9: LED Tape light

2.2.7 COVE LIGHTS

Cove lights create soft illumination. This not only helps the general lighting level, but also it produces a different effect on emotions by highlighting the edges of the space
Cove lights can be installed in ceilings, walls or shelves. The most common lamps used in cove lighting are linear fluorescent tubes,

neon lights and LEDs. The installation varies depending on the cove design.

There are many ways to create cove lighting inside the retail shop. One is using perimeter cove lighting to illuminate the wall, other is to use the same perimeter cove lighting but highlighting the ceiling.[15]

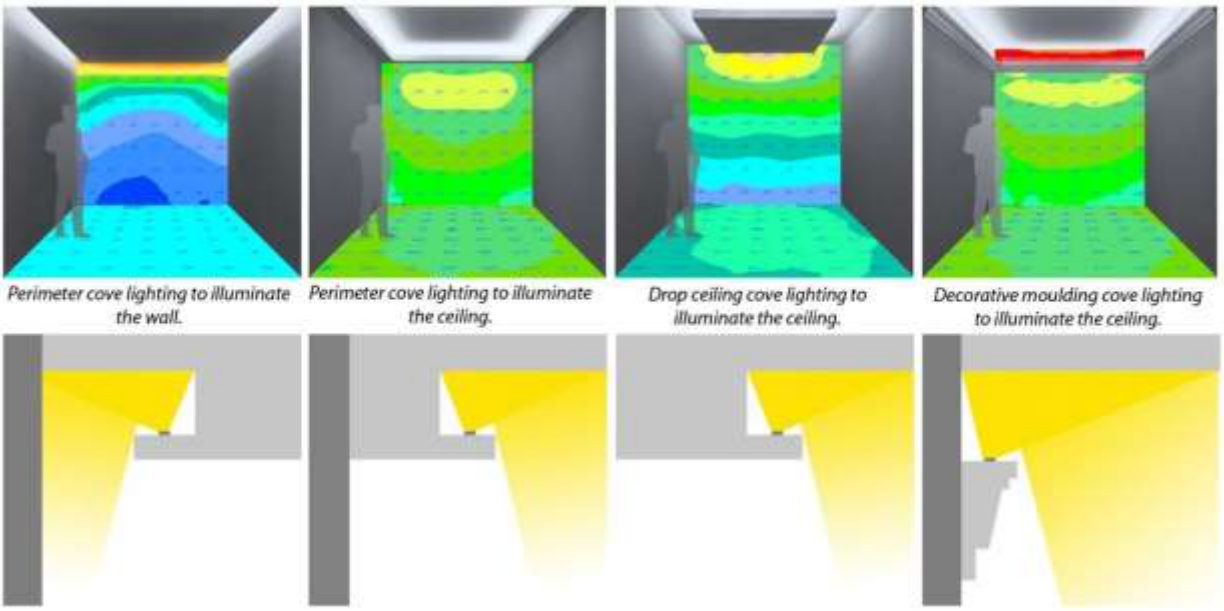


Fig.no. 9: Cove lights with different positions

Fig no 9 shown that different position of cove light like perimeter cove lighting to illuminate wall, perimeter cove lighting to illuminate ceiling, drop ceiling cove lighting to illuminate the ceiling ,decorative moulding cove lighting to illuminate the ceiling.

2.2.7 BACK LIT LIGHT

Back lit is another best way to enhance the overall ambience of the retail shop. It gives uniform effect and it widens the appearance of the room.

Most back lit fixtures are used for advertisements, but with the evolution of LED, it is becoming part of the lighting solution for overall illumination.

In working the lighting design calculation, it is necessary to understand the transmittance and reflection factor of the panel to be used.

The spacing and the distance of the LED to the panel must also be checked, otherwise the LED light dots will be visible (which

is not good because our main requirement for back lit is to have diffuse, uniform illumination).

Fig.no 10: Back lit lighting

2.2.8 VERTICAL LED CASE LIGHT (RETROFIT)

Vertical case led lights normally used as freezer or cooler lights. Vertical case light optimized light distribution throughout display case. It is convenient to install in retail refrigerator display. It has high color rendering index (CRI).

LED cooler refrigerator case lights for commercial display cases replace fluorescent fixtures in refrigerator. It require significantly less energy to operate, work better in cold temperature, easily connected to controls for dimming, occupancy sensing.

Key features of vertical LED case light given below pointwise.

- CRI = 85
- Long life up to 50,000 hours (L_{70})
- No UV or IR emissions
- Excellent color consistency
- Significant energy and maintenance saving compared to fluorescent lighting systems
- Polarity protected circuitry minimize the risk of damage in a reversed wired installation
- Available in 4000k to 5000k
- Standard lengths at 6, 12, 24, 36, 48inch.[16]

Fig no 9 , introducing a vertical case light picture, which installed in freezer and cooler vertical side, produce white light and make asset decorative .

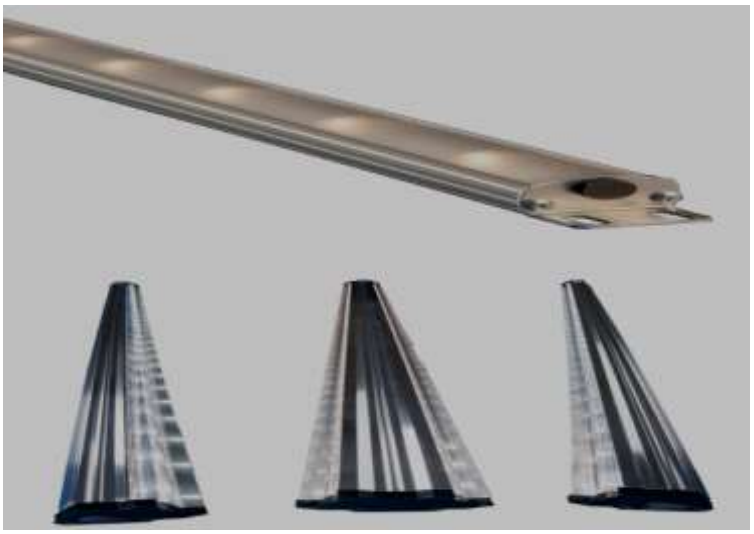


Figure No. 11: Vertical case light

2.2.9 GRID LIGHTS

Grid lights and down lights are embedded lamps, normally used for general lighting purpose such as commercial store. In general, grid lamps installed in the ceiling inside, the light port is as high as the ceiling. Here grid has several specification of 600 mm × 600 mm, 1200 mm × 600 mm, 1200 mm × 400 mm. the underside of grid lights manufactured with aluminum or stainless steel mask [17]

2.3 STRUCTURE OF LUMINAIRES AND LAMPS

When designing lighting in any space, lamps and fixtures are used together very often, because fixture have an impact on lighting design. It helps to provide tranquility and comfort by preventing glare
While physically protecting the lamp.
Different lighting styles have emerged due to the structures of the luminaires used in retail lighting design that provide visual comfort conditions. These are **1) Direct lighting 2) Semi-direct lighting 3) General diffused lighting 4) semi-indirect lighting 5) Indirect lighting**

2.3.1 Direct lighting: when the light is directed downwards with 90%-100% light reach on work plane. In case of direct

lighting light comes directly from lamps, it makes shadow and glare. To avoid glare, lamps can be placed deep into the luminaires. This lighting provides **a high level of illumination, so it is preferred in places with height** ceiling heights.

2.3.2 Semi-direct lighting: In semi-indirect lighting 60%-90% of the light is downwards, and 10%-40% of the light also illuminates the ceiling and upper walls with a small component inside. some of the light comes by reflecting, for this reason sharp shadow do not occur. Semi direct lighting is preferred in places such as stores and restaurants. semi direct lighting partially prevents glare.

2.3.3 General diffused lighting: In general diffused lighting system, light coming from the luminaires is mixed up and down luminous flux. Here light reflects 40%-60% upwards and 60%-40% downwards.

2.3.4 Semi-indirect lighting: It is a lighting system that emits 60%-90% upwards and 40%- 10% downwards. Here luminaire create illumination by emitting from the walls and ceilings, so chance of glare and shadow is very less.

2.3.5 Indirect lighting: 90%- 100% of the light upwards in indirect lighting. There is almost no possibility of glare from the beam reflecting off the surfaces.[18]

Figure No. 12: Luminous flux emitting picture with different structure

CHAPTER 3 **RETAIL SHOP LIGHTING DESIGN PARAMETERS**

3.1 Retail store lighting design standard

The lighting standard recommendation are selected as per National Lighting code (NLC 2010), Most of the standard refers to local situations
For this application, focus on the guidelines for following:

1. Illuminance (Lux level)
2. Luminaire Efficacy and Life Expectancy
2. Reflectance
3. Overall Uniformity
4. Unified Glare rating
5. Light Effect
6. Contrast
7. Colour Rendering
8. Correlated Colour Temperature
9. Light distribution
10. Sustainability Standards
11. Shadows and modelling
12. Lighting power density

IS 3646 (part-1992), IESNA and CIBSE, the most popular lighting guidelines are following here.

3.1.1 ILLUMINANCE

In photometry, illuminance is the total luminous flux incident on a surface. It is a measure of how much the light illuminates the surface through incident on surface. Lux is a unit of measurement of light level intensity, Lux stands for lumen per

unit area. Where the foot-candle is a non-metric unit of illuminance that used in photography. Illuminance is used as a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface.

There are generally two types of methods of illuminance calculation

- Point calculation method
- Lumen method

In case of point calculation method all detailed calculation of direct and indirect component of parameter at selected points considered.

Here I prefer lumen method to measure average illuminance inside the rectangular shape retail space.

The desired light level or lux level will depend on the shop brand requirements. If the client not know what the lux level should be, then designer can use the NLC Code for lighting as our basic guidelines. e.g. As per this Code, Sales area must have at least 350 Lux with 22 UGR and 80 CRI.[19] Average illuminance depends on various factors like number of luminaire, lumen package of luminaire, coefficient of utilization, maintenance factor

$$E_{avg} = \frac{N \times \oplus \times COU \times MF}{A}$$

here N = Number of luminaire use in a space

$\oplus$ = lumen package produced by per luminaire

COU = coefficient of utilization

MF= maintenance factor of luminaire

A= area of rectangular space.

3.1.1 Coefficient of utilization:

The coefficient of utilization is a factor used to determine the efficiency of lighting fixture in delivering light for a specific a specific application. The coefficient of utilization is determined as a ratio of light output of the lamps alone.

The illuminance and luminance levels in a luminaire do not constant over its period of operation. Both are decreased due to degradation and failure of luminaire. A high utilization factor

means less number of luminaire are required resulting in a more energy efficient lighting

Factors influencing coefficient of utilization

- The efficiency of luminaire
- The luminaire distribution
- The geometry of the space
- The reflectance of room surface

Each luminaire has its own CU table specific to that luminaire's light distribution and efficiency. As per national lighting code, the value of coefficient of utilization in interior lighting is 0.69[20].

3.1.1.2 Maintenance factor:

MF is a multiplier, used to determine average Illuminance of a work plane. The illumination produced by a light is considerably less after a few years of use than it was initially.

taken into account by including the maintenance factor.

MF is define as the ratio of the ultimate maintained meter-candle on the working plane to initial meter-candle.

If there is dust inside the store then MF will be 0.6 for regular cleaned working plane MF will be 0.8.[20]

A lighting system maintenance factor composed of four factors.

- Luminaire service life specification or luminous flux maintenance factor
- Luminaire maintenance factor
- Room maintenance factor(RMS)
- Lamp survival factor

Maintenance factor = luminous flux maintenance factor × luminaire maintenance factor × lamp survival factor × RMS.

The loss is partly to the ageing of the lamps and partly to the accumulation of dust on the lamp reflector, or accumulation of dust on the reflecting and transmitting surface of the fixture and on the ceiling. This all facts are

TABLE 1: Recommended Illuminance for Retail Applications

AREA	ILLUMINANCE (Lux)	COMMENT
Fashion &households stores		**Light both horizontal and vertical planes**
Department store	500	
Chain store	750	
Specialist retailer	500	
Food Store		**Light vertical displays**
Super market	750	
Grocery/vegetable store	500	
Retail catering outlets		**Consider point of sale lighting at design stage**
Food court	300	
Fast food court	500	
Family restaurant	200	
Small retail outlets	500	**Stationers, newsagent, bookshop, chemist**
Others store		
Super store	1000	
Car accessory store	550	
Electrical/furnishing store	650	
Hard ware store		
Show rooms	750	
Cover arcades and malls	550	**Dependent on ambience requirement**

3.1.2 LUMINOUS EFFICACY AND LIFE EXPECTANCY

The luminous efficacy refers to the ratio of luminous output emit by
a light source to power rating of light source. It measure how well a light source emits or how well light source convert energy to electromagnetic radiation. All the wavelengths of light are not equally visible or effective to human vision system. At 555 nm there are efficacy 683lumen/watt(maximum sensitivity of human vision).
Mathematical expression of luminous efficacy (K) given below

$$K = \frac{\emptyset_v}{\emptyset_e} = \frac{\int_0^\infty K_m V(\lambda) \emptyset_{e,\lambda}\, d\lambda}{\int_0^\infty \emptyset_{e,\lambda}\ d\lambda}$$

Where
$\emptyset_v$= luminous flux of light source
$\emptyset_e$= radiant flux of light source
$K_m(V_\lambda)$ = spectral luminous efficacy
$\emptyset_{e,\lambda}$= spectral radiant flux

Different type of light source has a different rated efficacy, where LED being the most efficacious light. Below is table of efficacy of different light source[21]

TABLE NO. 2 : Efficacy of different types of lamp.

Different types of lamp	Efficacy(lumen/watt)
Incandescent Lamp	5-15
Fluorescent Lamp	20-35
CFL Lamp	25-70
Metal Halide	45-100
Low Pressure Sodium vapor	80-150
High Pressure Sodium vapor	80-110
LED Lamp	50-150

Electric light source have the tendency to fail due to several factors, including faulty of component, corrosion inside lamp. As a result the depreciation of lumen output occurs gradually.

In case of incandescent lamp, life span 1000-2000 hours and lose about 10-15% of their lumen output. CFL lamp life span 12000 hours and lose about 10-15%[(12)]. Where LED light life span 50000 hours and above, LED light lumen output decrease very slowly over time. There is a term like L_{70} (or L_{60}) mentioned outside the LED luminaire, which means lumen out will be 70% of initial lumen out put after certain life span.[22]

3.1.3 REFLECTION

Reflection is the process by which the light falling on a plane and leaves from incident side of this plane, reflection may be specular, spread, diffuse or compound and selective and non-selective. If surface is polished, it reflects in specular way. If reflecting surface is not smooth, it spreads parallel rays into a cone of reflected rays. If textre have a rough surface or is composed of minute crystal or pigment particles, the reflection is diffuse. Most common materials are compound reflectors and exhibit three reflection components (specular, spread, and diffuse) to varying degrees.

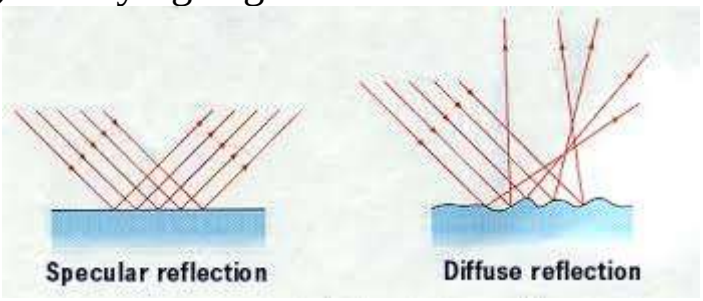


Fig.no 13: specular and diffuse reflection

Reflection of light of the surface within the space should be accounted in lighting design. Surface with higher reflectance texture are used, light is reflected into the space and level of Illumination also increased.

A scale of '0' light reflectance means total light absorption, while scale of '100' means total light reflection.

Room surface reflectance plays a significant role in maximizing the efficiency of a lighting system in retail space. IES

recommended surface reflectance in retail space given below in chart format.

Table.no 3: IES recommended reflectance percentage

RETAIL STORE SURFACES	REFLECTANCE PERCENTAGE
Ceiling	80%
Wall	50%
Floor	20%

Spread reflection material, such as brushed aluminum, white structural glass, stainless steel etc. have high reflectance value. In order to reduce energy costs white and light reflected surface help reduce shadows from selves, racks. Below is a chart of different material with reflectance value that may help owner at the time of retail store construction.

Table.no 4: Reflectance percentage of different material

MATERIAL	REFLECTANCE PERCENT
Lime stone	35- 60
White paint	75- 90
White structural glass	70-80
Brushed aluminum	55-60
Stainless steel	55-65

A study on "the impacts of high reflectance flooring materials in retail application" paper published by Richard Mistric (Pennsylvania University), looks at the impact high reflectance flooring on the illuminance from the general (downlights) lighting source. In grocery shopping aisles, for a shelf that is 1 ft. above the floor, which is difficult area to illuminate from general lighting. Floor reflectance percentage increased from 20% to 60%, as a result vertical illuminance of shelf increased by 41% at 1 ft. height above floor, consequently energy saving increased by 29% .[23]

Vertical illuminance is the dominant
Design criteria for the retail lighting
System layout, high reflectance flooring
Material can help increase Lux level
Vertical portion of shelves, as well as
Can help deliver energy saving.

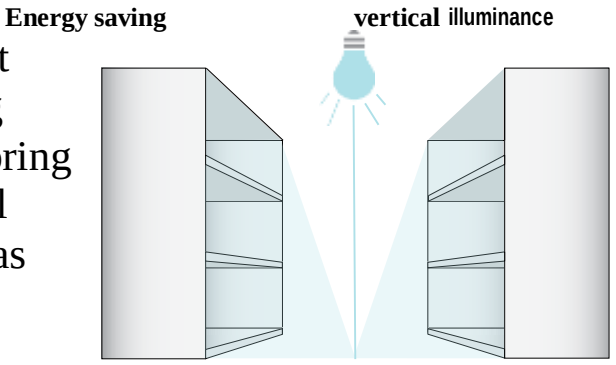


Fig. no 13. Vertical Illuminance on shelf

3.1.4 UNIFORMITY:

Illumination uniformity means to the uniformity of light in the place. From visual point of view, it indicates whether there is obvious dark area. Illumination uniformity refers to the ratio of the minimum illuminance to the average illuminance on a specified area. Whether use direct or indirect light, there should be standard uniformity throughout the task area.

As per the National lighting code 2010, regardless of the shop's profile, general lighting should be uniform, at least 0.70[24] overall uniformity (U_0). It can only achieve this in the lighting calculations when remove the objects and dim down or turn off the decorative luminaires

$$U_0 = \frac{E_{min}}{E_{avg}}, \quad U_1 = \frac{E_{min}}{E_{max}}$$

Here U_0 stand for over all uniformity in the space
E_{min}= minimum illuminance of working plane
E_{avg}= Average illuminance of working plane
For some case U_1 ratio is extremely useful as it allows to know the perfect distribution of light inside space, as difference between of average and minimum lux is not high.

When take U_0 in the retail shop calculations with objects inside it, it will give poor results due to the fact some areas will give 0 lux value because of furniture blocking the calculation surfaces.

Divide the entire shop into different type zones, then take horizontal calculation surface above 0.8 meter from the floor of space, then calculate individual zones uniformity. Which should be greater than 0.5.[25]

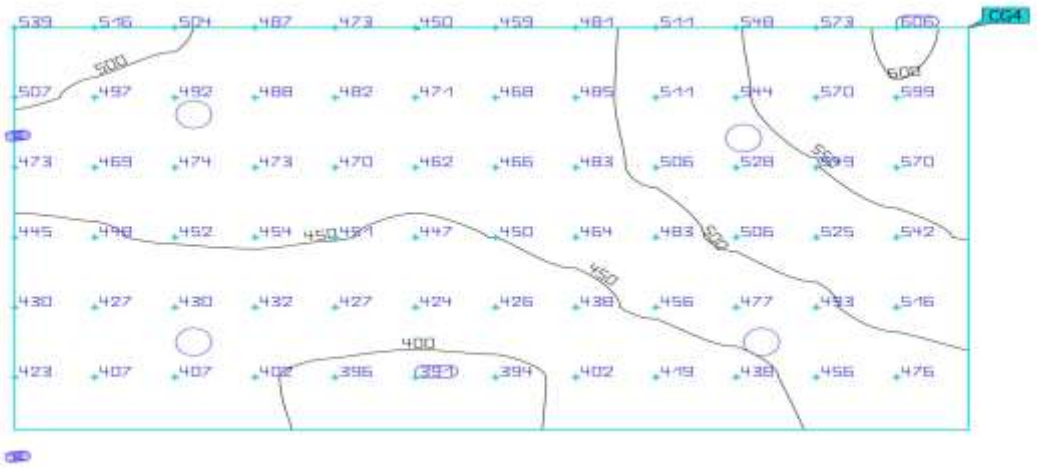


Fig. no. 14: uniformity (Iso-lux diagram)

This is the picture of sales area (Flat table furniture) Iso-lux diagram of my design project. Here minimum and average illuminance are 391 Lux and 475 Lux. therefore the overall uniformity for this particular zone is 0.8 (391/475).

3.1.5 UNIFIED GLARE RATING:

General glare may be caused by luminaire and window or by reflection of bright sources from surface with high reflectance, in interior lighting discomfort glare is likely to be more of a problem than disability glare.

In short form UGR is the measurement of calculating glare from luminaires. Glare is a caused by a significant ratio of luminaire between the task and the glare source. Glare generally divided into two types, discomfort and disability glare.

