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The Illuminance and The Discomfort of Glare Among Office Workers in Bangsar, Selangor

Thiruvengadish Sundaraju[1], Azmir Ariffin[2]

Faculty of Information Technology, City University Malaysia, Malaysia (vengadish@gmail.com), (azmir.ariffin@city.edu.my)

Abstract

Purpose: *Lighting acts as a significant component in a workspace, whether the source of light is artificial or natural. However, too much lighting can be very uncomfortable for the workers and cause glare. This study investigates the relationship between total illuminance in the office workspace and glare discomfort among workers. Furthermore, the combination of natural and artificial lighting might impose a high level of lux on the workspace, which exceeds the stated lighting requirement.*

Design*: The study design of this research is a cross-sectional study design. Moreover, it was studied among office workers in Bangsar Selangor, with 22 respondents.*

Result and Discussion: *The first objective recorded a lower value due to low lighting penetration around the area with a <0.01; hence, the lux in the workstation is more than 500lx. The second objective showed that glare in the workplace is not intolerable because DF lighting and glare values are perceptible. The third objective it can be deduced that the glare facing by workers is mostly Mid. In contrast, when it comes to their health discomfort due to glare, it shows the effects are Low. For the fourth objective, the analysis for the lux reading category was moderate, resulting in a moderate health effect. The fifth objective's results showed that the significant value for the Lux and DF correlation test was 0.945, and Lux and UGR correlation was 0.512. The final objective records the General discomfort and health discomfort, which are not significant because UGR and the General Discomfort result was 0.327 and UGR and Health Discomfort test was 0.079.*

Conclusion and Recommendation: *In conclusion, two were significant out of these three objectives, and the hypothesis was accepted as it matches the criteria studied throughout this research. The accepted objective in this research was to calculate total illuminance in the office workplace and measure the intensity of glare in the workplace.*

Keywords: *Daylight, Artificial light, Glare discomfort, Lux reading*

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1. Introduction

Great lighting plays a vital role in defending wellbeing at work by empowering workers to play out their work efficiently and effectively. For safety purpose, lighting requirements must be followed to find out types of hazards. Identifying the appropriate level of light falling on the surface on which employees work makes it the workers easier to identify hazards. This enables workers to read labels and safety instructions to guarantee consistency with wellbeing measures for the counteractive hazards. Measure illuminance at the selected area and compare the illuminance level with the given lighting standard in an office. For this, we can conclude who may be harmed by the illuminance level. Determine whether there is a need for advancement of control measures after evaluating the risk to keep the employees from harm and not limiting the lighting source.

Surrounding with excessive lighting results in glare. This situation can be worst most of the time and causes many side effects physically or work-base. This might affect the worker's health and lower the productivity rate due to uncomfortable surrounding for the worker to work. To assess the overall lighting and categories it into good lighting or bad lighting, special monitoring is required to do so. Additionally, daylight produces some benefits, but it can also show some drawbacks if it is excessive.

To know and understand the result of the workplace's lighting, it is most advisable to always refer to Guidelines such as Lighting Guidelines (DOSH) and the Malaysian standard MS1525. This will be an excellent factor to consider by officers, engineers, architects, or other personnel responsible for providing a conducive working environment.

The efficiency of workplace lighting may have a huge effect on productivity. More materials can be manufactured with less mistakes with sufficient lighting staff, resulting in a 10 to 50 per cent improvement in productivity. Adequate lighting can minimize errors by 30 to 60 per cent and reduce eye strain and eyestrain, which are often associated with headaches, nausea, and neck pain. Adequate lighting allows workers to concentrate more on their jobs, which increases efficiency. The intensity of illumination required by employees varies depending on the scope of the job, the sharpness of the workers' eyesight, and the atmosphere in which the work is performed.

2. Literature Review

The literature review in this study explains all the required aspect that helps throughout the research was conducted

2.1 Office workers

In this subtopic, general discussion about office workers' will be discussed, as what is their nature of work and what they do. (Lene Lottrup, 2015) stated that the office staff's ability to work is crucial for most businesses' profitability and productivity. In recent decades, a lot of activities aimed at raising the productivity of office workers have been adopted. These exercises based on information job procedures and accessible emerging technology (Davenport, Jarvenpaa, & Beers, 1996; Pan, Hawryszkiewycz, & Xue, 2007); employee networks (Burton, Wu, & Prybutok, 2010; Ditton, 2009); and developing employees' individual skills (e.g., Allen, 2001).

Occupants in daylit and full-spectrum office buildings reported an improvement in average satisfaction. Benefits of these types of office environments include better health, decreased turnover, expanded efficiency, cost saving, and staff choice. The advantages of office staff are so significant that many European countries need employees to be no more than 27 feet away from a window (Franta and Anstead, 1994).

The use of artificial bright lights has had a positive effect on the employees of buildings that natural lighting isn't really or can't be implemented. Shift workers can alter their internal clocks or circadian schedules to match their working periods due to bright lighting. Great illumination has indeed been linked to greater productivity, fewer injuries, higher levels of mental performance, improved sleep quality, and higher morale for night duty staff (Luo, 1998).

2.2 Lighting

Lighting is not just to illuminate, but it can do more than that. It can improvise safety and security, form, and function, and give an environment that makes us easy to do or adapt to the task done by ourselves. Energy-efficient lighting for the industry, for example, can reduce environmental pollution while also cutting costs, resulting in increased quality and productivity (Ruena Králiková et al., 2016).

Appropriate lighting within the workplace with well-lighted work areas is crucial for maximizing viewing experience, visual comfort, and associate degreed ambience, particularly with an aging workforce. Furthermore, the positive effects of bright lighting are more widespread than previously thought. Indeed, medical science has consistently demonstrated that light has a positive impact on health and well-being over the last two decades. Good lighting victimization environmental lighting sources (e.g., LED) increases productivity by speeding up tasks, lowering error rates, and supplementing the energy-saving aspects.

Feasible lighting can also be a powerful tool for improving business. Taking into consideration all natural and artificial light, its amount, and dispersion to ensures the comfort level, as visual comfort is without a doubt one of the most essential skill drivers, and, at the same time, seeing issues that are widespread leading to inadequate operating conditions, specific consideration will be given to the topic. In a production plant, productivity information is a crucial indicator of performance (Ružena Králiková et al., 2016).

Nevertheless, recent ties between health and performance and lighting have made the lighting of building interiors one of the most significant environmental factors in architectural design. According to the most recent research, there is a link among lighting and human efficiency and well-being. Light not only provides visual evidence, but it is also a powerful stimulator of our sleep cycle and many non-visual functions, such as alertness, mental concentration, and the output of psychological features (N. Shishegar and M. Boubekri, 2016).

2.2.1 Luminance

The luminous strength of a small part of a surface region in each direction divided by the orthogonal projection of this area onto a plane at right angles to the direction, calculated in candelas per square meter [cd/m2].

2.2.2 Illuminance

According to the International Commission on Illumination, illuminance at a point of a surface is known as the luminous flux's quotient incident on an aspect of the surface containing the point multiplied by the area of that element.

2.2.3 Artificial lighting

The effect of artificial lighting on the psychophysiological well-being and productivity of employees in a manufacturing plant relies on the type of source of lighting that:

- Brightness-illuminance.
- The spectrum of light colour.
- Light distribution: distribution of luminance in the space (Ružena Králiková et al, 2016).

The effects of artificial lighting on people are a lot pronounced, particularly throughout the winter season (in other countries), because daylight's natural impact within operating hours is minimal (Ružena Králiková et al., 2016). People also acknowledged that long-term artificial lighting work significantly affects health (Najib T. Al-Ashwal and Ahmad Sanusi Hassan, 2018). Also, artificial lighting is one of all the best electricity energy consumption. Therefore, reducing the employment of artificial lighting in a part of saving energy consumption is vital (Bukar Ali Kime and Halil Zafer Alibaba 2018).

2.2.4 Natural lighting

A good daylight architecture offers completely sufficient light for effective visual quality while still ensuring a relaxed and relaxing environment appropriate for its function (Zuraini Denan and Noor Hanita Abdul Majid 2015). Daylight contributes to an excellent indoor environment, bringing natural light into the building, giving the occupant a nice fall and the window opening while considering the view to the outside. The best use of daylight in an office building would minimize the use of artificial light and, at the same time, make the office building energy-efficient (Fadli Arabi et al., 2012).

In the first part of the twentieth century, natural light was the primary supply of building illumination. In an exceedingly short span of a couple of decades, electrical lighting became the first source of illumination, principally due to convenience. In recent years, energy conservation associates degreed environmental considerations have changed those practices and brought daylighting once more at the forefront of the property dialogue. Natural light was the primary source of building lighting in the early twentieth century. Artificial light became the main form of lighting within a few decades, largely due to ease. These practices have evolved in recent years as a result of energy conservation and environmental concerns, placing daylighting at the center of the sustainability debate once more (N. Shishegar and M. Boubekri 2016).

Generally, a high CRI of a light supply converts to the colour of an object seems about to the natural colour seen beneath daylight or an indecent light source of the same colour temperature (N. Shishegar and M. Boubekri 2016). To have an appropriate wavelength for all people to identify most colours, the sun produces a broad spectrum of light. As a result, sunlight is known to have a CRI of 100, which is the maximum value that light can attain (N. Shishegar and M. Boubekri 2016).

The multitude of advantages that daylight has in terms of its spectral properties, such as vitamin D production from our skin, have been shown in numerous studies. This is, in reality, the essence of the sunlight light spectrum, which makes it unique in the improvement of human health and cannot be found in electric lighting (N. Shishegar and M. Boubekri 2016). Daylighting is a significant feature of the architecture of green buildings. The advantages of good daylighting are well recognized for both energy conservation and visual relaxation, as a result (Lim Gene-Harn et al. 2017).

Daylighting will minimize dependency on electric lighting, that has been seen to reduce cooling load and demand for building energy. That's also probable as diffuse daylight, with a luminous efficacy of 110-130lm/watt, has a higher luminous efficacy than most artificial illumination, which has a luminous efficacy of 70-100lm/watt. Yu and Su examined 20 articles and discovered that daylight utilization would result in 20-87 percent energy savings in lighting.

Due to the daylighting technique, saving in energy usage for lighting is greater than the cooling Energy loses from the extra glazed surface, given that the building envelope is carefully built for daylighting. The suggested daylight factor range is 1.0 to 3.5 per cent. The visible light transmission of the daylight fenestration method should not be less than 30 per cent to take advantage of daylight harvesting. Alternative enforcement includes a lighting simulation analysis demonstrating a daylight factor of 1% from the façade building at a depth of no less than 3 m. In worst-case scenario, glare control systems can limit daylight fenestration's luminance intensity to a value of less than 2,000 cd/m2 with direct sunlight affecting daylight fenestration (MS 1525:2014).

2.2.4.1 Daylight preference

Public are persuaded that natural light is preferable then artificial illumination (Bodart & Deneyer, 2004; Galasiu & Veitch, 2006). Bodart and Deneyer (2004) studied that 91 percent of research participants choose to work in natural light. When asked reason on favouring daylight, nearly most of the participant suggested where natural lighting is better and convenient than artificial light and decreases work stress. Respondents were often asked what kind of luminaire is easiest to deal with. Natural lighting was preferred by 62% of the participants, and 37% of the respondents chose that daylight and electrical light are similarly pleasant to deal with. Very few chose artificial lighting rather than natural lighting. Roche et al. (2000) have found that workers enjoy curtain walls (window) in their working space. A sum of 73 per cent of the respondents found providing a window in office space is a must, and just 4 per cent chose artificial lighting to daylight. In a questionnaire test survey undertaken by Veitch and Gifford (1996), about half of the office staff and university students claimed that they were doing their best while in areas surrounded by daylight (Hellinga, 2013).

2.2.4.2 Daylight intensity

The amount of incoming solar Energy or radiation that strikes the Earth's surface is referred to as Sun Intensity. This force is measured by the angle at which the sun's rays strike the Earth. Therefore, the angle and the strength of the sun changes significantly based on the location of the specific spot, the time of year and the time of day. The angle created by sunlight rays entering the Earth is scientifically known as the angle of incidence. Rays just above the surface of the Earth, that is, at an angle of 90-degree from the horizon, are extreme. For most periods and places, the angle produced by the sun is less than 90 degrees in the horizon; typically, the sun is lower in the atmosphere. The smaller the tilt, the larger the surface area over which the sun's rays scatter. This influence decreases the power of the sun at any one spot. For example, at a 45-degree incidence angle, solar radiation is 40 per cent larger and 30 per cent less potent than at a 90-degree maximum incidence angle (Harris, A. 2015).

2.2.4.3 Daylight glare

Daylight Glare Daylight Discomfort is a common issue in many workplace settings. It has focused on a considerable body of research, and several attempts have been made to establish accurate evaluation and prediction models to resolve this issue (Osterhaus W, 2004). There is often a difference in the discomfort glare caused by one small source or several small sources, and a source with the same glare index underlies a large solid angle due to the impact of the more prominent source on the visual mechanism adaptation stage.

2.2.5 Lighting at workplace

Lighting engineering for office buildings has primarily concentrated on light for visibility and energy use reduction strategies. The perception of how light affects health has been given little consideration (Figueiro MG et al., 2015).

Several studies have illustrated the significance of the use of daylight within buildings. The availability of daylight in buildings provides environmental adaptation and management of the atmosphere to increase energy conservation. Usually, office workplace focuses on side daylighting strategies by vertical daylight harvesting windows. Findings of a significant field research found that office workers' satisfaction with indoor lighting was strongly affected by proximity to windows in their work setting that can provide natural light and an outside view. Vertical openings have an effect on both the energy usage of buildings and the visual satisfaction of their occupants. A building with a conventional facade and a window-to-external-wall ratio of 30-40% is consume low energy than a building with a fully glazed façade (Mehdi Amirkhan et al., 2017).

2.2.6 General Principles of Efficient Lighting Practice

Lighting, for example, would provide a suitable visual atmosphere in a given space, with proper and effective lighting to perform different tasks and provide the desired appearance. The retained illuminance levels with the corresponding Color Rendering Index (CRI) for general construction areas) are as shown, as shown in the table below (MS 1525:2014).

Table 2.1 Recommended average illuminance levels (MS 1525:2014)

Task and Application	Illuminance (Lux)	Minimum CRI
Infrequent reading and writing	200	80
General offices, shops and stores, reading and	300 - 400	80
writing	300 - 400	85
Drawing office	150	80
Restroom	200	80
Restaurant, canteen, cafeteria	150 - 300	80
Kitchen	150	60

Lounge	150	80
Bathroom	100	60
Toilet	100	80
Bedroom	100	80
Class room, library	300 - 500	80
Shop/supermarket/department store	200 - 750	80
Museum and gallery	300	

2.2.6.1 Illuminance and Planes

The higher the required illuminance, the better the detail. The lighting of the surrounding areas is also significant. It is insufficient to light in one location if the surrounding area in which movement happens is poorly illuminated. Another, frequently overlooked, element of illumination is the plane on which it will be delivered. In certain cases, because there is little interference and surface reflectance, such as in offices and computer factories where job is small in scale, high light level must be primarily on the horizontal plane. However, illuminance on other planes should be given if necessary when the prevailing operations are on vertical planes, such as in factories, or where illumination is significantly obscured. The horizontal, vertical or inclined plane where the visual role is placed is considered to be horizontal and 0.85 meters above the ground, unless otherwise specified (Guidelines on Occupational Safety and Health for Lighting at Workplace 2018).

2.2.6.2 Fluctuation of Illuminance

Fluctuations of lighting are defined through external and internal illumination. Fluctuation is also known as light intensity fluctuation, because it occurs when both increasing and decreasing light determines various meanings of light change. When a room's visibility reaches a certain amount, and the light fluctuates inconstantly, this is referred to as daylight or artificial light fluctuation (Shikakura and Morikawa, 2003). This variations in daylight can increase the effect of indoor visibility and lighting systems. Alternates in the illumination level, enforces the need for the designer to be aware of the acceptable level of illumination by the occupants during the preliminary design and post-occupation assessment.

There is a fluctuation of natural illuminance to spaces far from the window when the physical valuation and computer simulation conducted by Joarder et al. 2007. The high influence of the natural atmosphere induces a decrease in light to the interior of the room. Shikakura and Morikawa (2003) studied the impacts of lighting modifications by dealing with electrical lighting. Lighting fluctuation influence the people because the space had a consistent lighting ambience, but the actual illuminance fluctuated across time, and the required illumination could never be maintained as needed.

Illuminance fluctuation can be caused by factors as lighting conditions. Another option arose with different climatic/sky condition where sunny skies, partially gloomy skies, overcast skies, and partly cloudy skies. As per Kim (2007), daylighting indoor levels are dictated by daylight in outdoor levels. The number of light fluctuation ranges that reach maximum fluctuation has to do with the occupants' comfort level when executing the task (Elina Binti Mohd Husini,2016).