Unified glare rating (UGR) is an objective measure of glare that is used by lighting designers to help control the risk that occupants of a building will experience glare from artificial lighting. UGR is the relative intensity of the light from a light

fitting compared with intensity of the light from the surroundings area, which perceive by the viewer. UGR term use for an indoor light fitting on its own.

UGR values range from 40 (extremely high) to 5(extremely low). International standards such as CIBSE recommend limit of UGRs for different cases. In Retail lighting design recommended UGR is 22[26].
Below is a formula for calculating UGR

$$\text{UGR}= 8log_{10}[\frac{0.25}{L_b}\sum_{t=1}^{n}\frac{L_l^2 w_l}{P_l^2}]$$

Here,8 gives UGR numbers which nicely sit in a range from about 5 to 40.
P is the Guth index gets bigger the further the luminaire is from the line of the viewer.
L_b is luminance of the back ground. If back ground luminance increase then UGR will fall.
ω is solid angle of luminaire as seen by viewers.
L_l is object or task luminance.

Tabular method is a procedure to determine the UGR value of lighting installation in a standard room, where observer positioned either across or along the luminaire.

There are several steps could take during the design of an installation to reduce the UGR

- Increase the background luminance
- Decrease the luminance of the luminaire as seen by the viewer (narrow the beam angle or decrease the wattage)
- Angle the luminaires away from the viewer so they are not shining in their eyes
- Avoid positioning the fittings in the viewer's direct line of site

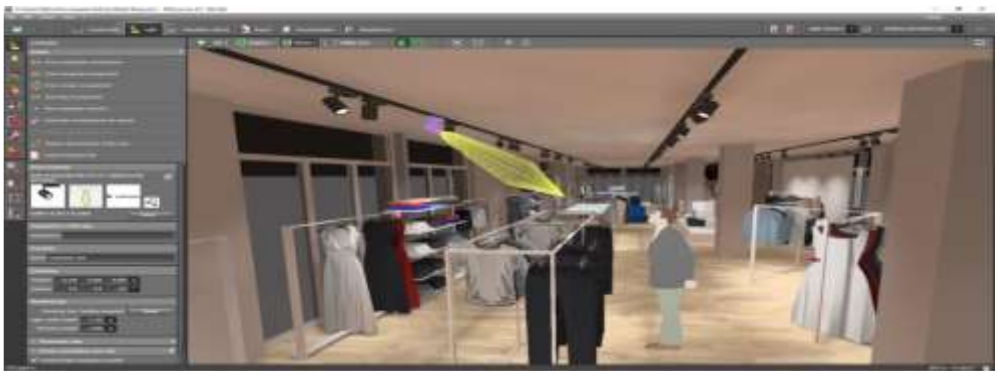


Fig. no. 15: Image showing glare create by direct lighting, which is harmful for human vision systems, may damage retina permanently.

3.1.6 LIGHT EFFECT

It is synonymous with luminance. it is the basic lighting parameter that is perceived by the eye. It indicates the brightness of a surface and is conditionally dependent on its reflectance, which include material color inside the store. Light effect is subjective to the people who see it. Luminance L, is the quantity of light reflected from an object or surface and transmitted into environment. Luminance is a function of illuminance and surface reflectance and directly relates to vision, thus it serves as a factor in many measurements of performance an perception. Current code does not includes recommended values for luminance, however luminance ratio suggestion are provided.

Several factors contribute to overall luminance levels including task luminance, back ground luminance and light source luminance, special consideration must be given to luminance in work setting and areas with video terminal display screen.

Room surface reflectance values greatly contribute to the overall luminance of a space.

According to the NLC / IESNA lighting standard, the luminance of the merchandise lit has to be higher than the luminance of its immediate background. It is mandatory because owners need to focus the attention of the customers on the merchandise rather than the texture or color of the floor and wall.

Present a table showing the Luminance ratio for different strengths of accent lighting.

Table no. 5: Luminance ratio of accent lighting

Luminance Ratio (accent/background)	Strength of accenting
1	None
2	Noticeable
5	Low theatrical
15	theatrical
30	Dramatic
>50	Very dramatic

Most of the big retail shop brands prefer to have lighting effects that are from theatrical to very dramatic.

3.1.7 CONTRAST

Contrast is a ratio between luminance difference (object luminance and background luminance) to background luminance. If object or task luminance is L_t,background luminance is L_b, then contrast(C) define as

$$C_o = \left|\frac{L_t - L_b}{L_b}\right|$$

This equation results in luminance contrasts that range between 0 and 1 for targets that are darker than their backgrounds, and between o and infinity for targets that are brighter than their backgrounds. This equation is used most often in the former case, where the background is brighter than the targets

$$C_o = \left|\frac{(L_g - L_l)}{L_g}\right|$$

L_g = greater luminance
L_l = lesser luminance

This equation results in contrasts between '0' and '1' for all subjects, whether brighter or darker than their backgrounds. It is applicable a duplex pattern in which neither of the areas on the two sides of the border can be identified as target or background.

$$C_o = \left|\frac{(L_{max} - L_{min})}{(L_{max - L_{min}})}\right|$$

L_{max} = maximum luminance, L_{min} = minimum luminance.

If an object is darker than its background it will be negative contrast, on the other hand, object is brighter than its background its luminance contrast is said to be positive.

Contrast describes how the highlights adaptation into the shadows. The brightest areas of the image are the highlights object. The darkest areas are the shadows. In retail store window display this can be seen in an object and its surroundings. It seen on backdrop of store window display in relation to objects being exhibit.

Contrast can achieve by using an increased illumination within different types of light like task and accent to emphasize featured merchandise against the general light level. Contrast creates visual hierarchies within the retail environment.

The table below outlines the luminance contrast between object (focal) to background to help attract attention and develop visual hierarchy[27].

Table No. 6: luminous contrast between object to background luminance

Perception of contrast	Effect	Potential application	Luminous contrast (object to background)
Negligible	Barely recognizable effect	Office artwork and retail sales rack	2 to 1
Perceptible	Recognizable focal effect	Task and surrounding	3 to 1
Marginal(suitable to moderate luminance)	Meaningful focal effect	Fine dine artworks, retail space display	10 to 1
Strong (strong luminance)	Strong focal effect, glary in most case	Between windows and adjacent	20 to 1

		surface of retail	
Very strong	Glary	Should not exceed this ratio anywhere within normal field to view	40 to 1
Dominant(very strong to intensive)	Strong significant centerpiece effect	Retail high bay display	1000 to 1

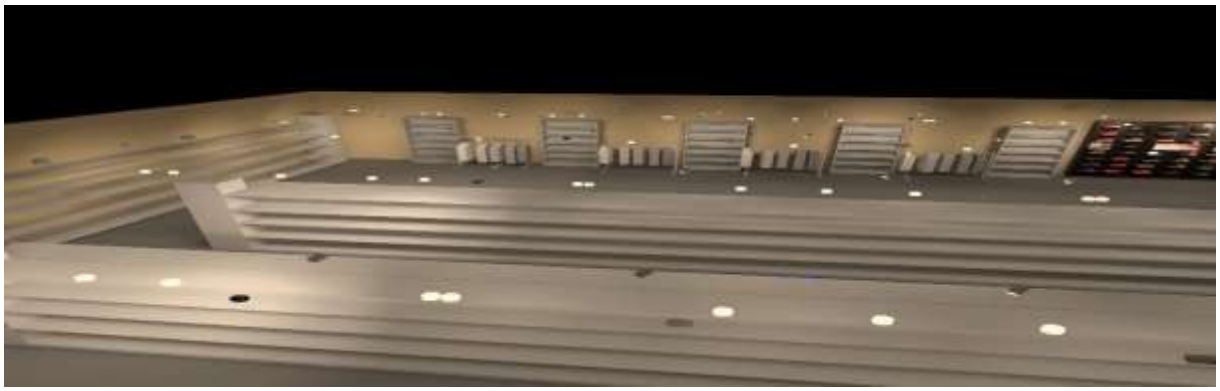


Fig. No.16: contrast (2 to1) on clothing racks and shoe racks for customer impression

3.1.8 COLOUR RENDERING INDEX

The Color rendering index (CRI) is a scale from 0 to 100 percent indicating how accurate a given light source is at rendering color when compared to a reference light source. The higher the CRI, the better the color rendering ability.

This is very important parameter in retail application because we need to show the true color of merchandise. No light manipulation, no chemicals, just true color to show off. We must use good CRI in our design. This does not necessarily mean that we will use CRI 90 in all parts of retail shop, we may use CRI 80 in general area.

Fig.no.17 : Color appearance of objects

The above image indicates the difference between good CRI luminaire and those that are not. CRI 90 to 100 is the best color rendering for retail shops. It will show the actual color of fabric, textile. Some retail shops use light to manipulate the judgment of their customers. The customers may then find that clothing is all in the shop, but are disappointed once they reach home and find that it looks different. This is one of the main causes of unhappy customers, which in turn affects the integrity of the retail shop or even the brand.

Some high CRI luminaire perform better than other luminaire. That means two LED luminaire with same CRI rating can look different. It happens because an LED's CRI is calculated by measuring its CRI rating for individual colors and then averaging them out, but it is only a measurement of color R1 – R8. This measured average fails to take into account R9 (red) and R13 (Skin tone) colors, among others.

LED light source with high R9 and R13 values, in addition to high CRI (R1 –R8), do a good job making skin tones healthy and natural.

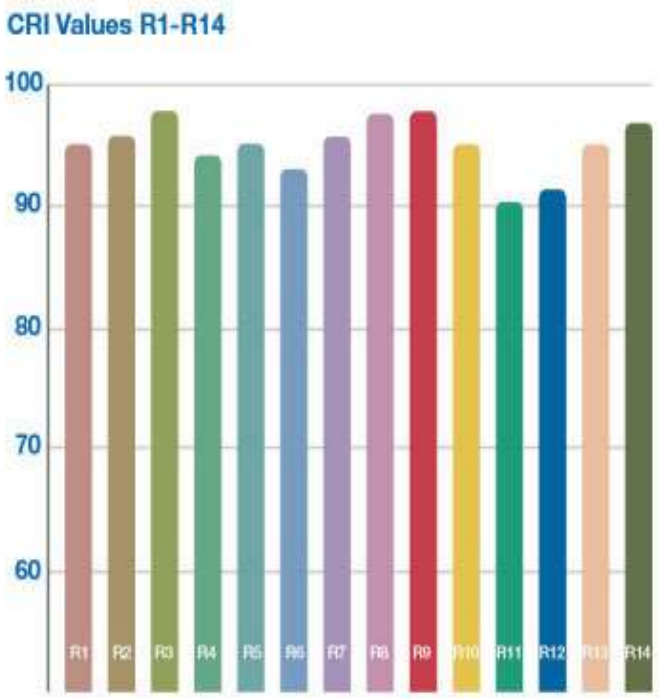


Fig.no. 18 CRI scale R1 to R14

This scale of R1 to R14, while R9 is one of the six saturated test colors not utilize in calculation of CRI.

R9 :

Fourteen refernce colors are typically used to measure color rendition, while CRI measure the first eight reference colors (R1 to R8). The ninth refernce color R9 scale measure spectral out put renders vibrant red. R9 scale is difficult to measurement when items illuminated with vibrant red including garments and jewelary. Cosmetics as well as human skin also appear more vibrant when it illuminated by source with R9 meusrement over 50 **[28].**

3.1.9 CORRELATED COLOR TEMPERATURE

Correlated color temperature is a measure of light source color appearance defined by the proximity of light source chromaticity coordinates to the black body locus, as a single number rather than the two required to specify a chromaticity.
The correlated color temperature (CCT) is a specification of color appearance of the light emitted by a lamp. It denotes in degree
Kelvin, on a scale from 1000k to 10000k.normally residential and commercial lighting application CCT fall on a scale of 2000k to 6500k

below is a kelvin temperature image which identifying different correlated color temperature with different type luminaire.

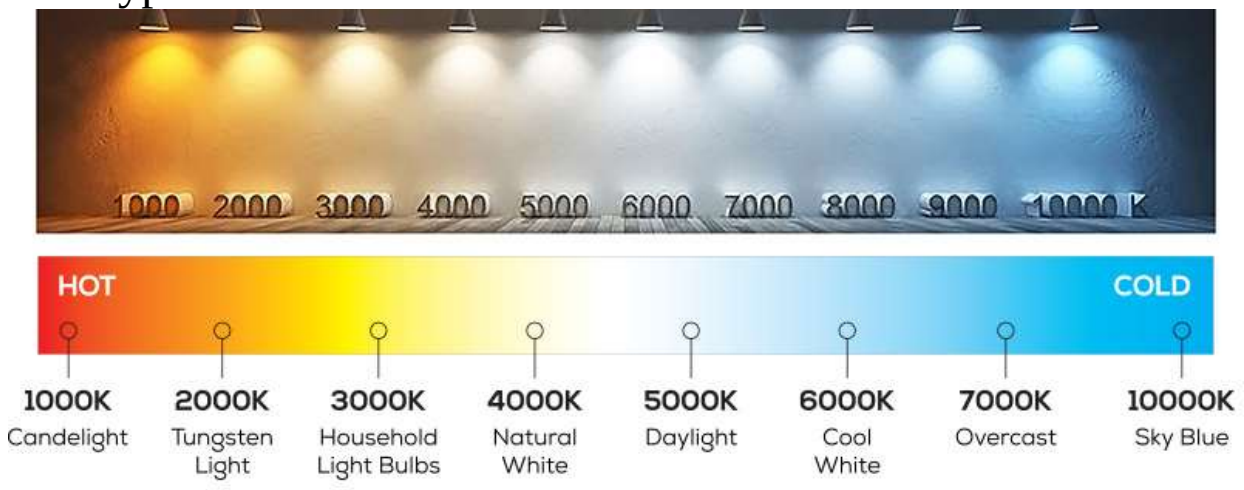


Fig.no. 19: correlated color temperature

Below is a chart identifying different color temperature with its characteristic.

Table No.4: Color appearance and best application areas of different CCT luminaire

Color temperature (Kelvin)	2000k -3000k	3100k-4500k	4600k-6500k
Ambience	Cozy, calm, inviting intimate	Bright, Vibrant	Crisp, invigorating
Best for	Living room, kitchens, bedrooms restaurant/commercial ambient lighting, decorative outdoor lighting	Basements, garage, work environments, task lighting, bathrooms	Display area, security lighting ,garage, task lighting

In retail application, CCT is important to set the mood of the customer. Warm color is welcoming and produces a homely effect, while white color brings formality and smoothness. CCT also affects the branding image The simple choice of light color will improve the feeling of the customers. therefore, CCT strategy must be well planned.

Below I introduce two pictures from my projects with different CCT luminaires. Left side store is illuminated by cool white luminaire (CCT 5500K) while right side store is illuminated by warm yellow light (CCT 2590K).

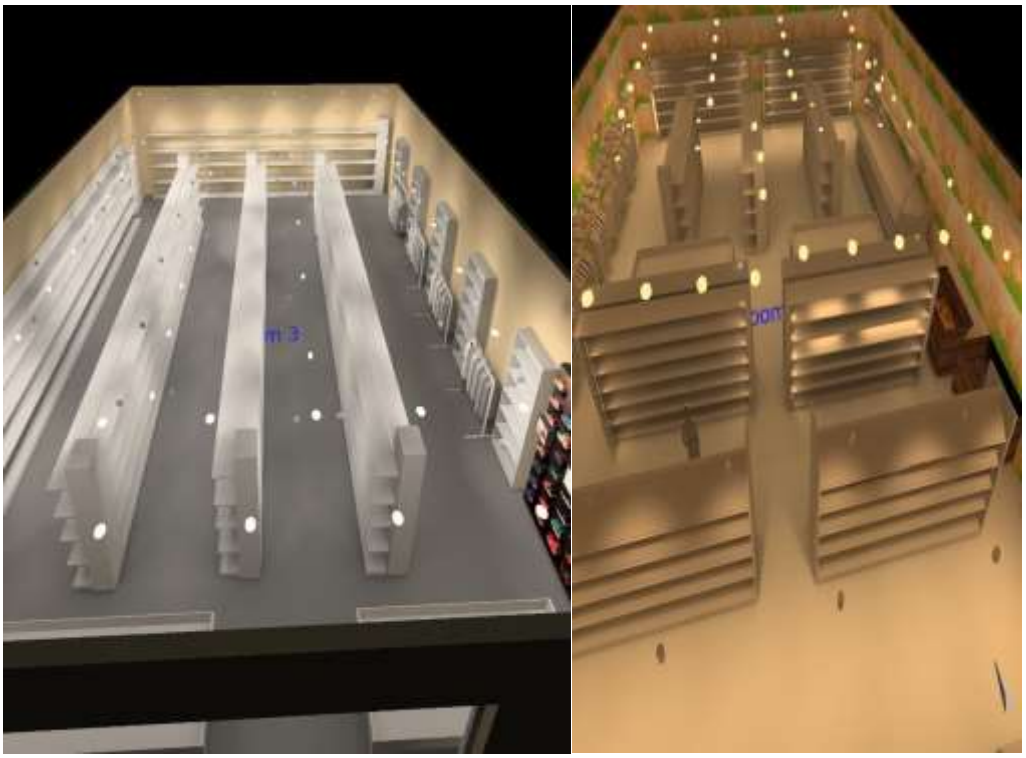


Fig. no 20: (Figure of two different CCT luminaire lighting system)

3.1.10 LIGHT DISTRIBUTION

When illuminating object, the right distribution of light chosen is important. Lamp distribute light differentially. Luminaire and lamp manufacturers provide lamp luminous intensity (candela) distribution curve for their light fixture. The light distribution curve provide the designer with important information about the way of light is distributed from the fixtures, and how that light falls upon a surface.
There are two type of light distribution curve mainly 1) symmetrical light distribution curve 2) asymmetrical light distribution curve.

Symmetrical light distribution:

Symmetrical light source distribute light evenly in all direction. This type of lighting is recommended for general lighting of large space.

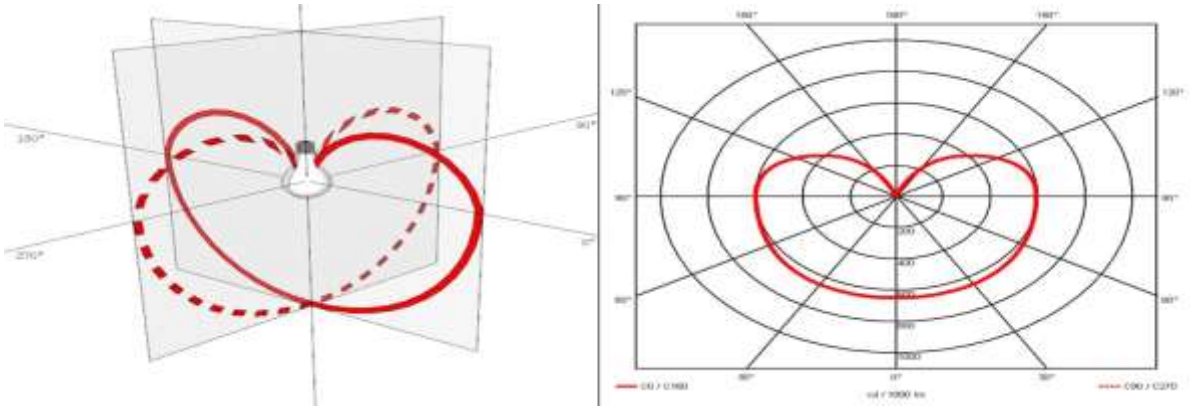


Fig.no: 21 symmetrical luminous intensity distribution

Here lamp position are in center, where two lines radiated from the center. The solid lines indicates the frontal view ($C_{0/180}$), the dotted line the side view ($C_{90/270}$)

Asymmetrical light distribution:

In asymmetrical light distribution light is concentrating in one direction, there fore it can be efficient solution for retail lighting, as it does not produce direct glare.

Below is a asymmetrical light distribution curve pic. Here I take elongated pendent with two separate TL lamps, there are two different type curves. First shape upward beam is spherical(top right), the downward beam is split into two spherical planes, because of in built reflector, the light is block by the reflector in the center

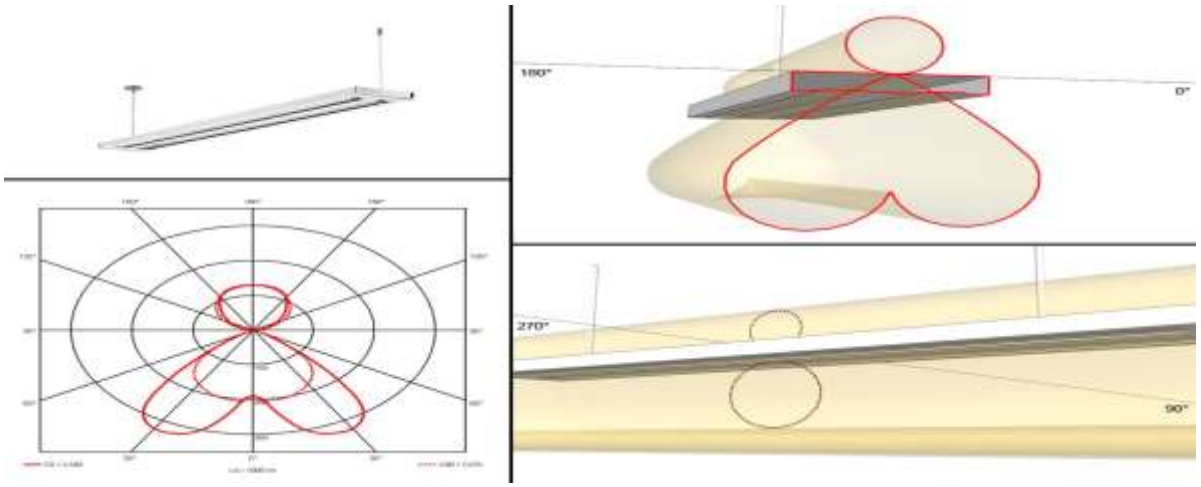


Fig.no 22: Asymmetrical luminous intensity distribution.