2.2.7 Lighting measurement

This section discusses and reviews the various types of lighting measurement method was used in this study. The most widely used instrument for determining light conditions is a lux meter, which enables quick estimation of the light and not subjective lighting of the area. This device is made up of an incorporated lux meter with a circuit that produces a signal based on the logarithm of an intensity is calculated and a display with a linear f-number scale (Jose-Maria Gutierrez-Martinez et al., 2017). Aside from that, DiaLux software is used to simulate the illumination level of artificial lighting and daylight, while Aftab Alpha software is used for evaluating quantity and quality of light conditions in a realistic space.

2.2.7.1 Lux Meter

Lux meter is a photoelectronic instrument used to measure illuminance in paint and polymer, industrial, chemical, building automation. During regular operation, these meters' characteristics deviate from the specification characteristics due to wear and tear in the sensor due to exposure to high light intensity. There are some precautionary measures to be taken to achieve optimum lighting measurements are as follows:

- Before taking any readings, the lux meter must be subjected to light for at least 3-5 minutes to allow it to be balanced;
- The light in the unit should be lit for a while to allow it to reach a stable condition before the sample was taken;
- The lux meter's zero reading should be measured and adjusted if needed;

2.2.7.2 DiaLux Evo

DiaLux software used to simulate the amount of illumination of artificial lighting and daylight, calculate the annual energy usage of electrical lighting, determine the energy efficiency of daylight, and obtain building energy output. Efficient and professional lighting calculations can be produced very quickly. DiaLux also measures daylight illumination under three different sky conditions, such as the overcast sky, the average sky and the clear sky, as stated in CIE 110–1994. DiaLux offers an extensive range of catalogues, from industrial electrical lighting devices, daylight management systems, daylight products, etc. (AsimAhmad et al., 2020).

It may be a building, space, or even a workplace. It will simulate and evaluate the efficiency of the lighting system in this environment. The present research used criteria for situations where there was no space for daylight. It simulates artificial lighting completely. The software also measures the perpendicular lighting on the working plane or the surface of the space. Relevant points are inside the respective surface and are not protected by furniture or other components. The summarized figures are based entirely on these points, and as in some situations, any other points will significantly skew the results. It also measures the average, minimum and maximum illumination. It is a factor that determines the reflection of the illuminance from the surface and depending on the colour of the surface (2014 by Alok Dixit, K. and Sudhakar).

2.2.7.3 Aftab Alpha

Glare sources are measured based on a threshold value, which may be manually defined by the consumer as a fixed luminance value or estimated based on the average luminance in the field of view. The adaptation level is measured using the indirect vertical illuminance as the background level. The setup has been completed, as seen in the figure below. Daylight Glare Index (DGI) & Daylight Glare Probability (DGP) values are determined from the calibrated High Dynamic Range (HDR) luminance chart using evalglare, the most commonly accepted programme for the study of luminance picture glare (Yu Bian and Tao Luo 2017).

The glare source was described as the luminance value of more than five times the task field's average luminance. As a scene-based showcase, the task description criteria, which describes the fastening region that occupies much of the view in the blue circle, and the visualization of the glare sources, has been illuminated by purple-red. The vertical eye illumination (Ev) was determined by an individual photo sensor on the camera's top. LR is the most common luminance-based metric referenced by design guides and recorded by daylight consultants.

LR was determined using the luminance values read from the HDR images, while two masks were used to pick the target region (Yu Bian et al., 2020). DGI & DGP values are determined from the calibrated HDR luminance chart using evalglare, the most commonly accepted programme for the study of luminance picture glare (Yu Bian, Tao Luo 2017). The following glare indices and quantities can be calculated:

- Guth Visual Comfort Probability (VCP)
- CIE Glare Index (CGI)
- Unified Glare Index (UGI)
- BRS Glare Index
- Daylight Glare Index (DGI)
- Guth Disability Glare Rating
- Direct Vertical Illuminance
- Total Vertical Illuminance
- Indirect Vertical Illuminance (Mehlika Inanici,2005)

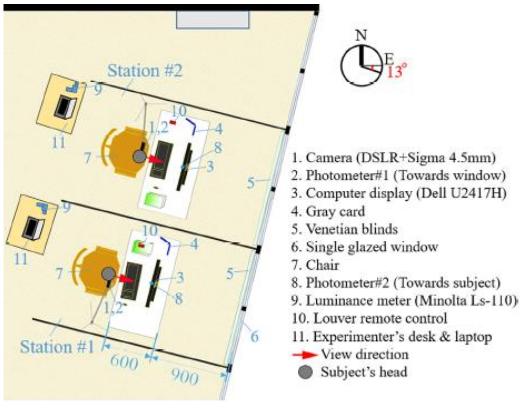


Figure 2.1 Plan of the test room and list of instruments (Yu Biana et al, 2020)

2.3 Daylighting in green office

The Government of Malaysia intends to reduce its greenhouse gas intensity (as measured by GDP) by 45 percent by 2030 compared to 2005 by implementing plenty of environmental-related policies and programs. One such system was the creation of Malaysia's Green Building Index (GBI) in 2009, which marked the beginning of Malaysia's green building movement (Lim Gene-et al 2017).

The Green Building Index Non-Residential New Construction (GBI NRNC) tool and the MS1525:2014 Code of Practice for Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings are the local Malaysian requirements needed for new green office buildings. Points are awarded under the daylighting credit EQ8 (for GBI NRNC) based on the percentage of coverage of the Net Lettable Area (NLA) that achieves a 1.0-3.5 per cent Daylight Factor (DF) calculated on the working plane (Lim Gene-et al 2017).

2.3.1 Review of Existing Office Buildings in Malaysia

Malaysia receives more than enough sunlight every day, and recent surveys have shown that there is an excess of daylight (Denan, 2004; Zain et al., 1999; Hamdan, 1996; Lim, 2011). and more According to Zain-Ahmed (2008), workplaces and shopping centers in Malaysia uses about 90% and more of the power for lighting and air conditioning in conventional energy consumption distributions. According to Kandar et al. (2011), as natural lighting is used properly on operating hours, it lowers total illumination capacity, the resources and money spent. According to surveys, 52 to 60% of air conditioning, 18 to 42% of artificial lighting, and 22% of office equipment typically constitute total use (Suruhanjaya Tenaga, 2005). Estimating the amount of natural lighting available in Malaysian lighting conditions is based on visibility and human factors (Zain-Ahmed, 2008).

Previous research addressed at visibility in an office interior in Malaysia, where daylight efficiency is being captured by applying effective daylight techniques. As per research studies by (Lim 2011) and (Dodo 2014), the recommendations are not followed in Malaysia, and they focus on electrical lighting. According to Kandar et al. (2011), the intensity of daylight in most Malaysian office towers doesn't really follow the lighting standard, which is Malaysian Standard 1525. To resolve this question of lack of daylight in deeper office areas, possible adaptive alternatives are being applied to building façades (Lim et al., 2012). Husini et al. (2011) investigated the desired luminous condition and worker comfort in office buildings to support an optimal degree of luminance of 300 to 400 lux, which is consistent with current guidelines.

To establish standards for an office building that facilitates psychological and human visual comfort well-being, adequate space must be provided, and the lighting that enters inside space must be studied (Elina Binti Mohd Husini,2016).

2.3.2 Daylighting Illuminance in Office Buildings

Daylighting entrance into the office is often overexaggerated. Illuminating interiors raises the question on where it should be based on enhancing worker efficiency or reducing energy use in the office. Malaysia's government recently undertaken significant steps to reach its national goal, which is to ensure that buildings meet Lighting Quality Social Density Environmental Benefit Window size and spread, as well as all sustainable design elements that contribute to energy efficiency while also offering user comfort (Kandar et al., 2011).

Day-to-day workplace fulfillment will be attained, according to previous researchers such as (Denan 2004), Hopkinson et al. 1966), (Szokolay 1980), (Pellegrino 1999), and (Schiler, 2001), when the inhabitants feel visually relaxed in the work region. Furthermore, visual satisfaction must be clear from glare, have a decent contrast of brightness around the visual area, and have enough adequate light to accomplish the tasks effectively. Denan (2004) has stated that correct seating orientation in relation to windows is ideal while operating in daytime hours, as this has a direct impact on visual comfort.

Danny et al., 2005 suggested that bright sunlight illumination ranges could range from 50,000 till 100,000 lux. The initial step in planning a building to use natural light to illuminate its inside landscape is to learn how much daylight is available. Daylight has a huge positive effect on people because it provides them with a feeling of cheer and visibility (Li and Lam, 2001).

As a result, people who've spent the day in artificial light in a building can experience "biological darkness," resulting in decreased efficiency (Leslie, 2003). Al though daylight has a significant ability to lower energy costs and environmental pollution, its most important effect is on the building's inhabitants. However, the effectiveness of such techniques is done on the basis of daylight data and the degree of lighting in each area of the planet (Andre, 2002).