The light distribution curve values:

This is always measure starting from the center point of the light source, candle is expression unit of lighting intensity, where larger circle denotes higher value of candela.
Point A in the diagram below tell us that the lighting intensity at 30^0 is 400 candela, in point B the lighting intensity at 20^0 is 800 candela.[29]

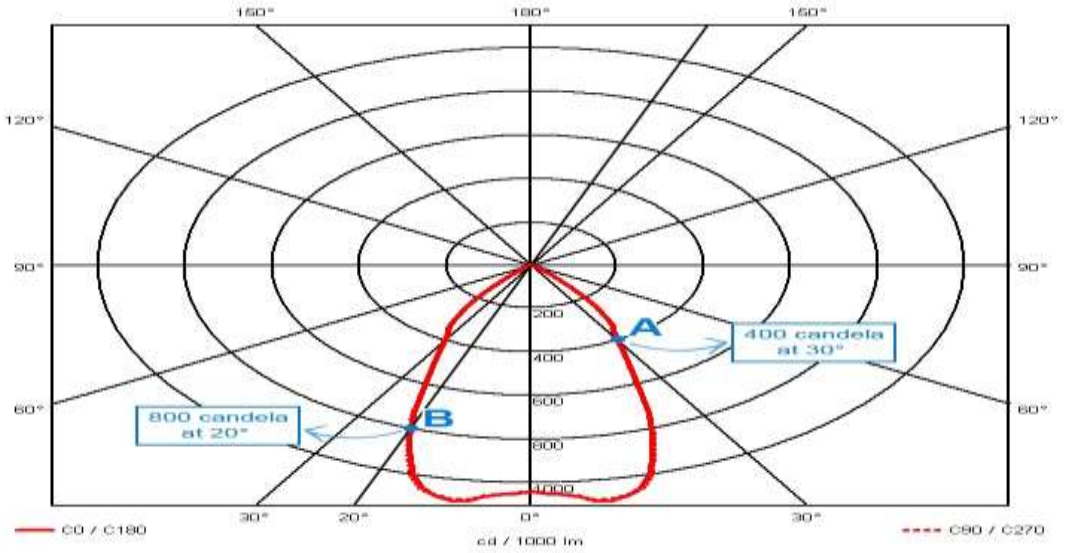


Fig.no 23: Light distribution curve with values

Additional examples: To make understand the concept here I discuss few examples which I used in my DiaLux simulation project.

Much moon (oktalite): It is diffuser type pendent light, it have three types installation like recessed, surface-mounted to three phase track. From intensity curve, we show that it is a down light, used for general lighting.

Fig.no 24 : pendant light luminous intensity curve

Toko recessed (oktalite) : its fresh light illuminates the space homogeneously, accentuated illumination is very easy. Beam angle of this lamp is 28^0 to $60^{0(28)}$. Luminous distribution curve shown that at 15^0 luminous intensity is 1100 candela and at 30^0 luminous intensity is 500 candela.

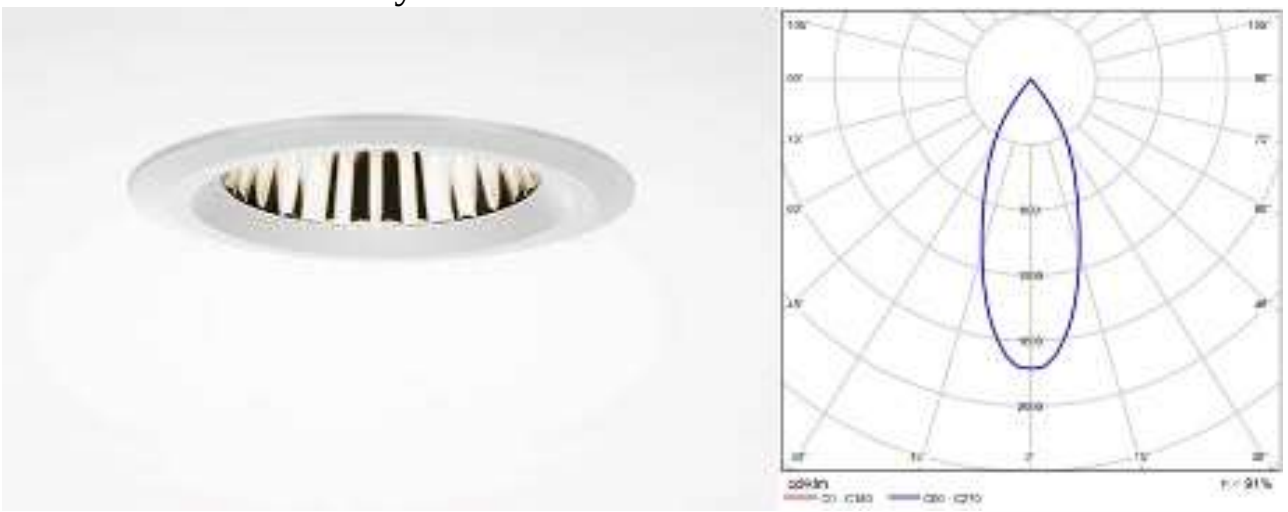


Fig.no 25: Down light (recessed) luminous intensity curve

B.veo track light(oktalite) : high performance track light, applicable for accent lighting, it can be tuned through 355^0 and tilted 110^0. In the case of this luminaire all lumen concentrated in small focus area.
From luminous intensity curve, we show that at 30^0 luminous intensity is 1300 candela and at 7^0 luminous intensity is 2000 candela.

Fig.no 26: Track light luminous intensity curve

3.1.11 SHADOWS AND MODELLING

The appearance of interior side is improved when their structural features, the objects and people within them are lighted. The shapes are revealed clearly, pleasingly and shadows are formed without confusion. This occurs when the light flows noticeable more in one direction than in any other. The term modelling is used to describe the way in which the shapes of three- dimensional objects are revealed by lighting. Requirements for revealing shape and texture for some specific types of task may be necessary in these cases to establish the best solution.

3.1.12 SUSTAINABILITY STANDARD

Aside from the above lighting (like CCT, CRI, Lux level) design standard, there are also guidelines in terms of sustainability. Now in India some retail shops are aiming to achieve a green building certification.

The rating method established criteria for green measure in the construction and uses of structures in order to create more Environmental friendly and sustainable. In India, green building certification is from either LEED (leadership in energy and environmental design) or GRIHA (green rating for integrated habitat assessment).
Energy efficiency is the main concern of sustainability. Lighting designer should maintain Lighting power density (LPD) which is provided by CIBSE(chartered institution of building service engineer). To achieve USGBC – LEED certification, the retail project must get the desire points for different criteria. The intention of green lighting certification in terms of interior lighting is to promote occupants productivity, comfort, and well-being by providing high quality lighting, while reducing waste and energy consumption.

Fig.no 27: logo of LEED (green light) certification.

3.1.13 LIGHTING POWER DENSITY

Energy efficiency is an integral part of lighting design. It has become top priority of a lighting designer. Lighting power density represents the load of any lighting equipment in any defined area. LPD is the lighting load in watts per square feet (watt per square meter). Lighting load should be 40 % [30] of the total load of any commercial building.

To certify any building under ECBC (energy conservation building code) certification the standard of BIS (bureau of Indian standard) should follow.

Lighting power density measured by following two steps

- Building area method
- Space by space method

Building area method

Building area method lists 30 different building type and provides LPD through entire square feet. In this method all fixtures energy consumption are added up then divided by entire building area.

- Determine the allowed lighting power density from below table provide by ECBC for each appropriate building area type.
- Calculate the gross lighted floor area type multiply the allowed watts square meter. Listed for each selected

building type by the corresponding lighted floor areas to determine the allowed LPD

- The sum of all the interior lighting power for various areas of the building cannot exceed the total watts to be in compliance.

TABLE NO 5: Interior lighting power for ECBC building-building area method

CATEGORY	W/m^2
Storage	6.8
Parking bays	2.2
Sales area	18.3
Mall concourse	12.8
Dressing room	9.10
Food preparation	12.1
Family dining	10.9

Space by space method

In space by space method consider each space/room of the building. Space by space 100 space type like class room, corridor etc.
This makes it more complex calculation and requires large number of very individual decision to be made.
Following are the inputs to calculate LPD

- Manufactures lighting fixture data (coefficient of utilization for three room cavity ratio)
- Input characteristics lamp data (lamp lumen depreciation, luminaire dirt depreciation)

In case of retail shop LED lighting LPD by using building area method is 1.5 watt per square feet, while LPD by using space by space area method is 1.7 watt per square feet.[31]

3.2 LIGHTING TECHNIQUE OF DIFFERENT PARTS OF RETAIL SHOP

The different parts of the retail store need to be lit differently because of all the different sections of the retail store stock different types of products and items. Based on the type of items retail store divide with various sections.

3.2.1 GROCERY SECTION:

One of the important parts of the retail store is the grocery section. It is where all the dry food products can be found. Here the products are packed in huge plastic bags, bottles, bags, or boxes. These food item are normally stacked up in parallel shelves running through long corridor. The ratio that can be used for lighting in these section vertical to horizontal can be **2 : 1**[32] to effectively bring out the colors of the package and make them look bright and clear. Neutral white (3000k to 3500k) lighting is suitable for grocery.

3.2.2 VEGETABLE & FRUIT & OTHER PERISHABLE SECTION :

In many retail store, the vegetable and fruit department is in the central area of the store. The display of fresh, healthy and tasty products triggers the customer attention on the task of buying food.
Directional lighting with bight and warm white light focusing on these items can be of great help. A warm and brilliant light (CCT 3000K) with CRI > 85 similar to daylight, brings out the original color and texture of the merchandise.

3.2.3 BAKERY SECTION:

Lighting for bakery should makes it looked delicious as if just taken out of oven, so the right light to be directed without causing glare. For delicate products like cheese, pastry, bread, cake, lighting is essential but protection against heat and UV rays is critical. This is where quality LED light can help ensure freshness while reducing any negative impact like UV

emission. Warm color (CCT 2700k) such as yellow, brown with CRI > 90 is ideal for bakery.

Fig no 27: bakery section pic

3.2.4 FISH & FISHMONGER SECTION:

- To optimally light fish and aquaculture products always recommends using LED accent lighting to enhance presentation of fresh fish on ice.
- It is recommend to create an average light level of around 750-1000 lux on display. This is important because the right amount of light is needed to create a pleasant atmosphere in the fresh fish area and to attract the attention of customers.
- Assuming a spacing of 1.8 meters between luminaires.

. For mounting height 3 meter use 1700 lumen package luminaire.

. For mounting height greater than 3 meter use 2700 lumen package luminaire.

- Create evenly distributed light without harsh peak illuminances.
- Uniformity should be 0.6, therefore use an wide beam light.[33]

3.2.5 FREZERS AND COOLERS SECTION:

Customers appreciate a well stock chiller and freezer section that everything they need, milk and other dairy products, pre-packed meats, frozen food, fruit juice and soda. This is an area filled with ‘glass showcase’. Direct and indirect led lighting fixture on the ceiling and cove lighting are suitable to provide comfortable light with minimum glare. Freezers have to be

illuminated uniformly across the entire surface without any point of special focus. A colder light about 4000k is also important to visual communicate coolness and freshness. To ensure this effect, we provide LED luminaire suitable for any type of refrigerator and freezer.

3.2.5 **WAREHOUSE AND COLD STORE:**

Ease of operation tops the list when it comes to designing a warehouse. High visibility enables through optimal lighting means a safer and smarter work place that can run efficiently for 24/7. Strong focused lighting and extraordinary color temperature and rendering most recommended light for warehouse, linear high pressure sodium vapor, metal halide, fluorescent light we can use. But when we use LED warehouse light fixture. It can be less expensive.

Fruit vegetables and other perishable goods stored in distribution center need controlled condition to preserve them. The operating temperature of cold store area often lies between 5°C to 8°C[34] and sometimes down to -30°C. Lighting solutions for these areas must provide a long service life and low maintenance for minimum disruption. Therefore we need a robust luminaire with high IP and IK rating to avoid breakages, faults, and damage.

Fig.no 28 : weather proof luminaire

weather proof luminaire used for extreme weather condition of cold store area for retail business.

3.2.6 CLTHING STORE

In retail cloth stores, lighting has a major influence on how consumers arrive at in store purchase decisions. Lighting is a powerful form of visual communication between the retailer and the consumer and is keys to the overall success of the shopping experience.

In clothing section illumination, we follows few tips which help the merchandise to sell more products

- Use accent lighting to highlight specific display or items. Accent light can be in ceiling or track mounted.
- Accent lighting aiming is angled, either upward facing or downward facing, depending on the location and type of cloth, that is why it is important to check from every angle.
- Choose bright light non display area, such as dressing rooms.

Lighting in the dressing room should be the best to make the customers look good after wearing the selected outfit.

- Use ambient lighting as a filler, suggested lux level of accent to ambient lighting is 3 to 1, if ambient lighting lux level 250, then accent lighting lux level will be 750.
- The contrast created by vertical illuminance in clothing section are important in creating a visual hierarchy that helps the customer navigate the shop more easily.
- In apparel section, prefer vertical LED lighting over horizontal lights. Temperature ranging between 3000k – 4000k is very effective when displaying apparels.

3.2.7 CASH COUNTER

Cash counter is the final encounter of the customers to sales staff. This section of retail is the last time that the customer will check the merchandise. Here, lighting must help the staff to do their task, therefore lighting must have the right level for rendering, writing and checking for avoid error.

Illuminance level of this section should be 500 lux, good color rendering at least 80 require

Counter should well lit to avoid errors. Luminaires should be glare minimizing, with an area UGR<19, similar to office light recommended values.
Suspended luminaire helps the cash counter to recognize easily, down lights is also use here for bring the cash counter brighter than sales floor area.

3.2.8 EXIT & EMERGENCY

Emergency lighting is required to illuminate building areas when things go wrong. For example, when the normal electrical supply is interrupted or fire or failure inside the space. In most facilities, the largest part of emergency illumination lights the pathways and exits that lead out of the building. It has intent to evacuation of facility, particularly in the event of failure. The exit sign must also properly illuminated to a surface value of at least 54 lux[35], be a reliable light source, and be distinctive in color. Exit signs are required along the exodus path and at exits, placed to ensure that an exit sign is visible from no more than 100 feet or the listed viewing distance of the exit sign (IBC 1013.1).
If exiting is not required, the emergency lighting should provide security and comfort for the occupants until the general lighting can be restored.

The exit signs are illuminated with the LED lamp source (red and green) making this exit sign very energy efficient and bright with uniform letter illumination.
For emergency lighting we must install 1) individual rechargeable battery for each exit sign, 2) an inverter system or a central rechargeable battery units that converts direct current into alternating current,3) a generator that supplies power at the same voltage and frequency as the utility.

Fig.no 29: emergency exit light in retail space

3.3 THREE WAYS TO LIGHT A RETAIL SHOP

Lighting a retail shop may little complicated, when we are dealing with sophisticated clients. But, if we know the brand or product they are selling, we can easily categorized what kind of lighting design suits for the shop. There are three basic ways to light a retail shop:

- Common
- Formal
- Dramatic

3.3.1 COMMON LIGHTING

The common way of lighting a retail shop is by using one or two types of luminaires. The arrangement is typical and lighting level is uniform in all areas, we can say that common way is like a general lighting style.

The lighting design calculation aims to give better overall uniformity and enough Lux level. Luminaire selection is typically downlights or a combination with another type.

The main objective is to brighten all the areas to encourage customer to feel at ease when entering the premises.

3.3.2 FORMAL LIGHTING

The formal way mostly emphasizes the formality of the space. The selection of luminaire is exquisite but not fancy in design. Light source blend with the aesthetic design of the interior and arrangement of the merchandise. There is a clean arrangement of the luminaires.

Here CRI must be high to show the crisp line of fabric and show the true color and texture of merchandise.

Here CRI must be high to show the crisp line of fabric and show the true color and texture of merchandise.

Here uniform horizontal illumination is requirement for the general area. While vertical illumination is must for shelves and Gonodola light.

Below arrangement of luminaire and architectural integration of lights both in walls and ceiling.

Fig.no 30:- Formal type retail lighting

3.3.3 DRAMATIC LIGHTING

The dramatic way, on the other hand, is by using the luminaire as part of the interior design.The use of fancy design luminaires and spotlights are evident. For dramatic lighting the overall uniformity (U_0) is not part of lighting design calculation as long as there is emphasize on the key merchandise. These shops are either too intimidating on too fancy to look at.

Here three or more types of luminaire. Most of them are integrated

To the architectural decoration.

Fig.no 31- Dramatic type reatil lighting

Further Retail shop divide into three ways according to activity or concentration of customer for certain point of time inside the space:

High Activity:-

Merchandise is usually displayed in bulk and recognizable as it use. Evaluation and viewing time is short, minimal sales assistance and few customer amnesties are available. In this category are mass merchandiser, warehouse sales, grocery and discounts stores, Auto parts departments and hard ware department.

Medium activity:-Merchandise is familiar, but the customer may require time or help in evaluation of quality or usage or in the decision to buy, included in this category are department and stores.

Low activity:-

Merchandise is generally exclusive, of the first quality and highest price personal services and premium customer amenities are expected. Shopping is generally unhurried, included in this category are fashion boutique, designer signature shops, jewelry stores, fine art Gallery.

CHAPTER 4: LIGHT SOURCE, CONTROL DEVICE AND CONTROL PROTOCOL

4.1 LIGHT SORCE

CFL LAMP:

A CFL lamp can be seen as an advanced version of a fluorescent lamp that usually have phosphors. The operation of CFL lamp is that electrons are bound to mercury atoms and excited to the state where they radiate ultra-violet light as they return to a lower energy level. This emitted ultra-violet light is converted into visible light as it strikes the fluorescent coating of the bulb.

CFL radiate a spectral power distribution that is different from the conventional lamp. Imported phosphor formulation have improved the perceived color of the light emitted by CFL.

CFL available in different wattage like 9w, 10w, 11w, 13w, 18w, 20w, 26w, 36w, 40w, 55w.

CFL lamp classified into two categories

- **Non integrated CFL:**
  Non integrated CFL have the ballast installed elsewhere. There are two type non integrated CFL.

  Bi pin tube: designed for a conventional ballast, non-dimmable.

  Quad pin tube: generally paired with electronic ballast and dimmable.
- **Integrated CFL:** integrated lamp combine the tube and ballast in a single unit.

4.2 LED LAMP

A light emitting diode (LED) is a semiconductor device that creates light using solid state electronics. A semiconductor is a material which has electrical conductivity, to a degree between that of a metal and insulator. In the case of LEDs, the conductor material is typically aluminum-gallium-arsenide. Where all of the atoms bond perfectly to their neighbor leaving no free electrons to conduct electric current. In doped material trace impurity elements such as crystalline (silicon and gallium) are inserted to alter the electrical or optical properties. Additional atoms change the balance, either adding free electrons or creating holes where electrons can go. Power applied to this p-n junction excites electrons which are able to recombine with

holes within the device, releasing energy in the form of photon. This effect is called electroluminescence, the result is the creation of light.

The colors of the light is determined by the energy required for electrons to cross the band gap of the semiconductor.

4.2.1 V-I CHARACTERISTICS :

There are different LED characteristics ties which include the color light or wavelength radiation, light intensity. At the time of invention color is only Red. After with the help of new metals (Ga, As & Al) the different colors were formed, which shown in fig no 32.

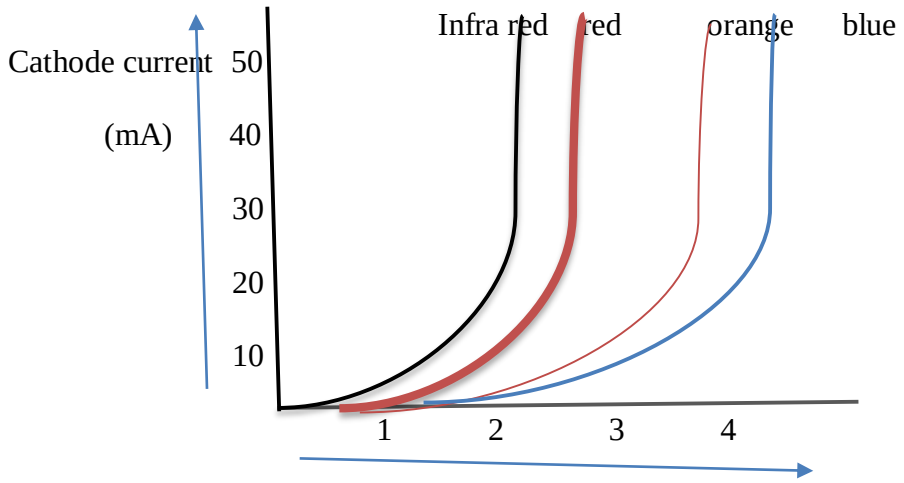


Fig.no 32: V-I characteristic of LED

4.2.2 MEASUREMENT OF LED

LM79: It is approved by illumination engineering society for electrical and photometric measurement. The testing report performed in EPA recognize Lab, provide total luminous flux, intensity, efficacy, wattage voltage characteristics.

LM80: Refers to the measure of lumen depreciation of solid state light source.