2.4 Glare in office

Glare happens once there is excessive sunshine that returns directly from a supply or mirrored from a shiny surface. IESNA Daylighting Committee describes glare happens when there is a "specular reflection of high surface luminosity in polished or glossy surface". Even supposing glare is usually avoided for visual discomfort; not all workers are equally sensitive to glare. Supported IESNA, the luminance of quite 200cd/m2 is taken into account severely. The suggested luminance based on the style of work, job work ranges from 100-200cd/m2. Stone reported that most people might not remember the existence of glare from interior lighting, whereas others could feel eye discomfort, headache, and eye strain (Zuraini Denan and Noor Hanita Abdul Majid, 2015).

Some researchers assume at the end of the spectrum that glare can cause immediate irritation and lead to possible exhaustion and even danger (Perry, 1995). The glare of daylight is related to the psychological and physiological properties of light. Unfortunately, the physiological and psychophysical mechanisms of discomfort glare don't seem to be nonetheless well understood (H Cai PhD and T Chung PhD 2012). The glare of daylight is related to the psychological and physiological properties of light. "Therefore, it is obvious to deduce that "the experiences of daylight glare differ by the time of day, not at a constant or almost constant level" (Kent et al., 2017). As a result, utterly different glare indices are severally developed in four fields to judge interior electrical lighting,9–27 daylighting (windows), 28–37 exterior space lighting,38–40 and route and traffic lighting (H Cai PhD and T Chung PhD 2012).

The foremost obvious disadvantage of daylight is that the glare that, if unchecked, reduces the extent of visual comfort. The CIBSE Lighting Handbook book (1994) outlined the factors of a visually snug daylit environment: there should be no glare, an average Daylight Factor (DF) of not less than 2%, clear visibility and visually comfortable in terms of a screen image's visibility and contrast to the background. Different studies have limited the typical DF to 5% in their description of visually comfortable surroundings (H Cai PhD and T Chung PhD 2012).

The utilization of huge glass areas following the study trends of the twentieth century has enlarged daylight accessibility in workplace spaces, leading to vital benefits in terms of energy savings and occupier satisfaction. However, increased solar gains and visual irritation (glare) accompany further daylight. Due to the presence of bright light sources, glare, identified as the contrast lowering effect within a visual area, has been studied from different scopes over the past decades and has been quantified using several indices (Fadli Arabi et al., 2012).

2.4.1 Types of glares

Glare is that the loss in visual performance or visibility, or the annoyance or discomfort, made by luminosity within the field of vision more extensive than the light to that the eyes are adapted. Luminosity is outlined in terms of the lumen: a unit of mensuration of the amount of light incident on a surface. The higher the luminance, the brighter the surface (Susan Stenson, MD and Denis Fisk, 2020).

I. Distracting Glare

The blinding glare results from the reflection of light from an optical medium's surface. Part of the incident light is mirrored as the incident light passes from one optical medium to another (e.g., from air to glass). This results in reflections from the lens's surface or in the appearance at night of halos around bright lights. Distracting glare can cause the audience to be irritated and contribute to eye fatigue (Christopher M. Putnam,2017).

II. Photostress (Scotomatic) Glare

The human visual system is capable of detecting luminance ranges spanning approximately eight orders of magnitude 25. Retinal adaptation changes the visual exposure spectrum to the luminance prevailing. Perceptual problems arise as the visual system needs to respond to these abrupt changes quickly. Glare occurs as light enters the eye that does not increase vision and is usually too bright or has a variable luminance in the visual field. Photostress or scotomatic glare occurs if a light source rapidly decreases visual sensitivity. It is caused mainly by rapid bleaching of retinal photopigments and subsequent slower regeneration. Photostress glare is a process that can persist after light exposure due to the time taken to return (Christopher M. Putnam,2017).

III. Dazzling Glare

Dazzling glare is a kind of discomfort glare relates with disability glare. In conditions such as expanses of snow or water and facing the sun while it is low on the horizon, it is usually found as high retinal illuminance around the visual field. Usually, Blinding Glare results in the conduct of light avoidance. In laser eye protection and anti-personnel laser systems, areas of research encompassing the physiological effects produced by blinding glare can be identified. Sheehy reported the precipitous loss in visual output resulting from wavelengths beyond the visible spectrum. Based on visual results, his study outlined the eye protection characteristics needed (Christopher M. Putnam,2017).

IV. Dysphotopsia Glare

Positive dysphotopsia is characterized by strips, flare, central flash, and haloes from light source, and dark crescents or shadows represent negative dysphotopsia. Intraocular lens (IOL) implantation resulting from the lens's square-edge nature, the location of IOL inside the capsular pocket, or the diameter of IOL relative to the capsulorhexis diameter can be associated with both positive and negative dysphotopsia. However, a few of the positive dysphotopsias have been identified in the literature as having a higher-order aberration aetiology, such as flare and haloes (in a monofocal IOL)27. In this case, the determined dichroic and polarising properties of IOL may have an ameliorating effect following an increase in MPOD (Christopher M. Putnam,2017).

V. Disability glare

Disability glare as a result of stray intraocular light is characterized as loss of retinal image contrast. Owing to surface reflections or bright sources of luminance, a reduction in visual performance can be caused by the loss of retinal image contrast, causing increased forward dispersion of light within the eye. Visual performance decreases can result from both veiling illuminances that decrease the contrast of the item and depletion and regeneration rates of photopigment. The sources of disability glare were identified by Stringham et al. as forwarding light dispersion resulting from retina illumination that directly reduces image contrast. Their study recognized that the glare of impairment has a significant reliance on the overall luminance provided by a glare source. Forward dispersion or straylight is not usually the sole source of glare symptoms of impairment. Neural inhibition may lead to glare disability at lower incidence angles (Susan Stenson, MD and Denis Fisk, 2020).

VI. Discomforting Glare

Direct or mirrored glare may create discomforting glare. It varies from 3000 lumens to approximately 10,000 lumens, at which point the glare is disabled. Also, mild degrees of discomforting glare cause discomfort in the eyes, often manifested by exhaustion or asthenopia symptoms. By squinting and constricting the pupil, the unprotected eye can respond to the discomforting glare. Sometimes by shading the eyes or turning the head in another direction, the affected person will prevent the glare (Susan Stenson, MD and Denis Fisk, 2020).

VII. Disabling Glare

As the amount of light increases to 10000 lumens or more, the disabling or veiling glare creates a glare that may interfere with or obscure vision. This kind of glare causes objects to appear to have lower contrast than if there were no glare. This happens because, due to inhomogeneities in the optical media that contribute to light scattering, the eye is not a perfect optical device, decreasing visual acuity and increasing the differential light threshold. In the elderly, disabling glare appears to become more troublesome, as the diminishing clarity of the crystalline lens that comes with age contributes to the development of incipient cataracts (Susan Stenson, MD and Denis Fisk, 2020).

2.4.2 Discomfort of glare

Discomfort glare happens when people may not feel comfortable with their lighting conditions (because, again, the light source might be too bright) but may not necessarily find their vision impaired. Discomfort glare is often referred to as 'psychological glare,' as physiological measurements cannot calculate it, and physiological principles cannot account for it. Discomfort glare is assessed and analyzed on a personal basis only. (The Phillips)

Discomfort glare, on the other hand, has been mentioned as a sensation of distraction, irritation and even pain from bright light. The cause of the annoyance glare feeling tends to be made up of two effects-a contrast effect and a saturation effect. The contrast effect happens where a light source is seen in a much lower brightness setting. When the light source has seen contains such a degree, saturation effects occur when the highest possible rate of neural response from the retinal elements is produced. In the windshield case, the glare of irritation is typically created by a difference between the window and the surrounding walls and the ceiling (Hopkinson et ai, 1966).

2.4.2.1 Daylight Glare Probability (DGP)

The Daylight Glare Probability (DGP) is a variant of the Daylight Glare Index (DGI). It is an empirical approach that is dependent on the longitudinal lighting of the eye and the luminance of the light source, as well as the solid angle and position index (Harvard, 2006). The DGP equation takes into account the overall brightness of the scene, the direction of the glare source, and the visual contrast. In contrast to other existing glare models, this approach gives a direct link to customer reviews on glare sensitivity. A review of DGPs-values and glare level categories for consumer glare irritation tests are presented below.

Table 2.2 DGPs-values and Glare Level Categories

			95% confidence Interval
Upper Limit	**Lower Limit**	**Average**	**Glare Rating**
0.352	0.314	0.33	Imperceptible
0.398	0.356	0.38	Perceptible
0.448	0.39	0.42	Disturbing
0.59	0.464	053	Intolerable
0.352	0.314	0.39	Average

DGP has not defined whether the vertical lighting is less than 320 Lux or greater than 0.2. A correction factor has been applied to the existing DGP equation based on the user's estimate to broaden the range of utility where the luminous flux scale is about 0 and 300 Lux (Dalia Ha iz,2015).

2.4.2.2 Daylight Glare Index (DGI)

The Daylight Glare Index (DGI) is a variation of the BGI, modified to estimate glare from a significant source. The equation was created by experimenting with the use of fluorescent lamps behind an opal diffusing screen. The DGI can only successfully work between the values of 16 (just noticeable) and 28 (intolerable glare). Generally, the DGI overestimates the discomfort under daytime conditions. Despite its contradictions, the index is still commonly used in pain glare analysis, with many attempts to expand the simple formula (Michael Hirning,2014).

The DGI, potentially the critical index for the measurement of daylight irritation glare, poses some drawbacks and some problems for sources of non-uniform degrees of luminance. The evaluation of DGI is not so immediate and straightforward, both because of the determination of the geometric parameters, particularly the solid angle and position index, and because of the determination of the luminance values perceived by the observer (Laura Bellia,2007).

2.4.2.3 Unified Glare Rating (UGR)

Unified Glare Rating (UGR) is known as a log of the light from the lamps in the visual field, separated by the visible light from the room's background (Dalia Ha iz,2015). UGR is a method of calculating glare from luminaires, light through windows and bright light sources (Northgate, 2017).

Glare increases with brighter lamps and poor background lighting, whereas it reduces with dimmer lamps and higher background lighting (Park, Augenbroe, and Messadi, 2003). If UGR < 10: glare is insignificant, it can be disregarded. If UGR > 31: Glare is intolerable (Rea, 2000). The comprehensive threshold and criteria for glare, as seen in the table below.

Table 2.3 UGR Threshold and Criterion

Glare Criterion	UGR
Just imperceptible	10
Perceptible	16
Just acceptable	19
Unacceptable	22
Just uncomfortable	25
Uncomfortable	28
Just intolerable	31

Limitation of method:

- Measurement of the glare is based on artificial illumination from ceiling fixtures (Dalia Ha iz, 2015).

2.4.2.3.1. UGR Formula

The CIE created Committees TC-25 "Fundamentals of Discomfort Glare" and TC 3-13 "CIE Discomfort Glare Evaluation System" in 1987, and approved Sorensen's revised evaluation methodology (1987). The Unified Glare Rating (UGR), a new CIE formula, is as follows:

$$UGR = 8\log_{10}\frac{0.25}{L_b}\sum_{i=1}^{n}\frac{L_s^2\omega_s}{P^2}$$

Figure 2.2: UGR Formula (Michael Hirning, 2014)

Where:

UGR = CIE UGR Glare Index

Ls = Luminance of the glare source (cdm-2)

Lb= Luminance of the background (cdm-2)

ω = Solid angle of the source (sr)

P = Position index of the source

Its purpose was to assess glare perceptions for an artificial lighting system (restricted to sources with a solid angle of 3 x 10-4 to 10-1 sr). The UGR and CGI both use the same discomfort rating scale.

As a result, it may be considered the "International Standard of Glare Prediction Methods" (Nuanwan Tuaycharoen, 2006).

2.4.2.4 Visual Comfort Probability (VCP)

Visual Comfort Probability (VCP) is a scale rating of 0-100 offered to indoor fixtures (in a standardized scheme of similar fixtures) to show how well accepted they are likely to be with respect to discomfort glare. E.g., a VCP rating of 70 means that 70% of the occupants at a given viewing position will not be distracted by direct glare. Calculation of the VCP requires a very complex process, beginning with calculating the cumulative glare sensation index, Mt.

Visual satisfaction is a core aspect of the standard of illumination, and people may adjust to a broad spectrum of visibility (Hopkinson, 1963). Poorly distributed light can cause eye issues, decrease vision efficiency, and impair the output of the occupants. Araji (2008) summarised the views of Olgyay (1963) and Elzeyadi (2002), describing comfort as a complex perception by human senses. They find that the balance of objective inputs and subjective processes were dependent on the relationship between environment and biology.

For good vision without exhaustion, a minimum amount of illumination is required. However, unnecessary illumination can often be inconvenient if the lighting designer is not aware of the appropriate illumination amount in the working environment. (Elina Binti Mohd Husini, 2016)

The validity of the system for a wide variety of available luminaires and potential installations is uncertain. Also, the model only makes assumptions about a given line of sight and presumably does not hold any other viewing positions that the occupants might take. Besides, there is evidence that there are visual variations between uniform and non-uniform sources that make the VCP model inaccurate in estimating glare ratings for non-uniform sources (Michael Hirning,2014).

2.4.2.5 Daylighting factor (DF)

The Daylight Factor (DF) is described as measuring the internal horizontal illumination on the work plane to the external horizontal illumination calculated under the CIE overcast sky. It has been well established that the CIE overcast sky is an idealized sky state available only in simulation and is challenging to observe. Malaysia's sky condition is mainly intermediate (85.6 per cent), followed by overcast (Gene-HarnLim, 2017).

The simplest way of defining the distribution, penetration and intensity of daylight is the DF, expressed as a percentage (MS 1525). The daylight factor was originally developed to analyze overcast conditions, but it is now considered a limitation when studying bright sky and direct sun conditions (Weinold and Christoffersen, 2005).

Table 2.4 Daylight Factors and Impact

DF (%)	Lighting	Glare	Thermal Comfort
> 6.0	Intolerable	Intolerable	Uncomfortable
3.5 - 6.0	Tolerable	Uncomfortable	Tolerable
1.0 - 3.5	Acceptable	Acceptable	Acceptable
< 1.0	Perceptible	Imperceptible	Acceptable

2.4.3 Effects of glare

In contrast to previous research (Gowrisankaran et al. 2012; Mocci et al. 2001; Ostrovsky et al. 2012), the current study found that psychological tension has no effect on the relationship among perceived illuminance and discomfort during computer work with glare exposure (VS, visual stress). Over time, glare can cause eye strain, difficulty viewing papers, blurred vision, burning eyes, and even headache eye-focusing problems and tired eyes, contributing to an increased number of typing errors (ASTIC,2015 Rachel Neuman and Karen Jacobs, 2010).

This is not how any company wants an office to work, and business owners want to do the right thing to take care of their workers (ASTIC,2015). Glare will dramatically decrease visibility depending on the proximity of the glare source to the spectator (Rachel

Neuman and Karen Jacobs, 2010). Increased eyestrain was reported by Gowrisankaran et al., 2012, by introducing a perceptual load to visual stress (induced refractive error) compared to visual stress alone.

2.4.3.1 Effects of Daylight

Human beings also developed several physiological reactions when they evolved under sunlight. Wurtman studies (1975) have demonstrated that light has a profound impact on human wellbeing and that exposure to artificial light can harm humans. Many of them spend most hours of work in the daylight, and light's primary purpose is to provide adequate illumination. When light enters the retina, it causes people to make contact with it by sensory sensation. Studies of the impact of light upon humans, such as performance, have been undertaken by a number of researchers (Boyce et al., 1997), sleep quality influence (Marquie et al. 1999: Foret et al., 1998), circadian mechanism effects (Arendt et al. 2005). From a physical viewpoint, light reveals the various amounts of shades that provide different expressions of the world during daytime (Mukae et al., 1992) and the strength of light temperatures that affect brain behaviour, contributing to an autonomic nervous system and a degree of exhaustion. It is found that the positive influence of light on people is not exclusively dependent on technical and economic considerations, including nervous and endocrine processes (Wurtman, 1975), circadian systems, alertness, and mood for shift workers (Boulos et al., 1995). The previous research on how illuminance impacts people in office buildings suggests that windows and light distribution can be considered critical factors. The occupant's consideration of the curtain wall(window) contributes to the belief in illumination.

According to multiple studies, natural light reduces stress and discomfort rather than artificial lighting, and electrical light can be harm to wellbeing (Galasiu et al., 2006). Meanwhile, Heerwagen, 1986 study suggests that natural light is ideal on psychological well-being. The benefits of workplace illuminance are linked to a safe working space and the impact on wellness. Statements on even light delivery and adverse consequences of fluorescent lighting can have implications for social environments (Galasiu et al., 2006). Characteristics of the illumination system, as personal control, direct vs indirect lighting and the use of natural lighting, are often considered to lead to good lighting performance. In this analysis, the daylight factor of between 2% and 5% is assumed to be an appropriate range for occupants.