TM21: It is a illumination engineering society method for taking LM-80 data and making useful LED lifetime projection.

L70: LED used in fixture typically don't burn out, they just gradually dim over their rated life. An LED is considered to have reached its rated life at that point in time when it emits 30% less light than it initially did. The 70% light level was established as the level at which the human eye can perceive the lumen depreciation.

4.2.3 ADVANTAGES OF LED:

- LED have high efficacy, over 100 lumens per watt.
- They have very long life, around 50000 hours.
- Energy loss through eat is lower in LEDs as compared to the conventional sources.
- LEDs are eco-friendly as they do not contain any lead or mercury.
- LEDs can be controlled very easily, Dimming is possible for 0.1% to 100% without changing the lamp co-related color temperature (CCT) and color rendering index (CRI).
- LED chips are small in size and hence luminaires of any shape and size can be created.
- LEDs emit light in a specific direction, thus reducing the need for reflectors.
- LED reach full brightness instantly with on striking delay.

4.2.4 WHITE LED:

An LED cannot emit white light directly, use two different types of technology in which white LED light is produce. two process are given below.

- Wave length conversion
- Color mixing

Wave length conversion:

In wavelength conversion process, LED's radiation is completely or partially convert to white light. There are some methods of wavelength conversion like blue LED and yellow phosphor, ultraviolet LED and blue, green, red phosphorous.

In blue LED and yellow phosphor conversion process, LED emit blue colour, which is used to excite a yellow color phosphor. This method is least expensive.

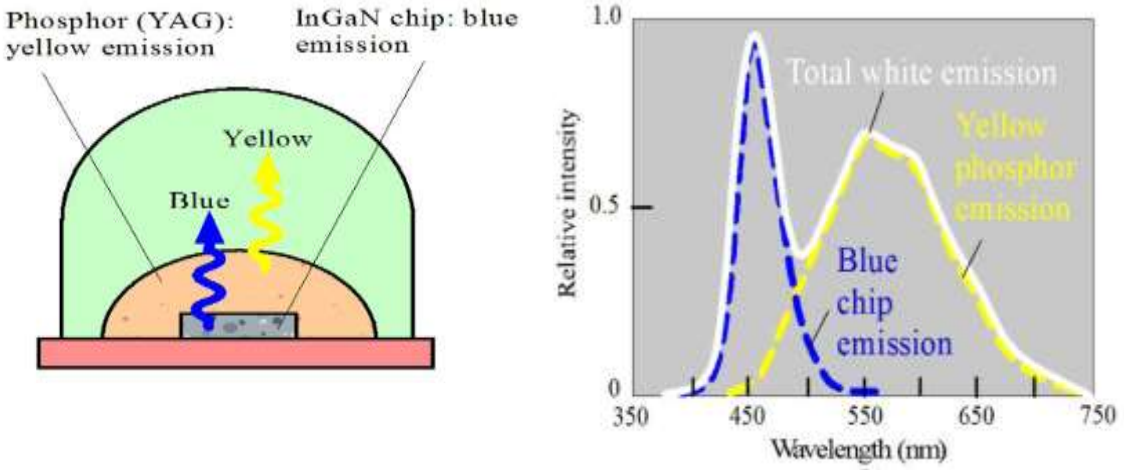


Fig.no 33: white LED with relative intensity curve

COLOR MIXING:

LED emitting the primary colors red, blue, and green are fitted inside a lamp and the intensity of each LED is tuned proportionately to obtain white light. This method has many applications because of the flexibility of mixing different colors and thus color temperature of the white light can be tuned easily.

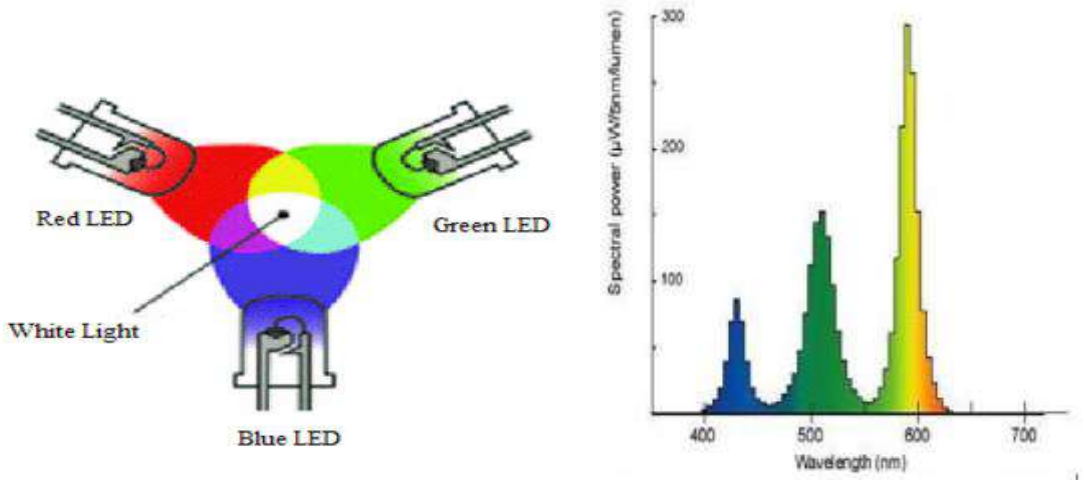


Fig.no 34: LED color mixing and spectral power distribution

4.3 LED DRIVER

LED driver is the brain of an LED lighting system. LED driver consist of voltage divider, bridge rectifier and control circuit. It provides power conversion (higher level ac voltage to lower level dc voltage), load regulation, and downstream component protection, also interface with sensors and wireless communication. Some types LED drivers have additional

electronics to enable precise control of the light output or to support smart lighting. In case of retail shop lighting we used separate LED driver for better dimming. Before connect any driver we must check following details:

- Power requirements: wattage requirements of driver always higher than lights.
- Higher efficiency: the efficiency of an LED driver range is between 80-85%. However, UL class 1 drivers that have the potential to run multiple LED lamps are considered as the most effective.
- Think over power factor: Here the conventional power factor in LED driver is 0.9.

TYPES OF LED DRIVER:

- Constant current type: The characteristics of constant current drive is that the output current is constant. The voltage is change in one range.
- Voltage constant type: Power LEDs that require a fixed output voltage with a maximum current. Here current is regulated by simple resistor, require constant voltage 12v or 24v dc.

4.4 SENSORS

Sensors are very important part of retail space to reduce energy bill gradually. In case of retail space, mainly occupancy or vacancy sensor are used.

OCCUPANCY SENSOR:

An occupancy sensor provides information about the occupancy within its detection range. Occupancy sensor is a device that detect when a space is unoccupied, then lights turn off accordingly.

According to the Lawrence Berking national library, occupancy-based strategies can produce average lighting energy saving of 24%. Occupancy sensing technology types include PIR, HFD,DT.

- Passive Infrared (PIR): The PIR sensor sense the occupant by detecting the change of infrared energy emitted from a warm object in motion. PIR sensor requires an unobstructed line of sight for operation. PIRs come in many configurations for a wide variety of applications. The most common models have numerous Fresnel lenses. Effective range is very short(30 to 40 ft)
- High frequency Doppler (HFD): High frequency Doppler technology operates on the principle of Doppler effect. It sense the presence of occupant by detecting the frequency shift bounced back from a moving object. HFD sensor operate with high frequency radio waves (4 GHZ- 12GHZ). HFD sensors are better at detecting minor motion.
- Dual Technology (DT): Dual technology is mixing of both PIR and HFD. It provide better sensing performance, greatly reduce the possibility of false activating caused by environmental interference.

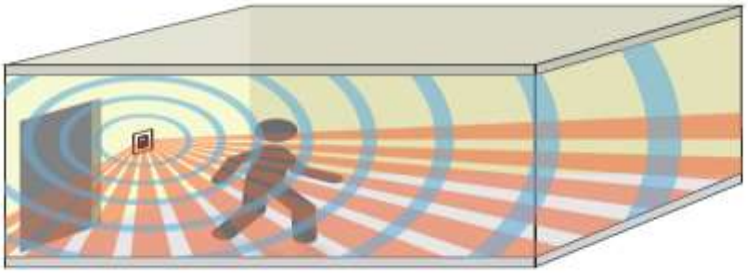


Fig.no 35: Dual type occupancy sensor

4.5 AUTOMATED LIGHTING CONTROL IN RETAIL_SPACE

Dynamic retail lighting is an important factor in successful retails sales. The right lighting can contribute to the saving power and ultimate productivity. Lighting system automatically adjust the output of a lighting device or devices in an automated lighting system. This can be based on time of day or occupancy. It can be controlled by DALI or DMX protocol with the help of different kinds of sensor.

Working function:

Automated lighting system consist of a main brain or controller, dimming technology, user interface.

Controller:

It controls the on/off timing, speed and brightness of each light Example of control protocol are DALI, DMX-512, KNX based, voice assistance based.

- DALI: DALI stand for digital addressable lighting interface. It is a two ways communications protocol that is used to control and communicate in lighting system. DALI permits the digital controlling of each lighting fixture in a given lighting system. This means it can offer more precise light level control and more consistent dimming. A DALI loop has a single DALI controller, a bus power supply and DALI drivers. A DALI loop supports up to 64 drivers. When more than 64 devices are needed, add additional loops to the installation. DALI drivers must be configured as part of the system start up.

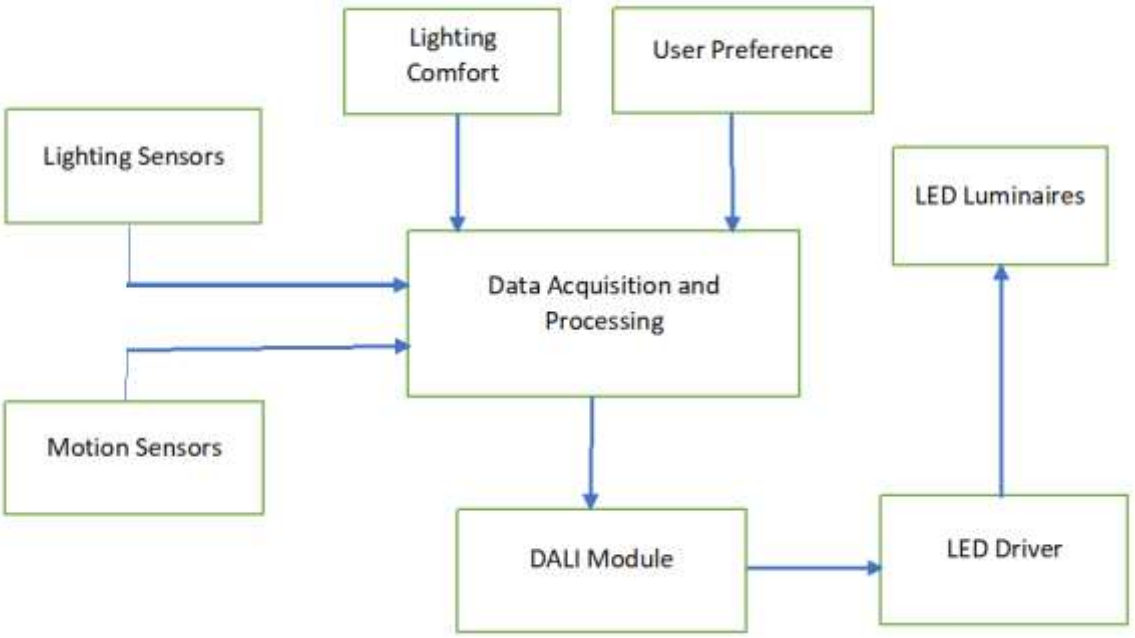


Fig.no 36: DALI module Block diagram

- DMX-512: DMX-512 is a standard for digital communication networks that used to control lighting. DMX-512 uses a unidirectional signaling at its physical layer. This control

protocol does not include automatic error checking and correction, therefore it is not prefer to busy side of the space.

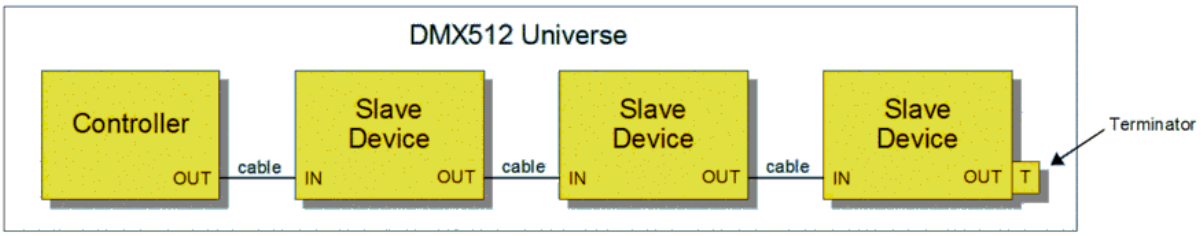


Fig.no 37: DMX module Block Diagram

KNX based system: KNX is an open standard for commercial and domestic building automation. KNX devices can manage lighting, blinds and shutters, HVAC, security systems, energy management, audio video, white goods, displays, remote control, etc.

PoE Based system: PoE lighting uses Power over Ethernet technology to connect, monitor, and control LED light fixtures used in smart lighting. Smart PoE lighting reduces installation and operating costs
by more than half and helps owners meet wellness and sustainability.

Mobile app and voice assistance: This type of technology used in the lighting system, smart lights are controlled using smart phone apps or smart voice assistants (Google Assistant, Alexa, Siri etc.) by connecting them to the internet or bluetooth via a smart HUB, gateway or directly.

Dimming control Technology: It control a wide range of light sources. Dimming driver can dim LEDs by a reduction in the forward current, pulse width modulation via digital control. LED drivers are the crucial component in dimming technology for LED lighting. There are two methods of dimming control.

- PWM : An LED driver that dims by using PWM is switching the power to the LED s on and off. The longer the on pulses the brighter the LEDs will appear to be and vice-versa, provided this takes place at frequency greater than about 200 Hz any flickering will not be visible to the human eye and the brain will average the perceived level of brightness.

- AM : Here the driver simply increase or decreases the output currents to the LEDs. The risk of flicker is eliminated, but some LEDs change colours slightly if their current is altered, especially at low level.

Some LED driver manufacturer use a combination of PWM and AM to achieve an optimal performance.

CHAPTER 5 DESIGN & COMPARISON

5.1 DESIGN CONSIDERATION:

All the consideration for the design are given below table, some of the considerations are as per standard.

Table.no 6: Lighting design parameters and its value.

PARAMETER	VALUES
Shop Dimension	15 m × 12 m
Shop height	3.5 meter
Mounting Height with Luminaire	2.9-3.5 meter
Height of calculation Surfaced placed(if any)	1m from floor level
Light loss factor	0.8
Maintenance factor	0.82
Reflector factors	Ceiling 70%, walls 52% Floor 20%
Maintained average Illuminance	>450
Overall uniformity	
Unified glare rating	<= 22 (over all area)

5.2 PHOMETRIC DATA OF LUMINAIRES & LAMPS

1. CFL lamp (cooper lighting): -Portfolio 6 inch CFL shallow horizontal recessed downlight fixture self flanged lensed diffuse glass specular clear trim.
    - Technical data:

Article No - CD6S142E- 6CLS1421LI2G, Φ_{lamp}(lumen package)- 2400 lm,

$\Phi_{luminaire}$(lumen package) – 1215 lm, luminous efficacy – 39.11 lm/watt

Wattage- 31.1 w, CCT- 3000k, CRI- 100, ή(efficiency) – 50.65%

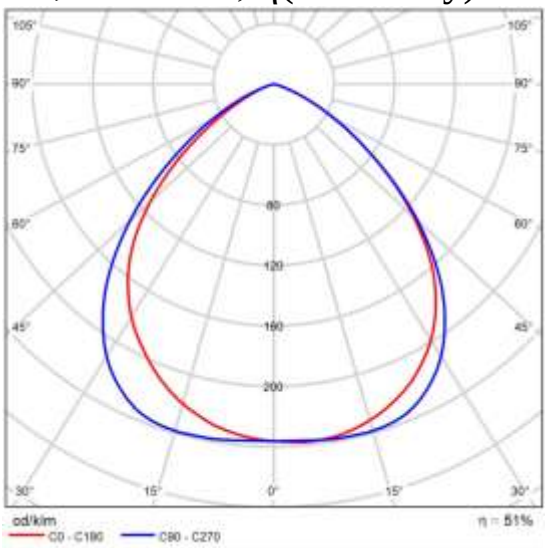


Fig.no 38: CFL lamp & luminous intensity curve

2. Endo lighting- fixed down light
    - Technical data:

Article No - ERD6280W, wattage- 18.7 w, Φ_{lamp}(luminous output)- 1740 lm

$\Phi_{luminaire}$ – 1740 lm, luminous efficacy- 93.0 lm/w, ή (efficiency) - 100%

CCT- 5000k, CRI- 82

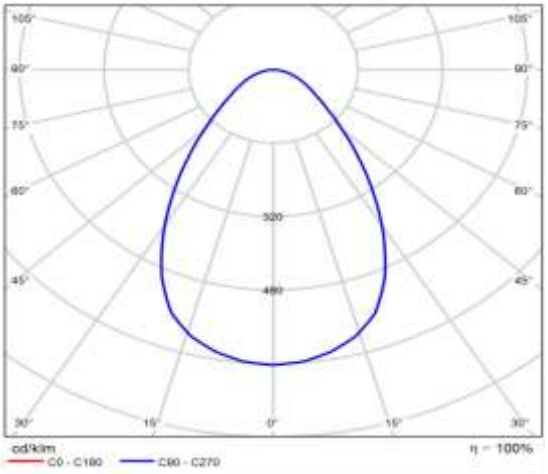


Fig.no 39: LED light and luminous intensity curve

3. Down lights 8″ 15 w 3000k-6000k

Technical data:

Article No-DLI15CCB, wattage-14.7, Φ_{lamp}(luminous output)- 1715 lm

Luminous efficacy-117 lm/w, CCT-3000k, CRI-100

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	19.8	21.1	20.1	21.3	21.5	19.6	20.9	19.9	21.1	21.4
	3H	20.8	22.0	21.1	22.2	22.5	20.6	21.7	20.9	22.0	22.3
	4H	21.1	22.2	21.4	22.5	22.7	20.8	21.9	21.2	22.2	22.5
	6H	21.1	22.1	21.4	22.4	22.7	20.9	22.0	21.3	22.2	22.6
	8H	21.0	22.0	21.4	22.3	22.6	20.9	21.9	21.3	22.2	22.5
	12H	21.0	21.9	21.4	22.3	22.6	20.9	21.8	21.3	22.2	22.5
4H	2H	20.2	21.3	20.6	21.6	21.9	20.1	21.2	20.5	21.5	21.8
	3H	21.4	22.4	21.8	22.7	23.0	21.2	22.2	21.6	22.5	22.8
	4H	21.8	22.6	22.2	23.0	23.4	21.6	22.4	22.0	22.8	23.1
	6H	21.8	22.6	22.3	22.9	23.3	21.7	22.5	22.2	22.9	23.2
	8H	21.8	22.5	22.2	22.9	23.3	21.8	22.4	22.2	22.8	23.2
	12H	21.8	22.4	22.2	22.8	23.2	21.7	22.4	22.2	22.8	23.2
8H	4H	21.9	22.6	22.4	23.0	23.4	21.7	22.4	22.2	22.8	23.2
	6H	22.0	22.5	22.4	22.9	23.4	21.9	22.5	22.4	22.9	23.4
	8H	21.9	22.4	22.4	22.9	23.3	22.0	22.5	22.4	22.9	23.4
	12H	21.9	22.3	22.4	22.8	23.3	22.0	22.4	22.5	22.9	23.4
12H	4H	21.9	22.5	22.3	22.9	23.4	21.7	22.3	22.1	22.7	23.2
	6H	22.0	22.4	22.4	22.9	23.4	21.9	22.4	22.4	22.8	23.3
	8H	21.9	22.3	22.4	22.8	23.3	22.0	22.4	22.4	22.8	23.3
Variation of the observer position for the luminaire distances S											
S = 1.0H		+0.2 / -0.3					+0.2 / -0.3				
S = 1.5H		+0.4 / -0.8					+0.4 / -0.7				
S = 2.0H		+0.9 / -1.5					+0.8 / -1.4				
Standard table		BK03					BK03				
Correction Summand		4.3					4.2				
Corrected glare indices referring to 1715lm Total luminous flux											

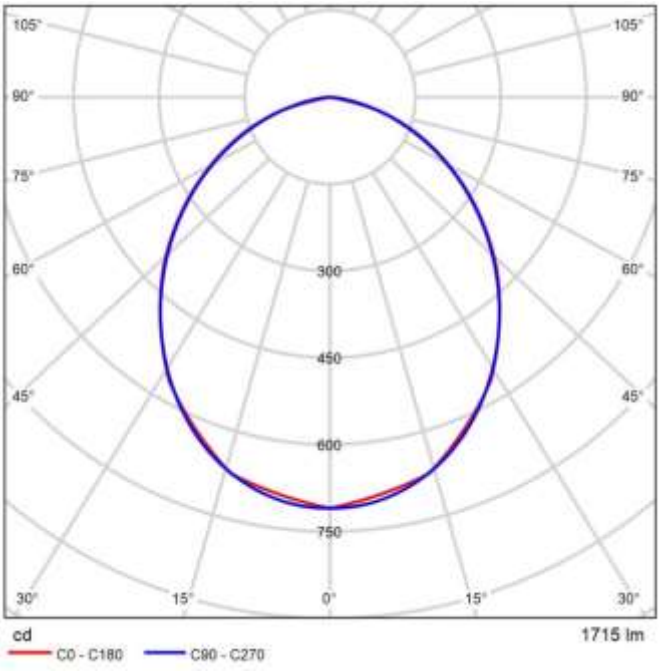
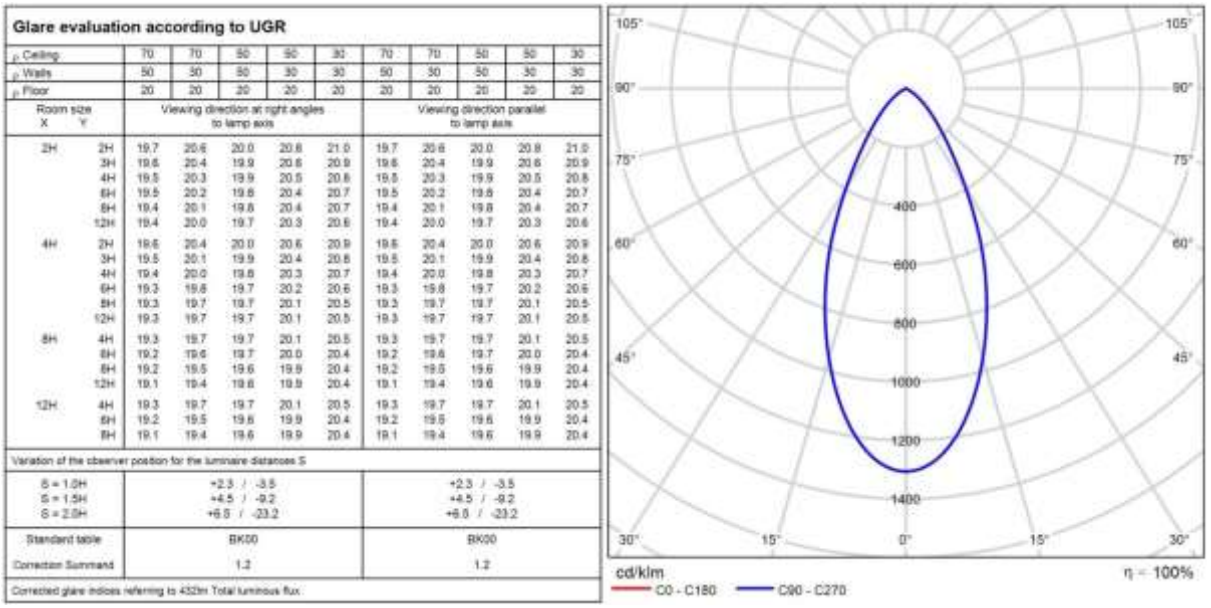


Fig. no 40: LED UGR table and luminous intensity curve

4. EMPOLI 200 mA MWFL 4000k Ra 90

Technical data:

Wattage- 8.7 w, $\Phi_{luminaire}$(luminous output)- 432 lm , luminous efficacy- 49.6 lm/w



Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	19.7	20.6	20.0	20.8	21.0	19.7	20.6	20.0	20.8	21.0
	3H	19.6	20.4	19.9	20.6	20.9	19.6	20.4	19.9	20.6	20.9
	4H	19.5	20.3	19.9	20.5	20.8	19.5	20.3	19.9	20.5	20.8
	6H	19.5	20.2	19.8	20.4	20.7	19.5	20.2	19.8	20.4	20.7
	8H	19.4	20.1	19.8	20.4	20.7	19.4	20.1	19.8	20.4	20.7
	12H	19.4	20.0	19.7	20.3	20.6	19.4	20.0	19.7	20.3	20.6
4H	2H	19.6	20.4	20.0	20.6	20.9	19.6	20.4	20.0	20.6	20.9
	3H	19.5	20.1	19.9	20.4	20.8	19.5	20.1	19.9	20.4	20.8
	4H	19.4	20.0	19.8	20.3	20.7	19.4	20.0	19.8	20.3	20.7
	6H	19.3	19.8	19.7	20.2	20.6	19.3	19.8	19.7	20.2	20.6
	8H	19.3	19.7	19.7	20.1	20.5	19.3	19.7	19.7	20.1	20.5
	12H	19.3	19.7	19.7	20.1	20.5	19.3	19.7	19.7	20.1	20.5
8H	4H	19.3	19.7	19.7	20.1	20.5	19.3	19.7	19.7	20.1	20.5
	8H	19.2	19.6	19.7	20.0	20.4	19.2	19.6	19.7	20.0	20.4
	8H	19.2	19.5	19.6	19.9	20.4	19.2	19.5	19.6	19.9	20.4
	12H	19.1	19.4	19.6	19.9	20.4	19.1	19.4	19.6	19.9	20.4
12H	4H	19.3	19.7	19.7	20.1	20.5	19.3	19.7	19.7	20.1	20.5
	8H	19.2	19.5	19.6	19.9	20.4	19.2	19.5	19.6	19.9	20.4
	8H	19.1	19.4	19.6	19.9	20.4	19.1	19.4	19.6	19.9	20.4

Variation of the observer position for the luminaire distances S

S = 1.0H	+2.3 / -3.5	+2.3 / -3.5
S = 1.5H	+4.5 / -9.2	+4.5 / -9.2
S = 2.0H	+6.8 / -23.2	+6.8 / -23.2
Standard table	BK00	BK00
Correction Summand	1.2	1.2

Corrected glare indices referring to 4321m Total luminous flux

Fig no 41: LED UGR table and luminous intensity curve

5. Toko plus- FL 9016 (trilux lighting)

Technical data:

Wattage- 36 w, Φ_{lamp}(luminous output) - 5210 lm, $\Phi_{luminaire}$(luminous output)- 4759 lm

Beam angle 28^0 to 60^0, luminous efficacy- 132.2 lm/w

ή(efficiency) - 91.34%, CCT- 3000k, CRI- 100

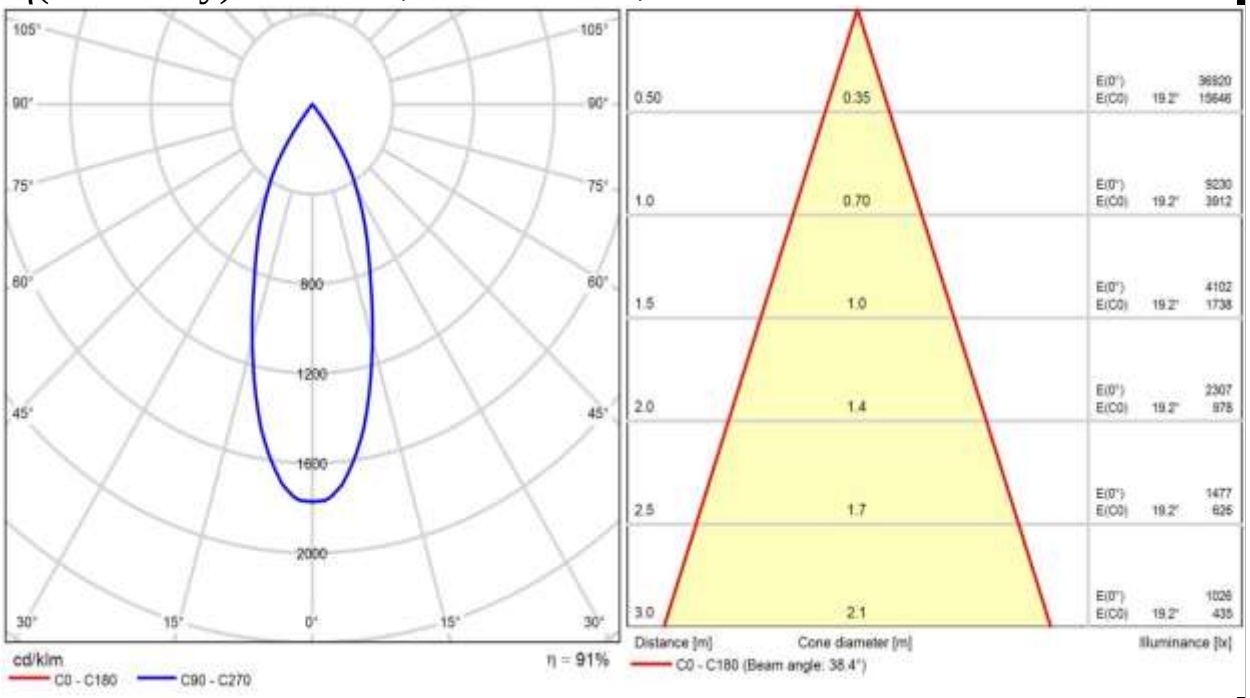


Fig.no 42: luminous intensity curve and cone diagram

6. Kalo plus-9016 (Trilux lighting)

Technical data :

TRACK light, beam angle -36.8 ^{0}, wattage-36 w, Φ_{lamp}(luminous output)- 5210 lm, $\Phi_{luminaire}$(luminous output)-4538 lm, ή(efficiency)- 87.10%

Luminous efficacy- 126.1 lm/w, CCT-3000k, CRI-100
Optic- 3D Face reflectror.

Fig. no 43: spot LED (track) light and luminous intensity curve

7. Amerlux 24-2F LED

Technical data:
Article no- PROD-WW-LED-E-WT-24-120-3000, wattage- 47.3 w $\Phi_{luminaire}$-3154 lm, luminous efficacy- 66.7 lm/w, CCT- 3000k CRI- 100.

Glare evaluation according to UGR

ρ Ceiling	70	70	50	50	30	70	70	50	50	30
ρ Walls	50	30	50	30	30	50	30	50	30	30
ρ Floor	20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	23.8	25.1	24.1	25.3	25.5	21.1	22.4	21.4	22.6	22.8
	3H	25.1	26.2	25.4	26.4	26.7	22.4	23.5	22.7	23.7	24.0
	4H	25.5	26.6	25.9	26.8	27.1	22.9	23.9	23.2	24.2	24.5
	6H	25.8	26.8	26.2	27.1	27.4	23.2	24.1	23.5	24.4	24.7
	8H	25.9	26.8	26.3	27.1	27.4	23.3	24.2	23.6	24.5	24.8
	12H	25.9	26.8	26.3	27.1	27.5	23.3	24.2	23.7	24.5	24.8
4H	3H	24.0	25.1	24.4	25.3	25.6	21.8	22.8	22.1	23.1	23.4
	4H	25.4	26.3	25.8	26.6	26.9	23.2	24.1	23.6	24.4	24.7
	6H	25.9	26.7	26.3	27.1	27.4	23.8	24.6	24.2	24.9	25.3
	8H	26.3	27.0	26.8	27.4	27.8	24.2	24.9	24.6	25.2	25.6
	12H	26.5	27.1	26.9	27.5	27.9	24.3	24.9	24.7	25.3	25.7
8H	4H	26.0	26.6	26.4	27.0	27.5	24.3	24.9	24.8	25.3	25.8
	6H	26.5	27.0	26.9	27.4	27.9	24.0	24.6	24.4	25.0	25.4
	8H	26.6	27.1	27.1	27.5	28.0	24.5	25.0	25.0	25.5	25.9
	12H	26.7	27.1	27.2	27.6	28.1	24.7	25.1	25.2	25.6	26.1
12H	4H	26.0	26.6	26.4	27.0	27.4	24.8	25.2	25.3	25.6	26.1
	6H	26.5	26.9	27.0	27.4	27.9	24.0	24.6	24.4	25.0	25.4
	8H	26.7	27.0	27.2	27.5	28.0	24.6	25.0	25.0	25.5	25.9
							24.8	25.1	25.2	25.6	26.1

Variation of the observer position for the luminaire distances S

S = 1.0H	+0.1 / -0.2	+0.2 / -0.2
S = 1.5H	+0.7 / -0.7	+0.2 / -0.5
S = 2.0H	+1.5 / -1.4	+0.6 / -1.0
Standard table	BK04	BK05
Correction Summand	9.2	7.4

Corrected glare indices referring to 3154lm Total luminous flux

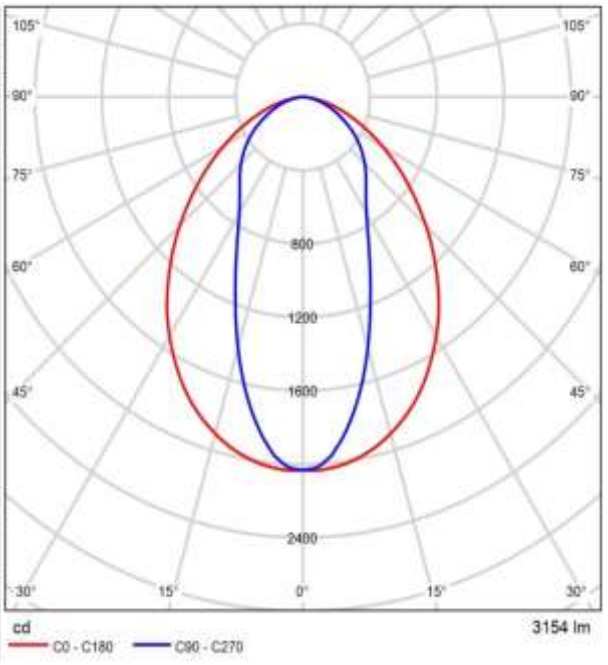


Fig.no-44 LED UGR table and luminous intensity curve

8. Color bright RGB digital pixel LED strip(flexfire)

Technical data:
Article No- CB RGB 24 v, wattage- 8.3 w, Φ_{lamp}(luminous output)- 194 lm

$\Phi_{luminaire}$(luminous output)-194 lm, luminous efficacy-23.4 lm/w, CCT-3000k, CRI-100

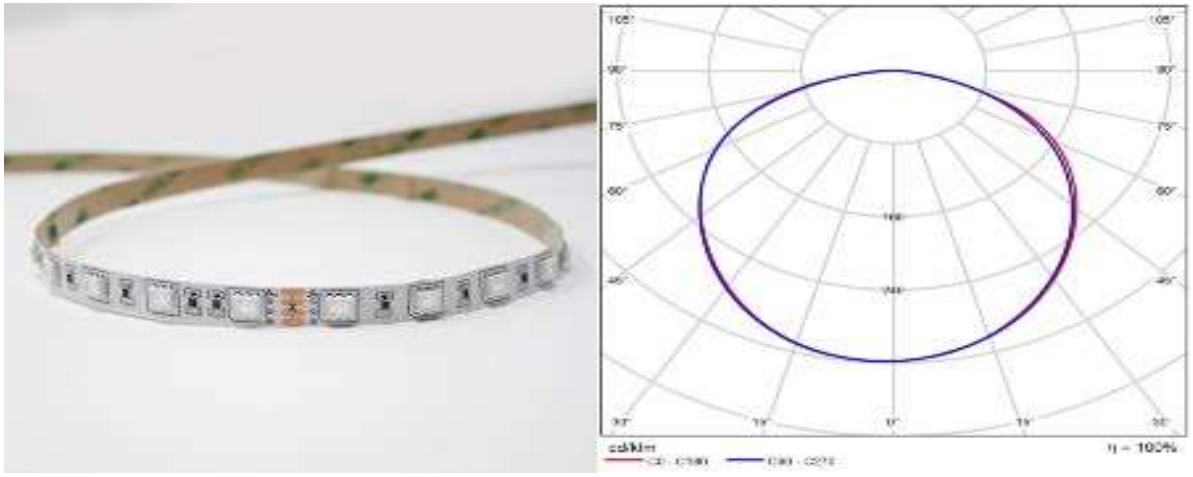


Fig.no-45 LED strip light and luminous intensity curve

9. B.veo- track light (oktalite)-9016

Technical data:

Wattage- 31, Φ_{lamp}(luminous output)-4240 lm,

$\Phi_{luminaire}$(luminous output)-3464 lm, ή(efficiency)- 81.69%

Luminous efficacy-111.7 lm/w, CCT- 3000k, CRI- 100,

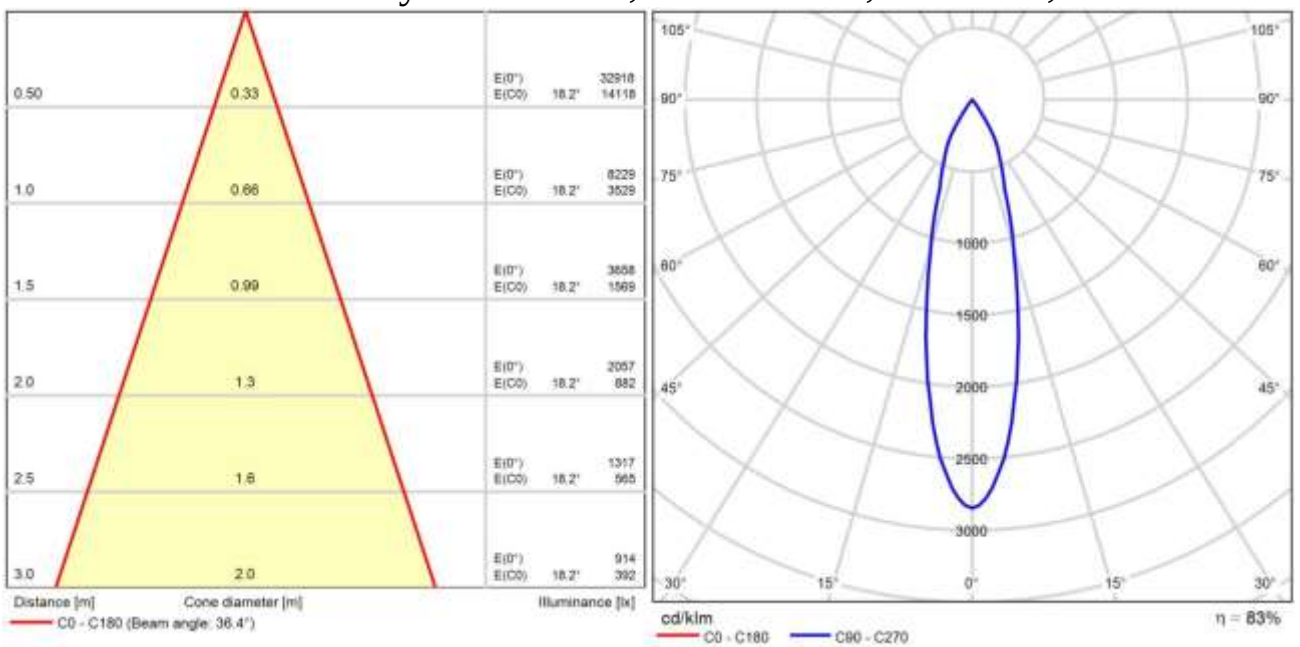


Fig.no 46: Spot LED light cone diagram and luminous intensity table

10.Juno twin 9016

This is the flamboyant track mounted spotlight. It is technically convincing due to its excellent glare suppression. It achieved by the special structure of the rear side of the lense. It has teardrop shaped lense and significant long –distance effect. Application area is asile zone illumination.

Technical data:

Wattage- 36 w, Φ_{lamp}(luminous output)- 5250 lm, $\Phi_{luminaire}$(luminous output)-4064 lm, ή(efficiency)-77.41 Luminous efficacy- 112.9 lm/w, CCT-3000k, CRI-100, material-die cast aluminum.