According to Malaysian Standard, the illumination level varies from 300 lux to 400 lux is usually observed under artificial lighting, and these ranges will be used in this analysis during the visual test trial. Table 2.3 indicates that the percentage of daylight factor between 1-2 per cent is perceived as appropriate, and the level of daylight factor between 2-5 per cent is favoured. These interpretations apply to a study that examines the range of appropriate and preferred daylight conditions (Elina Binti Mohd Husini,2016).

Table 2.5 Performance Indicators and Their Interpretations

No.	Performance Indicator	Interpretation
1.	Daylight Factor	
	<1%	Unacceptable
	1-2%	Acceptable
	2-5%	Preferable
	>5%	Ideal for paper work / too bright for VDT work
2.	Work plane illuminance	
	<100lx	Too dark for paper and VDT work
	100-300lx	Too dark for paper work / acceptable for VDT work
	300-500lx	Acceptable for paper work / ideal for VDT work
	>500lx	Ideal for paper work / too bright for VDT work

2.4.3.2 Productivity of work

The main issues are direct light from the sun that is hot and blinding. Many new buildings were designed, seeking to carry and shade the sun to an environmentally friendly design that contributes to the achievement of sustainable architecture. For visual comfort, the principle is to filter the bright daylight from outside. By applying several shading devices, including horizontal vertical, egg-crate and geometrical patterns, architects and building owners try to solve these problems. However, these shading devices seem to be ineffective in preventing glare and contributing to the use of internal blinds. As a result, office staff face inadequate light to carry out their everyday tasks (Zuraini Denan and Noor Hanita Abdul Majid 2015).

Several studies have correlate daylighting to enhanced productivity at the workplace. Boyce et al. defined an individual's or an organization's productivity as the ability to increase work production by increasing the quantity and/or quality of the product or service to be delivered. There are three routes by which lighting conditions can influence the output of individuals, according to these authors:

I. the visual system,
II. the circadian system,
III. and the perceptual system.

The effect of illumination on performance is unclear. The challenge in discovering the correlations between lighting and efficiency is that many other variables influence human output simultaneously. These variables include motivation, employee-management relationships and the degree of personal influence over working conditions. With adequate lighting, the ability to perform visual tasks can be improved, and visual distress can be avoided. This will provide conditions for improved execution of the visual and task and, eventually, productivity (Ružena Králikov et al., 2016).

2.4.3.3 Psychological effects

The luminous environment influences human physiological and psychological variables through a series of processes, which in turn influence human productivity and efficiency. It is not yet very well understood about the biological effects of light and its effects on human results (Ružena Králikov et al., 2016).

Lighting conditions decide the visual system's capabilities (N. Shishegar and M. Boubekri, 2016). The luminous atmosphere affects human physiological and psychological variables via a series of processes, which in turn affect human efficiency and productivity (Ruena Králikov et al., 2016).

The effect of illumination on performance is unclear. The challenge in discovering the correlations between lighting and efficiency is that many other variables influence human output simultaneously. These variables include motivation, employee-management relationships and the degree of personal influence over working conditions. With adequate lighting, the ability to perform visual tasks can be improved, and visual distress can be avoided. This will provide conditions for improved execution of the visual and task and, eventually, productivity (Ružena Králikov et al., 2016).

2.4.4 Symptoms of glare

Computer work and musculoskeletal complaints in the neck and shoulder are both famous in today's work (Waerted, M et al., 2010). Studies suggest that visually demanding computer work induces a substantial rise in eye-related discomfort (Thorud, H. et al., 2012), that visual distress in computer work is related to pain in the neck and shoulder (Helland, M, 2008), and that there is a correlation between prolonged nearby eye-lens lodging and trapezium function. Preliminary studies show that reading on a computer screen with sensitivity to glare relative to reading in optimum conditions effects the computer worker by substantially increasing muscle function in the muscle orbicularis and muscle blood pressure in the muscle trapezium. The findings also suggest a substantial rise in discomfort and tiredness in and around the eyes and photophobia. The frequency of pain in the shoulders and neck was also dramatically elevated during the recovery time after the glare session relative to the ideal session (Randi Mork, 2014).

According to the International Classification of Headache Disorders, migraine is the most common neurological condition that causes photophobia, and photophobia is one of the primary diagnosis conditions for migraine. (Headache Classification Committee of the International Headache Society) Up to 80% of migraine patients develop photophobia during an attack (Choi JY et al., 2009). (Drummond and Woodhouse 1993) found that migraines were more responsive both during and between migraine symptoms compared to non-migraine monitors. Vanagaite et al. (1997) reported that patients with migraine undergo increased light exposure to gradually increased light levels during and between episodes of headache relative to controls. They concluded that photophobia "seems to be an inherent property of migraines." In addition, 30% – 60% of migraine attacks are caused by light or glare. Various visual stimuli that induce migraine include sunlight, motion picture flickering, tv, and artificial light (Vincent AJ et al. 1989; Good PA et al., 1991). Migraine has been postulated to be synonymous with "visual pathway dysfunction" from the retina to occipital lobes (Chronicle EP and Mulleners WM, 1996; Kathleen B. Digre and K.C. Brennan, 2012).

Glare sensitivity during screen reading caused increased development of eye symptoms, increased muscle movement of the orbicularis oculi and increased blood pressure of the trapezium relative to reading with optimum illumination. (Blehm C et al., 2005) Orbicularis oculi muscle function was associated with blood supply and neck pain during both direct and optimal glare exposure. When subject to direct sunlight, eye pain, dry eyes, poor vision, photophobia, and headache improved dramatically after 30 minutes of reading than optimal settings (Randi Mork, 2016).

When a visual system is needed to work close to these limits for a more extended period, people can operate less effectively, often with signs and symptoms of discomfort. Typical symptoms are red, itchy, or watery eyes. Typical signs include pain in and near the eyes, fever, nausea, and exhaustion. These signs and symptoms can be triggered by several physiological and psychological causes (PR Boyce, 2018).

2.5 Visual comfort evaluation method

Heschong et al. (1999) conducted a report that discussed consumers' varied desires to assist them in selecting the appropriate daylight performance metrics. It presented a Daylight Analysis Framework which contained all the simulation tool's outputs and inputs. The index values for (CGI, Daylight Glare Index (DGI), and Unified Glare Level (UGR) for Hopkinson's 1950 categorical discomfort glare rating scheme were compared to the Daylight Glare Probability (DGP) and the Visual Comfort Probability (VCP) in Nazzal 2005 study, as seen below:

Table 2.6 Glare Index Values Relation

	DGP	DGI	UGR	VCP	CGI
Imperceptible	<0.35	<18	<13	80-100	<13
Perceptible	0.35-0.40	18-24	13-22	60-80	13-22
Disturbing	0.40-0.45	24-31	22-28	40-60	22-28
Intolerable	>0.45	>31	>28	<40	>28

2.6 Sky Conditions in Malaysia

Malaysian sky conditions are overcast to clear (Denan, 2004). Based on various studies, Zain-Ahmed et al. (1998) identified it as an intermediate or regular sky. According to Mohd Hamdan (1996), cloud formation in Malaysia will change the characteristics of the sky, with a luminance value of up to 100 000 lux. Another review by Fadzil et al. (2004) discovered that clouds in Malaysia are mostly overcast, as well as the period of March was selected for the analysis because it is Malaysia's hottest time.

Table 2.7 Sky Conditions

Sky Conditions			
Sky type	**Description**	**Cloud cover (%)**	**Sky Illuminance (lux)**
Standard overcast	Sun not visible; sky covered with thick, milky white cloud	100	5 000 - 20 000
Cloudy	Sky partially covered by cloud	> 70	20 000 - 100 000
Intermediate	Sky mostly covered with 30 % to 70 % cloud	30 - 70	30 000 - 100 000
Clear blue sky	Sky with almost no cloud	< 30	50 000 - 100 000

2.7 Legal requirement

There are several guidelines that provides practical guidance and advices on hot to comply with the acts that has been stated under Factories and Machinery Act (FMA) 1967, Factories and Machinery (Safety, Health and Welfare) Regulations, 1970 and Occupational Safety and Health Act (OSHA), 1994.

2.7.1 Factories and Machinery Act (FMA) 1967

Section 22(1)(e) of the Factories and Machinery Act, 1967 stipulates effective provision shall be made for securing and maintaining sufficient and suitable lighting, whether natural or artificial, in every part of a factory in which persons are working or passing.

2.7.2 Factories and Machinery (Safety, Health and Welfare) Regulations, 1970

Regulation 29 of the Factories and Machinery (Safety, Health and Welfare) Regulations, 1970 prescribed the responsibility of occupier with regards to lighting provisions. The responsibilities include:

I. Specifying the intensity of lighting required;
II. Adequate measures to prevent the formation on shadows; and
III. Provision of emergency lighting.