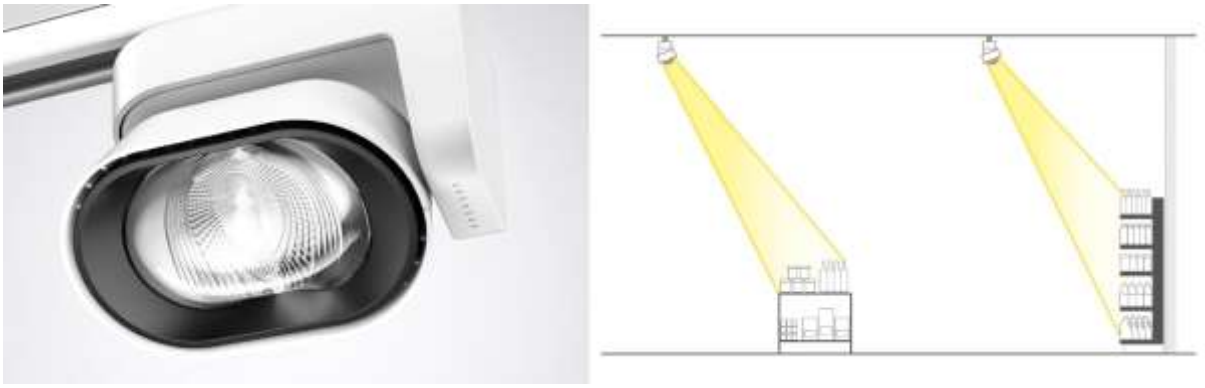


Fig.no-48 LED lights and its aiming pic

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	12.7	13.5	13.0	13.7	13.9	28.0	28.8	28.2	29.0	29.2
	3H	13.2	13.9	13.5	14.2	14.4	27.8	28.6	28.1	28.8	29.1
	4H	13.8	14.5	14.1	14.8	15.0	27.6	28.3	28.1	28.7	29.0
	6H	14.9	15.5	15.2	15.8	16.1	27.7	28.4	28.0	28.6	28.9
	8H	15.8	16.4	16.1	16.7	17.0	27.6	28.3	28.0	28.6	28.9
	12H	17.0	17.6	17.3	17.9	18.2	27.6	28.2	28.0	28.5	28.8
4H	2H	12.8	13.6	13.1	13.8	14.1	27.7	28.5	28.1	28.7	29.0
	3H	13.4	14.0	13.7	14.3	14.6	27.6	28.2	28.0	28.5	28.8
	4H	14.1	14.7	14.5	15.0	15.4	27.5	28.1	27.9	28.4	28.8
	6H	15.6	16.1	16.0	16.5	16.9	27.5	27.9	27.9	28.3	28.7
	8H	16.8	17.2	17.2	17.6	18.0	27.4	27.8	27.8	28.2	28.6
	12H	18.2	18.6	18.7	19.0	19.5	27.4	27.8	27.8	28.2	28.6
8H	4H	14.1	14.5	14.5	14.9	15.3	27.4	27.8	27.8	28.2	28.6
	8H	15.7	16.1	16.2	16.5	17.0	27.3	27.7	27.8	28.1	28.5
	8H	17.2	17.5	17.6	17.9	18.4	27.3	27.6	27.8	28.0	28.5
	12H	19.0	19.2	19.5	19.7	20.2	27.2	27.5	27.7	28.0	28.5
12H	4H	14.0	14.4	14.5	14.8	15.3	27.4	27.8	27.8	28.2	28.6
	6H	15.7	16.0	16.2	16.5	16.9	27.3	27.6	27.8	28.0	28.5
	8H	17.1	17.4	17.6	17.9	18.3	27.2	27.5	27.7	28.0	28.5
Variation of the observer position for the luminaire distances S											
S = 1.0H		+1.3 / -0.7					+4.4 / -8.4				
S = 1.5H		+2.4 / -1.0					+7.2 / -15.0				
S = 2.0H		+2.8 / -1.3					+9.2 / -18.3				
Standard table		—					BK00				
Correction Summand		—					8.4				
Corrected glare indices referring to 5250lm Total luminous flux											

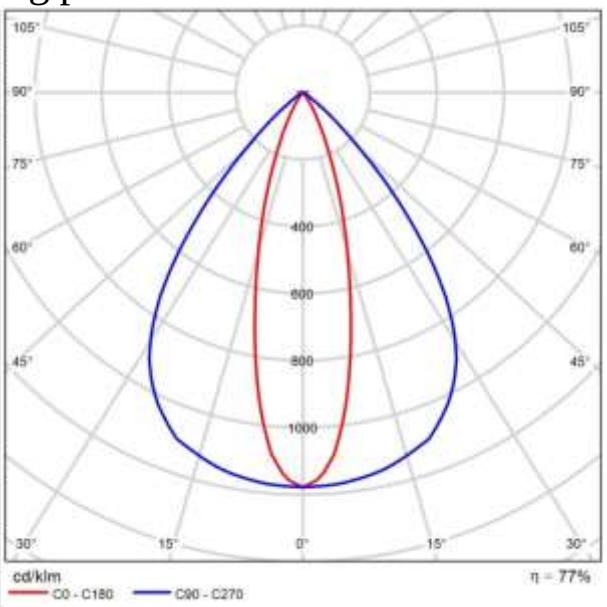


Fig.no 49: LED UGR table and luminous intensity table

11.Much moon pendent light(oktalite)

Technical data:

Wattage-17 w, Φ_{lamp}(luminous output)- 2060 lm, $\Phi_{luminaire}$(luminous output)-2060 lm, ή(efficiency)-100% Luminous efficacy-117.3 lm/w, CCT-3000K, CRI-100,

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	23.8	25.1	24.1	25.4	25.7	23.8	25.1	24.1	25.4	25.7
	3H	25.3	26.5	25.7	26.8	27.1	25.3	26.5	25.7	26.8	27.1
	4H	25.9	27.1	26.3	27.4	27.8	25.9	27.1	26.3	27.4	27.8
	6H	26.4	27.5	26.8	27.9	28.2	26.4	27.5	26.8	27.9	28.2
	8H	26.6	27.7	27.1	28.0	28.4	26.6	27.7	27.1	28.0	28.4
	12H	26.8	27.8	27.2	28.1	28.5	26.8	27.8	27.2	28.1	28.5
4H	2H	24.4	25.5	24.8	25.9	26.2	24.4	25.5	24.8	25.9	26.2
	3H	26.1	27.1	26.5	27.5	27.9	26.1	27.1	26.5	27.5	27.9
	4H	26.9	27.8	27.4	28.2	28.6	26.9	27.8	27.4	28.2	28.6
	6H	27.6	28.3	28.0	28.8	29.2	27.6	28.3	28.0	28.8	29.2
	8H	27.8	28.5	28.3	29.0	29.5	27.8	28.5	28.3	29.0	29.5
	12H	28.0	28.7	28.5	29.2	29.7	28.0	28.7	28.5	29.2	29.7
8H	4H	27.2	27.9	27.7	28.4	28.9	27.2	27.9	27.7	28.4	28.9
	6H	28.0	28.6	28.6	29.1	29.6	28.0	28.6	28.6	29.1	29.6
	8H	28.4	28.9	28.9	29.4	30.0	28.4	28.9	28.9	29.4	30.0
	12H	28.7	29.2	29.3	29.7	30.2	28.7	29.2	29.3	29.7	30.2
12H	4H	27.2	27.9	27.7	28.4	28.9	27.2	27.9	27.7	28.4	28.9
	6H	28.1	28.6	28.7	29.1	29.7	28.1	28.6	28.7	29.1	29.7
	8H	28.5	29.0	29.1	29.5	30.1	28.5	29.0	29.1	29.5	30.1
Variation of the observer position for the luminaire distances S											
S = 1.0H		+0.1 / -0.1					+0.1 / -0.1				
S = 1.5H		+0.2 / -0.3					+0.2 / -0.3				
S = 2.0H		+0.4 / -0.7					+0.4 / -0.7				
Standard table		BK06					BK06				
Correction Summand		11.3					11.3				

Corrected glare indices referring to 2060lm Total luminous flux

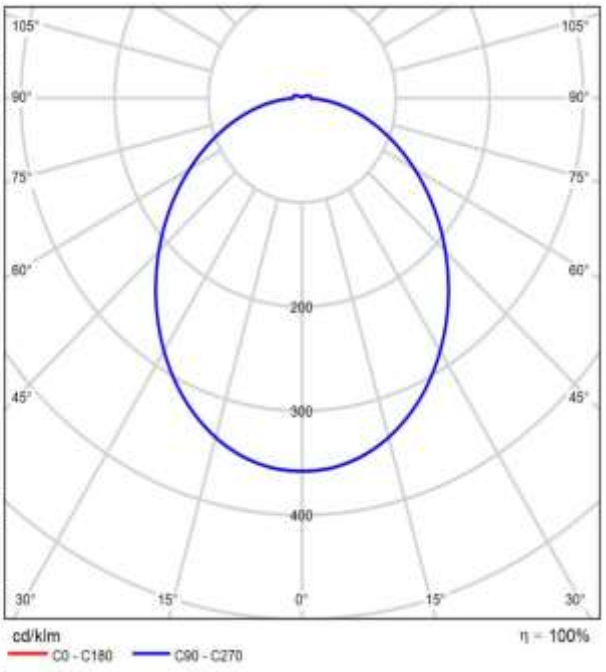


Fig. no 50:LED UGR table and luminous intensity curve

DESIGN DETAILS

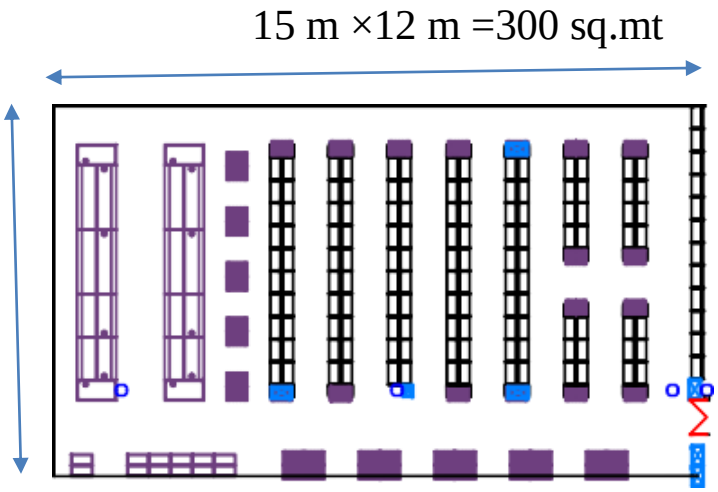
The design of the Retail space with both CFL and LED light fixtures has done. The design summary of some areas, representing one or more such areas, have been shared. It includes all the necessary input data like overall dimension of the room, light loss factor and reflectance factor, height of work plane over which the illumination level is calculated and output data like average level of illumination, overall uniformity, LPD value. It also shows an isolux diagram i.e. the points of similar illuminances joined by a contour. Details of the luminaires used for simulation is also obtained from the summary report. The luminaire photometric data have also been shared the position and mounting height of the luminaires inside the retail space shared in luminaire layout diagram. Report of illuminances on the various sales area and the UGR values obtained for most occupied positions have also been given below.

Lumen maintenance factor (LMF) – 0.69 (CFL), 0.82 (LED)
Lamp lumen maintenance factor – 1.0 (LED)
Lamp survival factor (LSF) - 1.0
Maintenance factor (MF) = RMF × LMF ×LLMF ×LSF= 0.82 (LED)
Mounting height – 3.5 m.
Pollution category – medium to heavy traffic and dust exposure area.

Shop open time consider – 7.5 hours per day and 2.5 hours per night .(10 hours per day)

DIALux EVO lighting designing software used here for lighting design. the flexibility and whole simulation is one of the best feature of evo. The resolution of image and rendering style is also another important feature. EVO is free to all.

5.3 DESIGN OF RETAIL SPACE



this is autocad drawing of retail space including all furniture, which have one entrance, one cash counter, two storey with multiple sections, height of retail space 3.5 meter and total area 2 ×300 sq.mt=600 sq.mt.

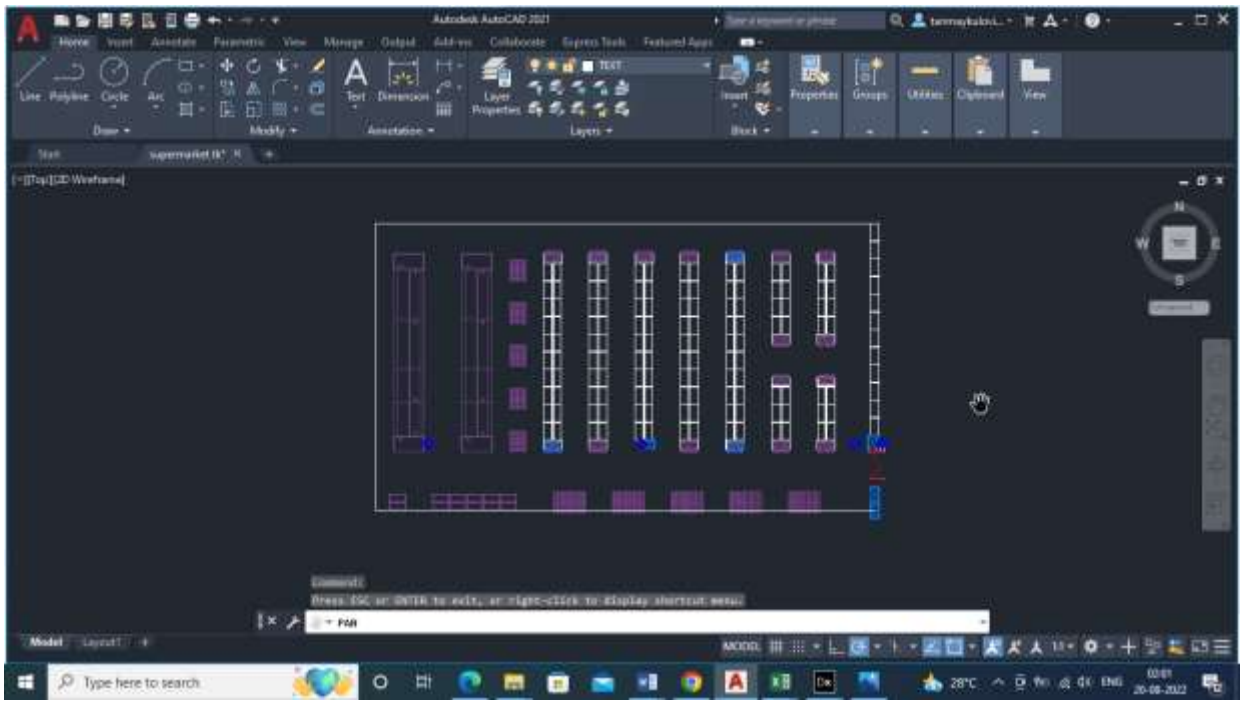


Fig.no 51: autocad design of retail space

5.3 LIGHTING SIMULATION REPORT

LIGHTING DESIGN WITH CFL LUMINAIRE

Room dimension – 15 m× 12m = 300 sq.mt
Shop height- 3.5 m, mounting height- 3.5 m,
Reflectance factor – ceiling (80%), wall (52%) floor (20%)
Luminaire used – CFL, NO of luminaire- 80 pieces(CFL)
g1 consider as overall uniformity, E. max and E. min maximum and minimum illuminance.

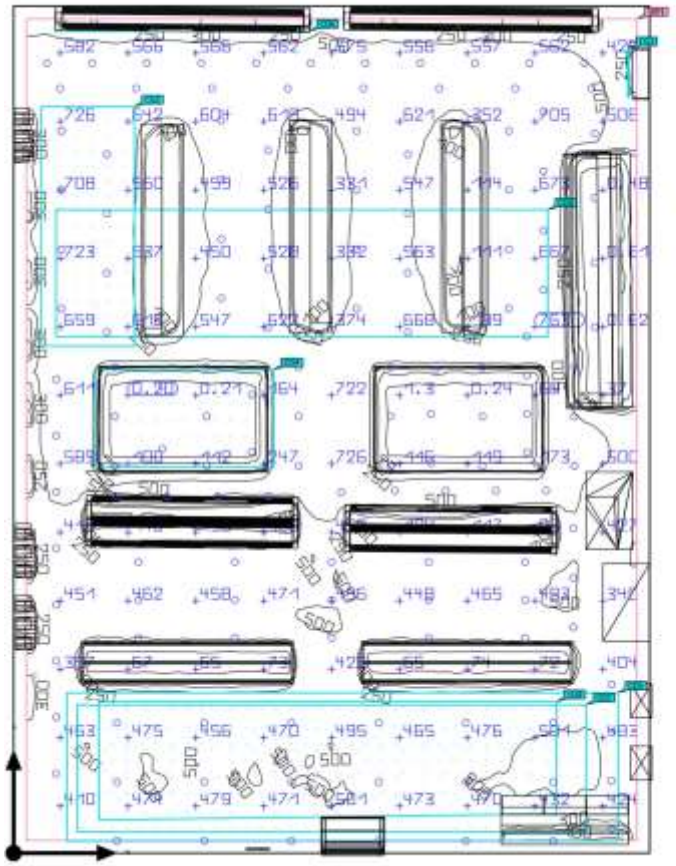


Fig.no 52: layout with lux level of each grid point.(CFL lighting)
Average illuminance and uniformity result:

Results

Symbol	Calculated	Target	Check	Index

Working plane	$\bar{E}_{perpendicular}$	416 lx	≥ 350 lx	✓	WP1
	g_1	0.000	-	-	WP1
	Lighting power density	16.14 W/m²	-	-	
		3.88 W/m²/100 lx	-	-	
Consumption values	Consumption	[1000 - 16250] kWh/a	max. 10550 kWh/a		
Room	Lighting power density	15.03 W/m²	-	-	

DESIGN WITH LED LUMINAIRE

Room dimension- 300 sq.mt
reflectance factor- ceiling (80%), wall (52%), floor (20%)
luminaire used- LED type, NO of LED only for storey-1 – 65 peices

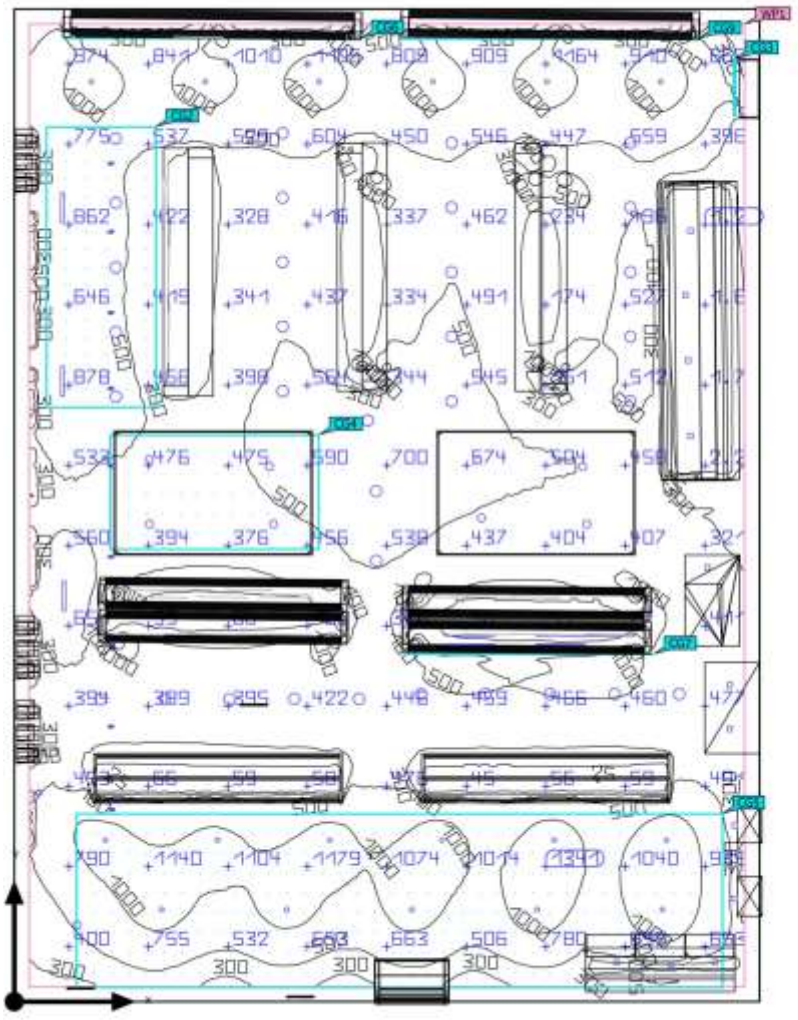


Fig.no 53: layout with lux level each grid point(LED lighting)

Results

	Symbol	Calculated	Target	Check
Working plane	Ēperpendicular	523 lx	≥ 400 lx	✓
	g1	0.52	-	-
	Lighting power density	7.19 W/m²	-	-
		1.37 W/m²/100 lx	-	-
Consumption values	Consumption	[6700 - 7200] kWh/a	Max. 10550 kWh/a	✓
Room	Lighting power density	6.69 W/m²	-	-
		1.28 W/m²/100 lx	-	-

Obtained result:

CFL luminaire lighting (300 sq. mt dimension retail space)

Average illuminance- 416 lux
LPD (lighting per density) – 16.14 w/sq.mt

LED luminaire lighting (300 sq. mt dimension retail space)

Average illuminance - 523 lux
LPD (lighting power density)- 7.19 w/sq.mt

Calculation surface position in retail space: here four calculation surface has been consider for calculation of average illuminance, fruit vegetable section, front space , vertical grocery and cloth store, space between two shelves.

retail space lighting design

DIALux

Building 1 · Story 1 · Room 1 (Light scene 1)

Calculation objects

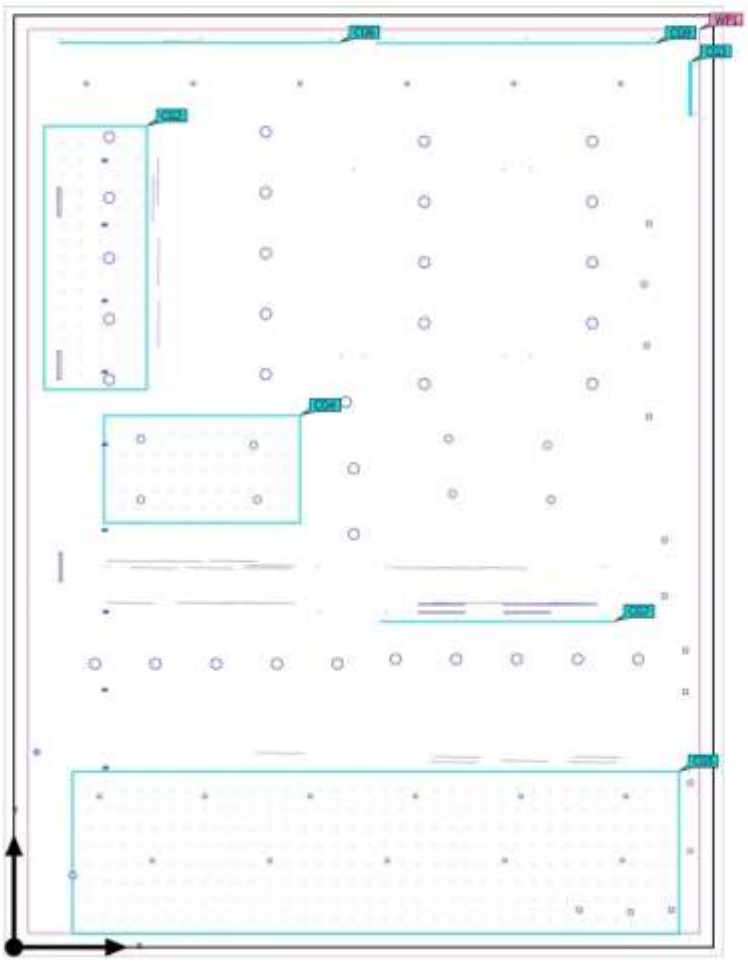


Fig.no 54: Result of all calculation surface and work plane in one page:

Building 1 · Story 1 (Light scene 1)

Calculation objects

Working planes

Properties	Ē (Target)	E_{min}	E_{max}	g_1	g_2	Index
Working plane (Room 1) Perpendicular illuminance (adaptive) Height: 1.000 m, Wall zone: 0.300 m	523 lx (≥ 400 lx)	309 lx	747 lx	0.51	0.47	WP1

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 6 Perpendicular illuminance Height: 0.800 m	602 lx	400 lx	804 lx	0.68	0.49	CG2
Calculation surface 6 Horizontal illuminance Height: 1.00 m	790 lx	459 lx	1000 lx	0.58	0.27	CG2
Calculation surface corner shelves Perpendicular illuminance Height: 1.00 m	391 lx	233 lx	514 lx	0.64	0.41	CG3
Calculation surface corner shelves Vertical illuminance Rotation: 0.0°, Height: 1.00 m	391 lx	232 lx	614 lx	0.64	0.41	CG3
Calculation surface table Perpendicular illuminance Height: 1.00 m	475 lx	391 lx	606 lx	0.82	0.65	CG4
Calculation surface table Horizontal illuminance Height: 1.000 m	526 lx	394 lx	642 lx	0.75	0.61	CG4
Calculation surface front space Perpendicular illuminance Height: 1.00 m	881 lx	381 lx	1381 lx	0.32	0.19	CG5
Calculation surface front space Horizontal illuminance Height: 1.00 m	984 lx	308 lx	1591 lx	0.31	0.26	CG5
						CG6

Above dialux result define summary of all calculation objects.