2.7.3 Occupational Safety and Health Act (OSHA) 1994.

Under Section 15 of the Occupational Safety and Health Act 1994, duties and responsibilities of employers and the self-employed persons are clearly stated. The responsibilities include:

(i) Provision and maintenance of plant and system of work to ensure safety and without risk to health;
(ii) Make arrangement to ensure safety and absence of risks to health in connection with the use or operation, handling, storage and transport of plant and substance;
(iii) Provision of necessary information, instruction and training to and supervision of employees to enable them to perform their work safely;
(iv) Provision and maintenance of working environment that is safe and without risk to health and adequate welfare facilities; and
(v) Providing good visual environment is in conformance to these requirements.

2.8 Malaysian Standards (MS 1525:2013) Energy efficiency and use of renewable energy for non-residential buildings

The following are the objectives of this Malaysian Standard:

(a) encourage the design, development, operation and maintenance of new and existing buildings in ways that minimize the use of energy without restricting occupants' creativity in terms of design, construction features and comfort or productivity; and address cost considerations appropriately;
(b) include the specifications for energy efficiency and minimum standards for new building construction, the refurbishment of existing buildings and the methods for determining compliance with those criteria and minimum standards;
(c) guide energy efficiency designs that demonstrate good professional judgement in order to meet minimum standards; and guide designs for energy efficiency which demonstrate good professional judgement in order to comply with minimum standards; and

(d) Encourage the use of renewable energy in new and existing buildings to reduce reliance on non-renewable energy sources, pollution and energy consumption while maintaining the comfort, health and safety of occupants. Since the specification only lays down the minimum requirements, designers are encouraged to design and select equipment above those set out in this Standard.

3. Methods

The sampling location of this research was in Bangsar South, Selangor. The study was done among the office workers from The Vertical Bangsar. There are 32 storey in the building with 7 types of layout with a total of 250 unit. A specific layout of type D is chosen. The total office space for this study consists of an area of 3174sq ft. Only 1 section was chosen for this study which gives an area of 1202sq ft. This space is used by most of the department, such as the Human Resource Department, Marketing Department, Business Leads Operation Department, and others. This space contains around 25-30 workers. It is divided into 4 sections where the first 2 section contains 8 tables for each row, 3rd section has 7 tables with 2 tables split and around 6-8 on the other side. The table used in this room has a glossy finishing surface. This room has a curved curtain wall that lets the daylight enter and use as the primary source of light, and the artificial lighting is used only when it gets darker. The wall of this space is painted in slight greyish color and has a soft white flooring.

3.1 Data collection, sampling and procedures

The sampling population of this study is office workers from The Vertical II, Bangsar, Selangor. The population for this study is 55 workers. Among them, a sample of 48 workers is chosen based on the Krejcie and Morgan table. Convenience sampling was chosen for this study due to different number of workers working in the office day by day because of this current pandemic.

Sampling procedure

I. Initial process

During the first quarter of the year, the initial process was to get approval for research from the university and fixing an appointment with the company was done. The process started with the approval of the topic that has been selected. Then, approached the company to fix an appointment date to explain the research and get approval from their side to continue the study.

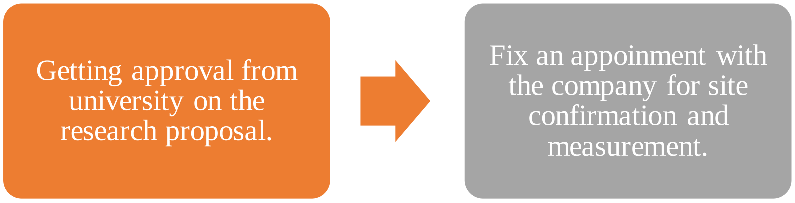


Figure 3.1 Initial process Flowchart

II. Mid process

The measurement was conducted at the workspace. This was done to introduce the reading in the calculation of room index to determine the total illuminance and architectural design using DIALux Evo. Then the workspace was designed in Revit so that the file can be imported in DIALux Evo for further analysis. The usage of luminaires' brand was confirmed to be included in the design and get a technical reading or the actual reading of the workspace. This was to compare current reading / live reading and the actual reading / theoretical reading to show the difference between old lamps and new ones. Aftab Alpha was tested with several High Dynamic Range (HDR) pictures to test the software's stability, so there will not be any glitch during the process. Then the analysis of glare was done using the software. The Daylight Glare Probability (DGP), Daylight Index Probability, etc., will be studied by analyzing the glare's intensity.

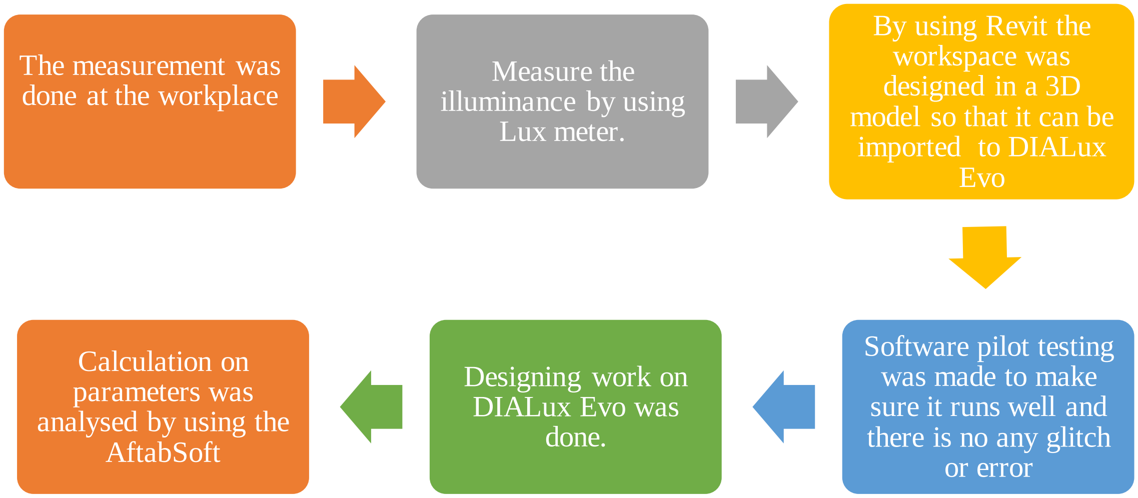


Figure 3.2 Mid process Flowchart

III. Final process

The final process of this study was to extract all the information that has been collected. Firstly, it started with the questionnaire to segregate according to a specific group. After the survey was completed the workers was interviewed for a justification on their opinion and which was mentioned in the questionnaire. Then the workspace was analysed without the aid of the software. A deeper study was made with the software by using DIALux and Aftab Alpha Evalglare. The DIALux showed the reading of total illuminance, which will then be compared with the standard, and study the result. The Aftab Alpha Evalglare will show the reading of Daylight Glare Probability, Unified Glare Rating, etc. Finally, conclude the research.

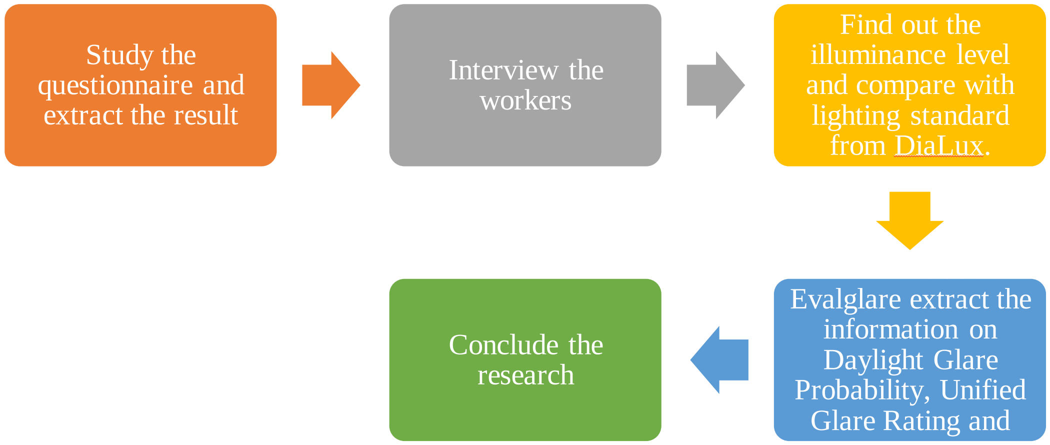


Figure 3.3 Final process Flowchart

3.4.1 Illuminance Measurement Procedure

(i) Measured the total area of the workplace/lab to find the room index.
(ii) From the room index calculation, find out the measuring point needed in a workplace.
(iii) Then the workplace was divided according to the measuring points.
(iv) Measure the illuminance level at the center of each area by dividing each point into another 9 representative points.
(v) Lighting measurement was taken at the height of the workplace.
(vi) Measuring procedure using Lux Meter
- Slide the "ON/OFF Switch" to the "ON" position.
- Proper range was selected on the "Range Switch."
- The sensor was exposed to the light for 3-5 minutes.
- The light sensor of the Lux Meter was placed on the work plane horizontal.