RESULT OF INDIVIUAL CALCULATION OBJECTS:

Calculation surface 2 (vegetable and fruit section)
Luminaire height-3.5
Height of calculation surface – 1mt
Grid dimension - .3 m × .3m

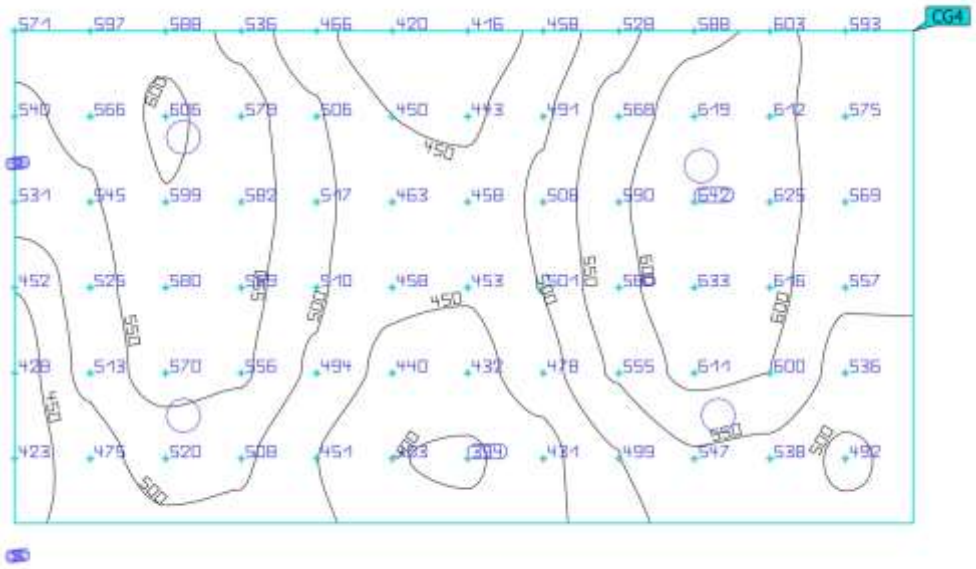


Fig.no 55: iso lux diagram of vegetable and fruit section

Properties	Ē	Emin	Emax	g1	g2	indx
Calculation surface table (vegetable and fruit section) Horizontal illuminance Height: 1.050 m	526 lx	394 lx	642 lx	0.75	0.61	CG4

Obtained result- average illuminance (fruit and vegetable) – 526 lux
Uniformity (g1)= (minimum illuminance/average illuminance) – 0.75, g2(minimum illuminance/ average illuminance) – 0.61

Calculation surface 5 : front space of retail.
Grid dimension- .3m × .3m , luminaire height- 3.5 mt

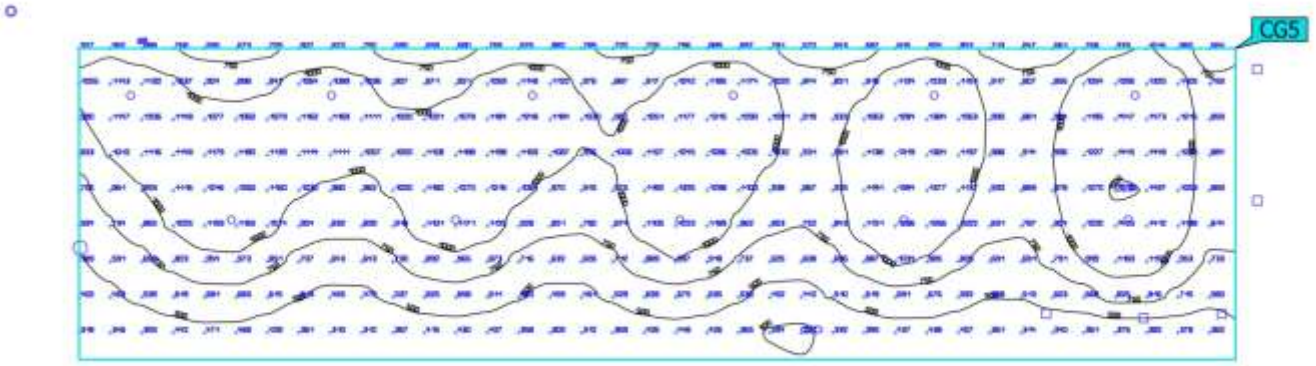


Fig.no 56: iso-lux diagram of front space

Properties	Ē	Emin	Emax	g1	g2	Index
Calculation surface front space Horizontal illuminance Height. 1.050 m	681 lx	381 lx	1018 lx	0.52	0.31	CG5

Obtained result- average illuminance (front or entry zone)- 681 lux
Uniformity (g1= minimum illuminance/average illuminance)- 0.52
Uniformity (g2 = minimum illuminance/ maximum illuminance) – 0.31

calculation surface 6 (cloth store): grid dimension- .3 m× .3m,

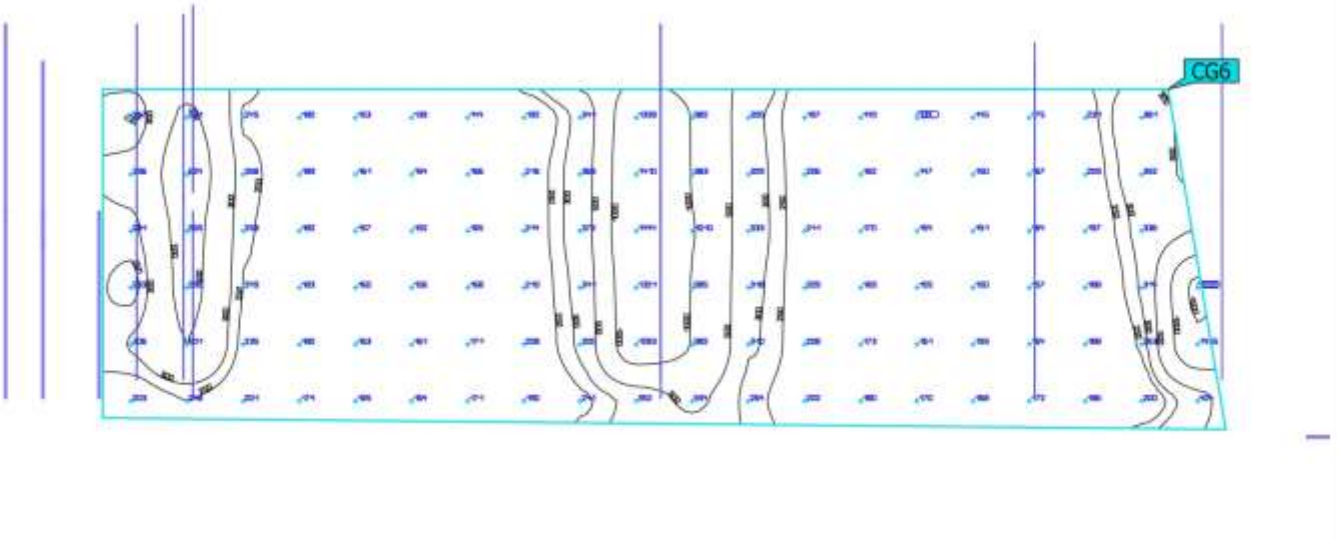


Fig.no 57: isolux diagram of vertical shelves (cloth store)

Properties	Ē	Emin	Emax	g1	g2	Index
vertical shelves (cloth store) calculation Perpendicular illuminance Height: 0.958 m	533 lx	334 lx	792 lx	0.51	0.32	CG6

Obtained result – average illuminance (cloth shelves) - 533 lux
Uniformity(g1= minimum illuminance/average illuminance) - 0.51
Uniformity (g2= minimum illuminance/ maximum illuminance)- 0.32

Calculation surface 2 (between two shelves)
Grid dimension - .3 m × .3 m, luminaire height – 3.5 m

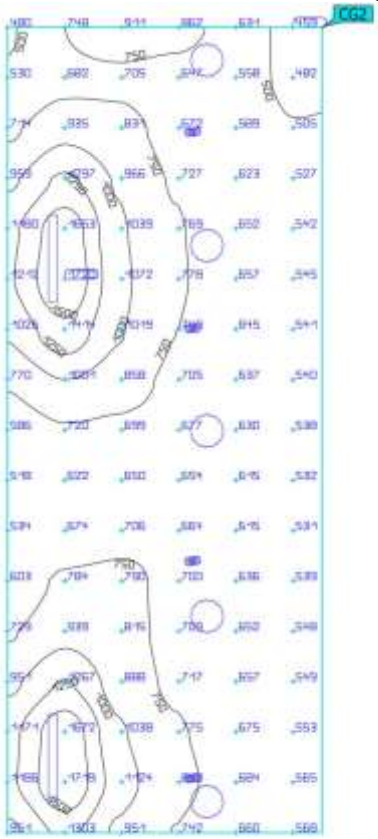


Fig.no 58: iso lux diagram of general lighting (between two shelve of grocery section)

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 6 (between two shelves, grocery) Horizontal illuminance Height 1.00 m	590 lx	259 lx	920 lx	0.58	0.27	CG2

Obtained result – average illuminance (general lighting between two shelves) – 590 lux, uniformity (g1=minimum illuminance/average illuminance) -0.58, uniformity (g2= minimum/maximum illuminanace)- 0.27

LAY OUT OF STOREY 2 OF SAME BUILDING:

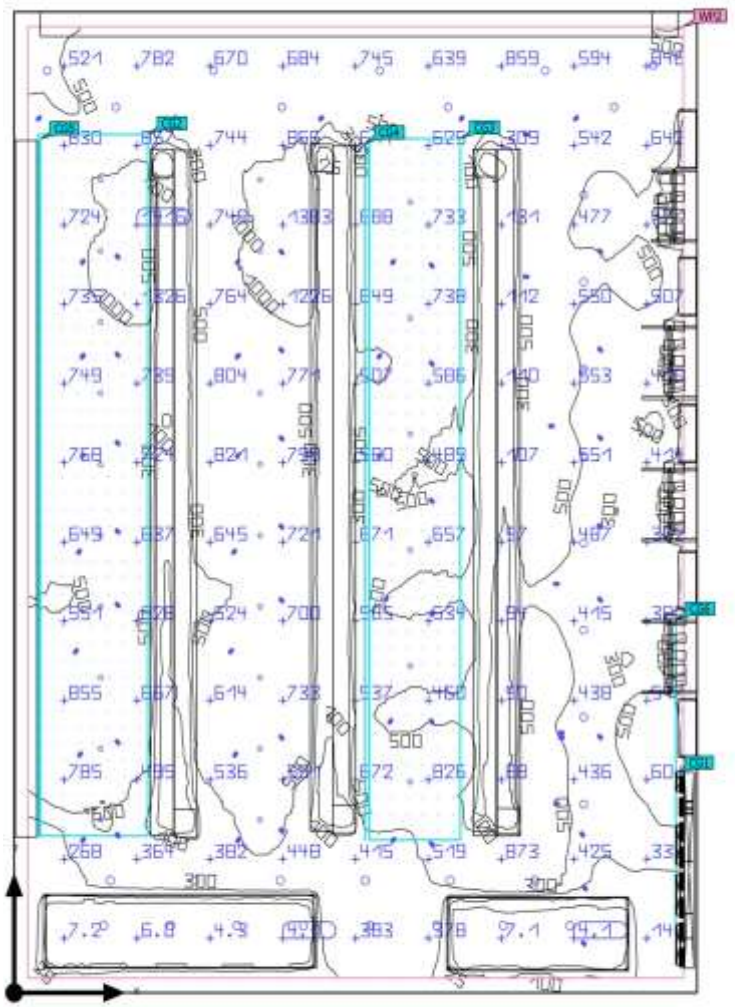


Fig.no 59: layout of storey-2 with lux level display each grid point

Summary of storey-2 of same building:

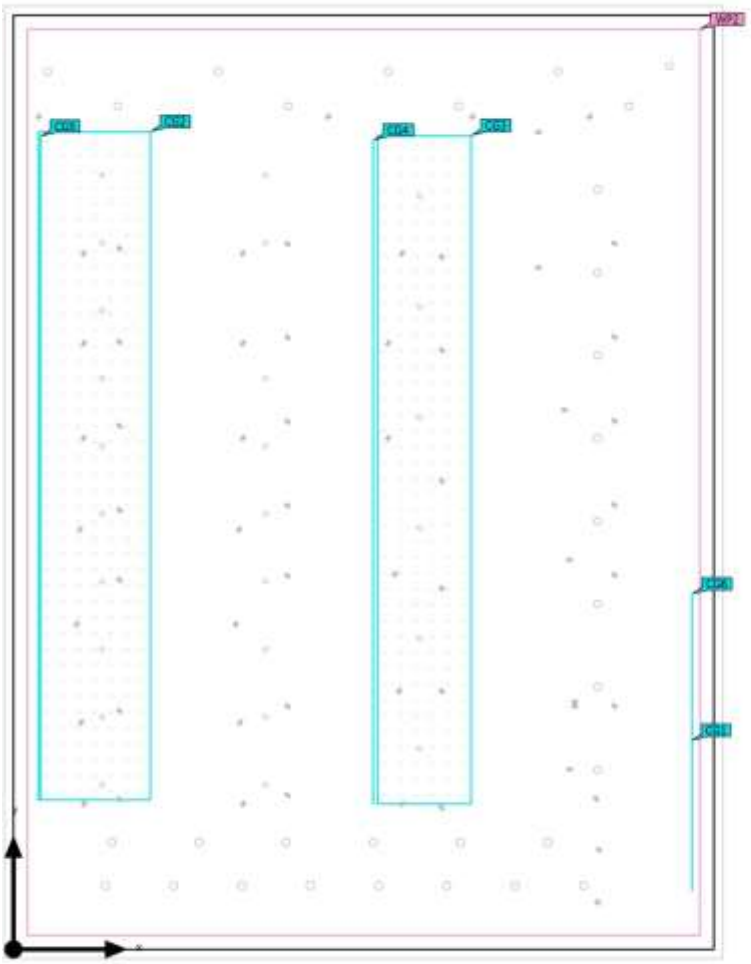
	Symbol	Calculated	Target	Check
Working plane	Ēperpendicular	528 lx	≥ 400 lx	✓
	g1	0.52	-	-
	Lighting power density	10.43 W/m²	-	-
		1.97 W/m²/100 lx	-	-
Consumption values	Consumption	[10050 - 10500] kWh/a	Max. 10550	✓

			kWh/a	
Room	Lighting power density	9.72 W/m²	-	-
		1.84 W/m²/100 lx	-	-

Here, g1 stand for overall uniformity (minimum illuminance/ average illuminance).

Calculation surface of storey-2 of same building:

Two main calculation surface are taken here at height 1 mt, and grid point of this two surface is .3 m× .3m . one calculation surface set in aisle portion(area between two shelves of grocery), other calculation surface set in vertically on shoe & garments display side,



Calculation surface sales floor (aisle portion)

Calculation grid dimension- .3 m × .3m, area of surface 12 m × 2 m.

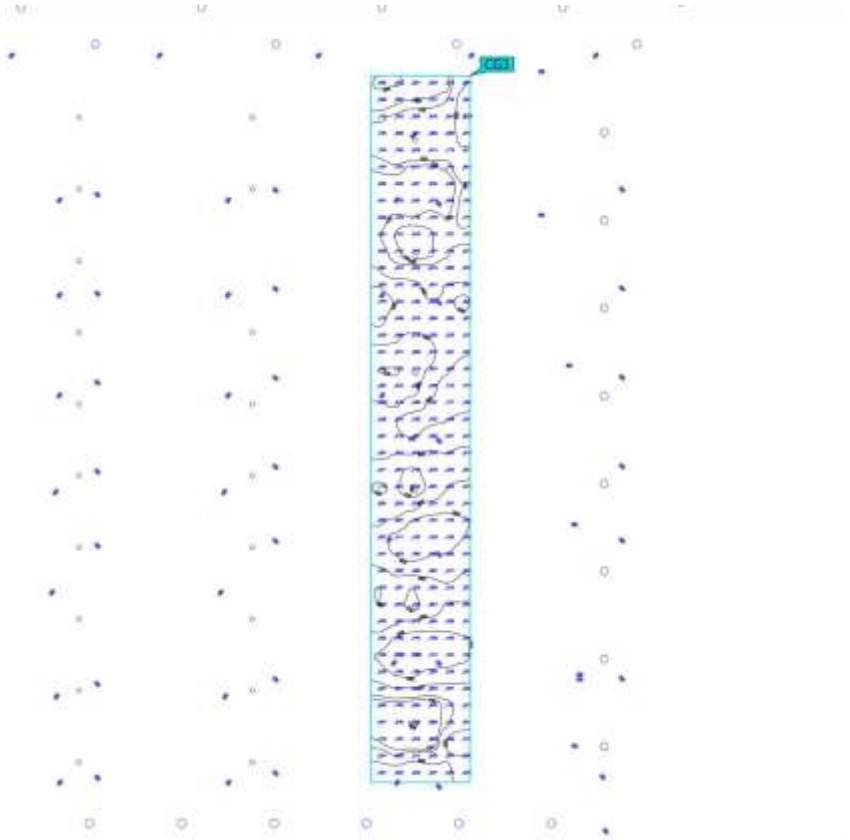


Fig.no 61: isolux diagram of general lighting (sales floor)

Properties	Ē	E_{min}	E_{max}	g_1	g_2
Calculation surface 5 Horizontal illuminance (sales floor) Height: 1.00 m	431 lx	223 lx	779 lx	0.57	0.53

Obtain result

Average illuminance (sales floor) – 431 lux

Uniformity g1 (min/avg.) – 0.57

Uniformity g2 (min/max) – 0.53

Minimum illuminance – 223 lux

Maximum illuminance- 431 lux.

Calculation surface of shoe case (vertical)

Grid dimension - .7 m × .7 m

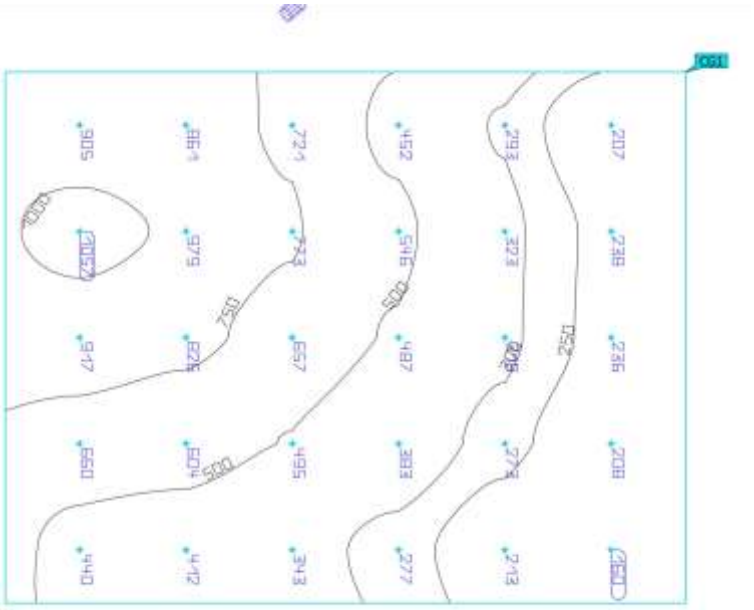


Fig.no 62: iso lux diagram of shoe case

Properties	Ē	E_{min}	E_{max}	g_1	g_2
shoe case (Vertical illuminance) Height: 1.005 m	509 lx	360 lx	1057 lx	0.65	0.35

Obtained result

Average vertical illuminance (shoe case) – 509 lux

Uniformity (min/avg.) – 0.65

Uniformity (min/max) – 0.35

Minimum illuminance- 360 lux

Maximum illuminance- 1057 lux.

UGR CHECK:

According to IS-3646 (1992) paper UGR inside retail space must be less than 22.

In this design, Glare observer height from floor =1.2 m

Rotation of observer 0^0 to 360^0

Calculation surface 10 (front space of retail shop)

Maximum glare = 18.5 (< 22)

Minimum glare less than 10

Calculation surface 12 (sales floor)

Maximum glare = 18.3 (<22)

Minimum glare less than 10

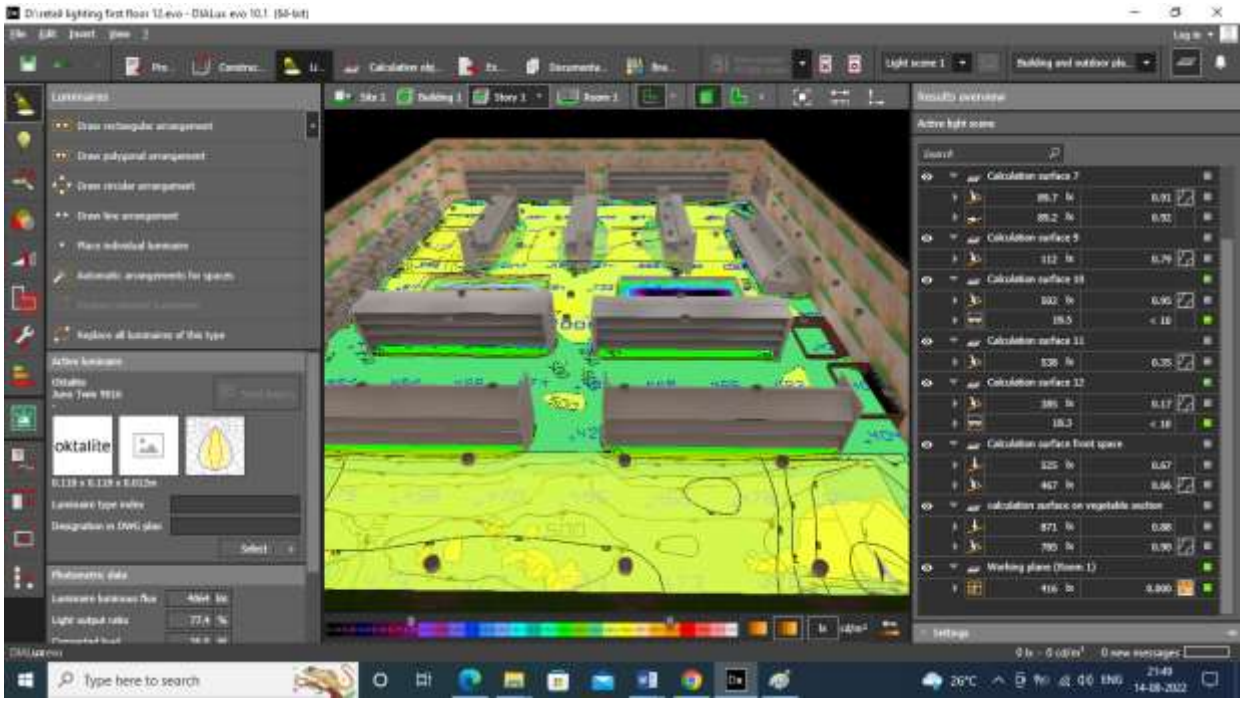


Fig no 63: UGR calculation in dialux (result given right side of pic in goggles symbol)

Leo alignment and false color rendering pic:

With the help of leo alignment features of individual luminaire, designer can change individual luminaire aiming for illuminate the object.

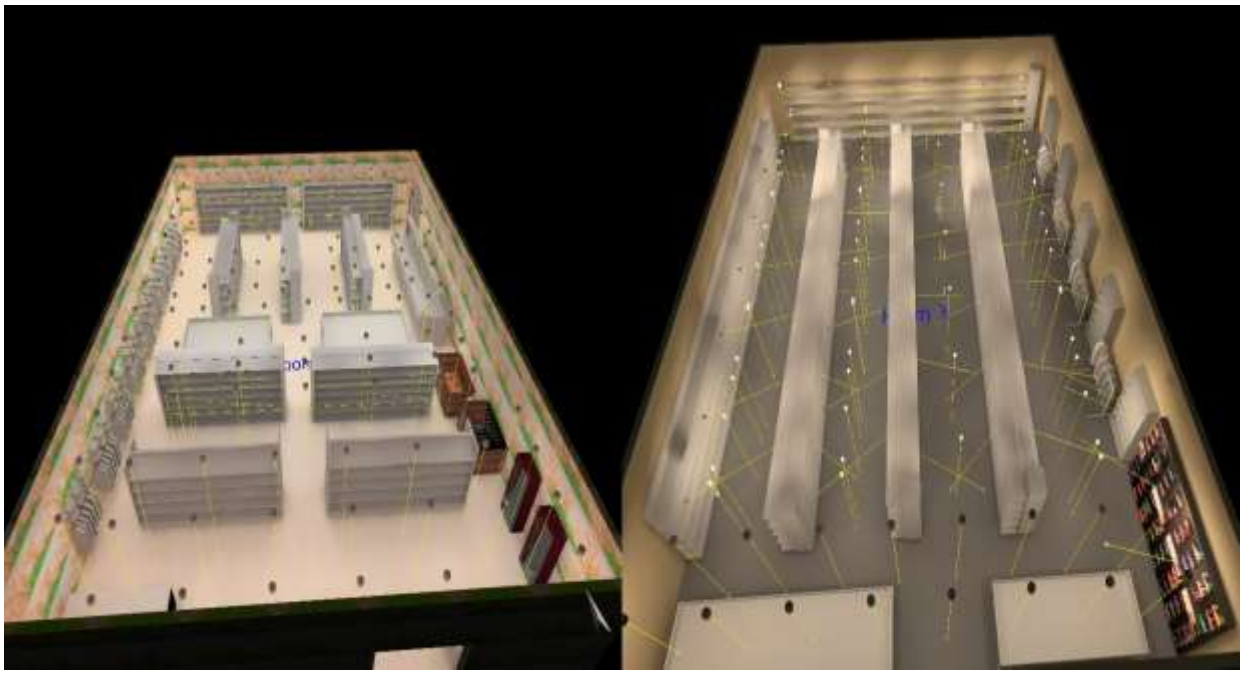


Fig.no 64: pic of LEO alignment of luminaire of both storey-2 of same building.

With the help of false color rendering features of dialux, designer understand if there any light concentrate in any place.

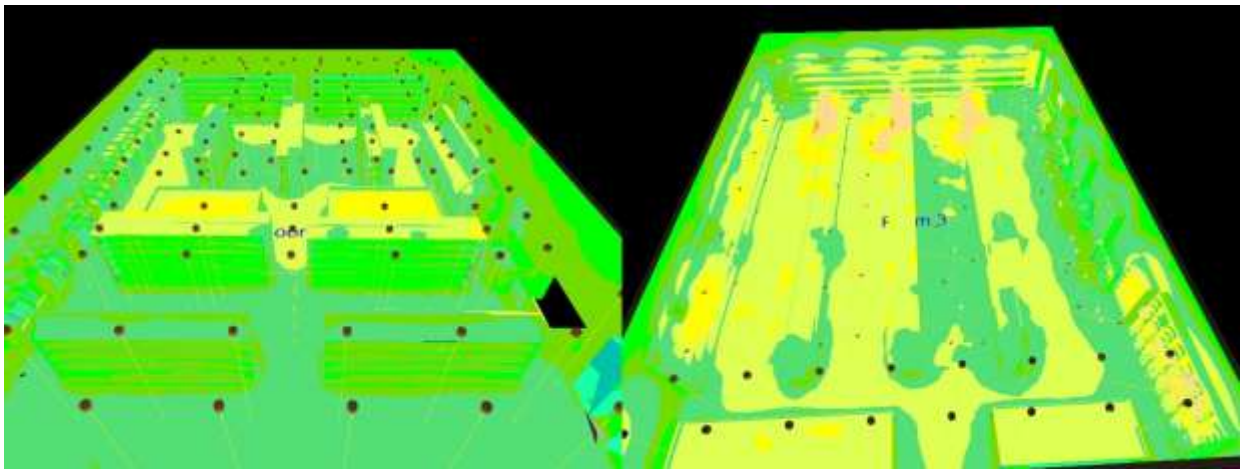


Fig.no 65 : pic of false color rendering of both storey of same building.

5.4 COST COMPARISON:
COST COMPARISON BETWEEN CFL AND LED LIGHT:

It is found that the LED fixture can save 63% energy as compared to CFL lamp. The price of the LED is higher than CFL, so initially installation cost of LED lighting is twice the CFL lighting. But this extra cost must be returned in the form of saving energy before the LED light life end. Here calculation of price and consumption energy price of two different lighting system within two years done below,

CFL lighting case:

- Installation cost: area of the room 300 sq.mt
  Total number of unit- 80 pieces
  Price of per unit- 390 INR (as per india mart price rate)
  Installation charge per unit-80 INR
  Total cost during installation time = (80×390) + (80×50)
  = 32,200 INR
- Re lamping cost:
  Average no. of lamp replacement per annum = 0.4/annum
  Here take two years for calculation
  Then light installation charge – 20 INR
  Total cost = (o.4×390×2) + (20×2)
  = 352 INR
- Energy consumption cost:
  Here take two years for calculation
  As per DIALux simulation data energy consumption per year – 10,000 kwh, consider shop open 10 hours per day. For two years total energy consumption 20,000 kwh.
  Per unit electricity cost 10 INR
  Total energy consumption cost= 200000INR

Therefore, total cost including installation, re lamping, energy consumption = 3,30752INR

LED lighting case:

- Installation cost:

Cost of 30 units LED downlights (450INR/piece) = 30×450
= 13,500INR
Cost of 5 units LED pendent lights (670INR/piece) = 5×670
= 3350INR

Cost of 18 units LED recessed lights (1850INR/piece) = 12×1850
= 31, 500INR
Cost of 12 units LED strip RGB light (140 INR/piece) = 12×140
= 10,924 INR
Cost of 9 units another LED lights (500INR/piece) = 9×500
= 4500
Total installation cost = 67,274 INR

- Re lamping cost: in case of LED lighting re lamping cost '0'
- Energy consumption cost :

Here we consider shop open 10 hours per day. Total energy consume per year is 6100 kwh, as per dialux simulation result.

Total energy consume within two years is 12,200 kwh
Energy consumption cost = 12,200 ×10 (10INR/unit)
= 1,22000INR

Operating cost (energy consumption) comparison within 2 years between CFL lighting and LED lighting in 300 sq.mt =

$$\frac{(200000-122000)}{122000}\times 100$$
$$=63.9\%$$

Operating cost (energy consumption) of CFL lighting is 63.9% higher than LED lighting operating cost within two years.

Initial installation cost comparison between CFL and LED luminaire in 300sq.mt space (excluded extra driver and sensor cost):

$$=\frac{(67,274-32,200)}{32,200}\times 100$$
$$= 108.3\%$$

LED luminaire installation cost 108.3% higher than CFL luminaire installation cost. (excluded sensor & other cost)

5.5 BAR GRAPH:

Below is a chart which shows cost comparison between CFL and LED luminaire lighting installation as well as operating cost in two years. Lighting installation cost of LED is much higher than CFL luminaire lighting, but LED lighting energy consumption cost is much lower than

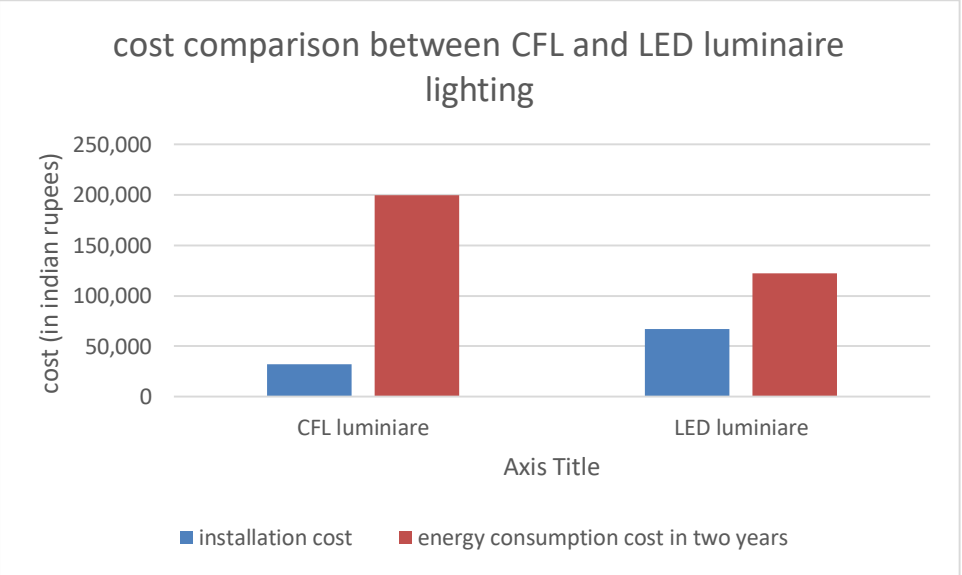


Fig no 65: cost comparison chat between CFL and LED luminaire.

Lighting power density (LPD) for LED lighting retail shop is 7 (as per Super ECBC), here calculated LPD for LED 7.1 w/sq.mt.

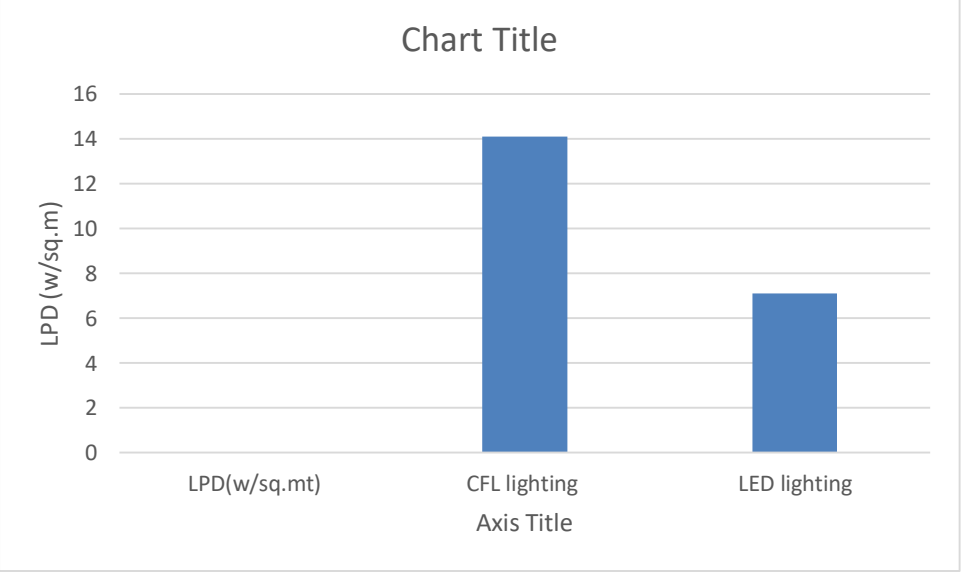


Fig.no 66: LPD comparison between CFL lighting and LED lighting in same dimension room

Below is a bar graph of average lux level of different section of retail LED lighting.

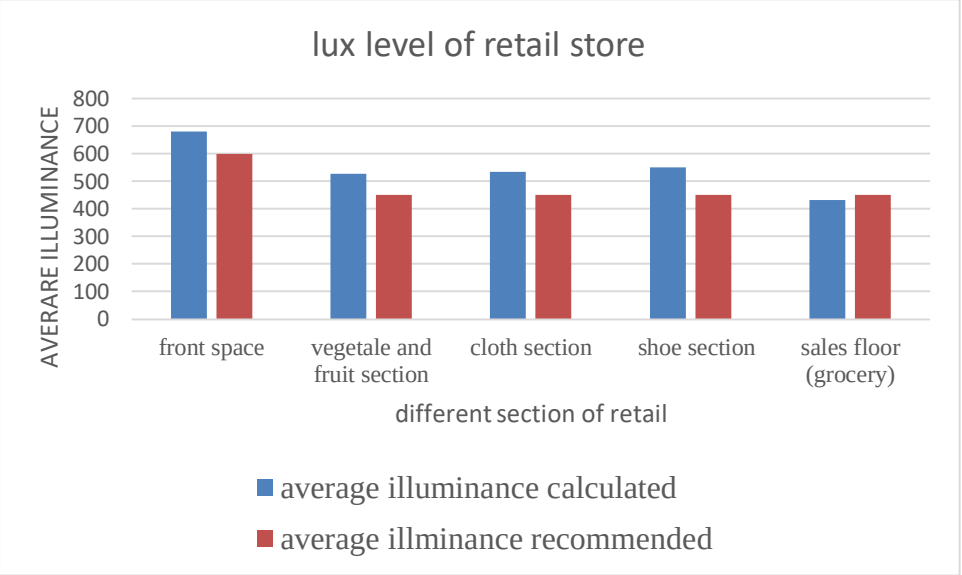


Fig.no 67: comparison chart of lux level of different section of retail store (LED lighting)

Above bar graph comparison between recommended lux level of each section which already given when explain individual section in theory part and average illuminance of retail space which got from dialux simulation by LED luminaire lighting(red graph showing recommended illuminance and blue graph showing what we got from result). From fig 67, we show that all section average illuminance achieved recommended average illuminance.

6.1 CONCLUSION

The thorough analysis of the proposed designs discussed in the previous chapter clearly shows that by using LED luminaires instead of conventional fixture (CFL), energy saving as high as can be achieved. This when accompanied with proper lighting control implemented using occupancy sensors and automated control protocol, can achieve a further saving in energy which in turn reduces carbon foot prints and also the electricity bill. The high cost for new installation or extra cost for replacement is returned within 4 to 5 years installation/replacement through savings in energy. As LED lasts more than that it can be easily concluded that the LED lighting solution is completely viable for both the cases. In the design shown in the previous chapters, the ECBC+ building ratings are achieved in all areas and super ECBC building ratings are also achieved in some spaces indicating that LED luminaires can be used to easily satisfy the ECBC standards. Whereas, the conventional luminaires are having trouble in achieving the basic ECBC rating. All the luminaires used in the design help in satisfying the illuminance criteria as per the IS 3646:1992 but in many areas, they fail to limit the maximum glare as per the standard suggesting that a more careful design of the luminaires should be considered so as to limit the maximum glare. Moreover, the intensity distribution of the luminaires can also be worked with, like using direct and indirect intensity distribution or using better diffusers, in order to reduce glare.

CHALLENGE FACED:

There are several challenge when design a retail lighting. First challenge is selection of perfect CCT luminaire, because imperfect luminaire may distract object appearance. Second challenge is overall uniformity, in case of retail design it is impossible to get proper overall uniformity, due to furniture, shelves and other decorated things. So, here only focus on sectional uniformity. The glare prevention is another challenge in retail design, because of using direct lighting. The challenge is wrong IES file light source because wrong photometric data light source may lead to wrong simulation

REFERENCE

[1].Retail lighting and consumer product perception: a cross cultural study, by Dalam Anwar, Arizona university.

[2]. Retail lighting and consumer product perception: a cross cultural study, by Dalam Anwar, Arizona university.]published in lighting research technology, 2017.

[3]. Color enhanced light emitting diode (LED) light with high gamut area for retail lighting byXf feng, w. xu (fudan university, china, 16sept 2015).

[4]. Effectiveness of retail lighting in terms of user satisfaction and quality by izmir institute of technology published in GCRIS.

[5]. Retail lighting and textiles: designing a lighting probe set by b. bratati, E. karana, D. sekulovski, Deft university of technology, published in lighting research technology, 2017.

[6]. Sustainable lighting in interior space by khaleid alsaid ,Rodrigo muro , royal institute of technology.

[7]. Retail design: lighting as an atmospheric tool, creating experience which influence consumers mood and behavior in commercial spaces by katelijin qartier, hensi Christians, university of hasset,published in lighting research tecnolog, belgium,2008

[8]. Lighting impact on consumer's shopping behavior in retail cloth store by j.deepika, t. neeraja (international journal of science and research)

[9]. IESNA lighting guide.

[10]. NELCA ROCO lighting guide book (UAE)

[11]. NELCA ROCO lighting guide book (UAE)

[12]. NLC-2010 lighting guide book

[13]. IESNA lighting guide book

[14]. https//aglosystems.com.au/news/led-shelving-works/

[15]. IS-1992 indoor lighting guide

[16]. https://www.intl-lighttech.com/products/vertical-caselight-led-coolerfreezer-lights-retrofit

[17]. Lighting research and technology: impact of lighting design on brand image for fashion retail store.

[18]. Research gate: effective of retail lighting in terms of user satisfaction.

[19]. NLC-2010 lighting guide book

[20]. NELCA ROCO lighting guide book (UAE)
[21]. NELCA ROCO lighting guide book (UAE)
[22]. IS-3646(1992) indoor lighting guide
[23]. Effect of surface reflectance on lighting efficiency in interior by rohini singh, rajan singh, 12th conference of international building performance.
[24]. Research gate: "impact of high reflectance flooring material in retail application, paper of Pennsylvania university

[25]. IS-3646(1992) indoor lighting guide
[27]. https://www.lightology.com/index.php?module=how_to&sub=cri
[28]. TRILUX (OKTALITE) retail lighting specification
[29]. https://www.dmlights.com/blog/interpret-light-distribution-curve/
[29]. Energy conservation building code 2017 offered by bureau of Indian standard.
[31]. Energy conservation building code 2017 offered by bureau of Indian standard
[32]. CONTECH lighting guide, https://www.contechlighting.com/en/docs/contechretaillightingguide2018.pdf

[33].https://www.contechlighting.com/en/docs/contechretaillightingguide2018.pdf
[34]. PHILIPS retail lighting guide