(vii) The average measurement of the illuminance at the task position was calculate and tabulate.

3.6.2. Autodesk Revit designing

(i) The design was created by using Autodesk Revit in a 2D plan format.

(ii) Then the walls were erected together with the curtain wall. The curtain wall was used to mimic the same design as the workplace and make sure it can show the penetration of daylight.
- The size of the wall was (9.8 m X 9.8 m)
- The height was 3 meters

(iii) The model then was decorated with interior furnishing and decoration to make it look realistic.

(iv) The table was designed with a height of 0.76 meters from the ground.

(v) The final touch was given on the wall paint.

(vi) The file was then converted to an IFC file so DiaLux Evo can read it.

3.6.3. Dialux Evo Simulation

(i) The model from Revit was used to interpret the calculation.

(ii) The model was then redesigned again (refer to 3.6.3.1 Limitation of Revit IFC Format in DiaLux) and converted to the DXF file, which contains the plan only.

(iii) The plan was then illustrated and drawn exactly with the reading given on the plan.

(iv) Once it is done, the model's light scene was set, and luminaires were fixed.

(v) For calculation
- The calculation object was set for each table.
- The calculation area was plotted for the whole office area that is chosen for the study.

(vi) The parameter was set for each calculation area, and some of them are
- Daylight factor
- Unified Glare rating
- Horizontal illuminance
- Vertical illuminance

(vii) As a final result the calculation was interpreted, and the report was generated

3.6.3.1. Limitation of Revit IFC Format in DiaLux

Several limitations in using Revit are:

(i) Revit formatted in IFC was not read by DiaLux Evo due to the selection of curtain wall.

(ii) To overcome this issue, the model was redesigned in DiaLux Evo again with the help of a sketched plan in Autodesk Revit.

(iii) The modal was redesigned with a cutout on the initial stage and then added the window to the cutout. This was done to make sure the daylight enters the office space.

(iv) Only windows and doors from DiaLux Evo must be sued to ensure the daylight enters and the Daylight Factor can be calculated

3.7 Data Analysis

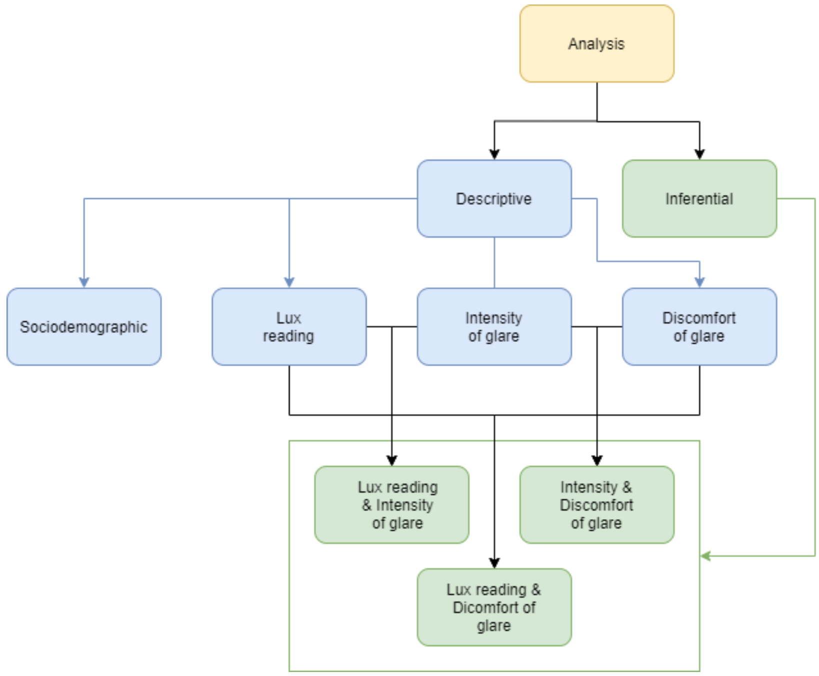
In this research SPSS was used as a tool for data analysis. With the aid of this software the pilot test of questionnaire was done before generating the data. Crombach's Alpha was used to do the pilot testing analysis and the reliability value was 0.734. SPSS also analyze and better comprehend your data, understand huge and complicated data sets rapidly using powerful statistical techniques that aid in decision making accuracy and quality.

Table 3.1 Data Analysis

Objectives	Data Analysis used
Sociodemographic	Descriptive
To calculate total illuminance in the office workplace.	Descriptive
To measure intensity of glare in the workplace.	Descriptive
To determine the discomfort of glare among office workers.	Descriptive
To study the relationship between total illuminance in the office workplace and glare discomfort among office workers.	Inferential: Crosstabs, One Sample t Test
To study the relationship between the total illuminance and the intensity of glare in the office workplace.	Inferential: Spearman, Pearson, One Sample t Test
To study the relationship between the intensity of glare and discomfort of glare among office workers.	Inferential: Spearman, Pearson, One Sample t Test

4. Data analysis and Results

This chapter will explain on the results and discussion from the analysis that has been made throughout this research process. The analysis was made with the regards to the survey, observation, field measurements, visual test, and simulation. This analysis will describe the lux reading, discomfort of glare and the intensity of glare in a workspace. The total sample for this research must be 44 however due to this current pandemic and the current SOP, only ½ of the sample population/ 22 respondents managed to do the survey as the rest were working from home and any results that is being answered from home will be prone to have more bias compared to the one in the office. This is because whoever working from home for too long might have been forgotten the aspects that they go through in their office environment as they are currently so used to work from home.



4.1 Demographic Profile

In this section of sociodemographic, the collected data from the questionnaire survey will describe the population studied. For this section descriptive analysis was performed. Table 4.1 shows the percentage and numbers of responses from the sociodemographic section. The results show that 12 (54.5%) female respondents and 10 (45.5%) respondents are male. There are four age categories, and 19 (86.4%)) of them falls under 20 – 29. The rest contributes to 1 (4.5%) for the remaining three categories, which are 30-39, 40-49, and 50-59. The workspace is entirely on computer-based task 22(100%), and none of them is on paper-based task 0 (0%).

The usage of Glasses and no eye corrective shares the same number of respondents, which is 11 (50.0%), and none of them are using lenses. The most working years spent in the company was 1-5 years voted with 12 (54.5%) and around 9(40.9%) worked for less than one year and 1 (4.5%) with more than five years. On average, 3-5 days was spent per week in the same workspace, with 16 (72.7%) and 6 (27.3%) work more than five days and no one work for 1-2 days with 0 (0). However, the working hours spent a day by each respondent is the same with more than 4 hours, 22 (100%) and less than 2 hours and 2-4 hours of them have a score of 0 (0%).

Table 4.1 Sociodemographic

Item	Frequency, n (%)
Gender	
Female	12 (54.5)
Male	10 (45.5)
Age	
20-29	19 (86.4)
30-39	1 (4.5)
40-49	1 (4.5)
50-59	1 (4.5)
Types of work	
Computer-based task	22 (100.0)
Paper-based task	0 (0)
Are you wearing corrective eyewear at the time of this survey?	
Glasses	11 (50.0)
Lenses	0 (0)
No	11 (50.0)
For how long have you been working in the same workspace	
Less than 1 years	9 (40.9)
1-5 years	12 (54.5)
More than 5 years	1 (4.5)
On average, how many days do you work in the same workspace?	0 (0)
1-2 days	16 (72.7)
3-5 days	6 (27.3)
More than 5 days	
On average, how many hours do you spend in the same workspace?	0 (0)
Less than 2 hours	0 (0)
2-4 hours	22 100.0)
More than 4 hours	

4.2.To measure intensity of glare in the workplace

This section explains the intensity of glare in the workplace. For this section descriptive analysis and One Sample t Test was performed. The intensity of glare was identified using two parameters: Daylight factors and Unified Glare Rating (UGR). DiaLux simulation was used for this to run and analyze the needed results. Figure 4.1 shows the false-color chart.

Figure 4.1 False Color Analysis Scale

Figure 4.2 shows the glare's intensity by false color analysis of the workspace. This analysis shows that it helps to understand the exposure levels of any region of the image, as different colors represent various luminance values. The rendition shows a higher value around the window panel area as the amount of daylighting in that area is higher than any other workspace space.

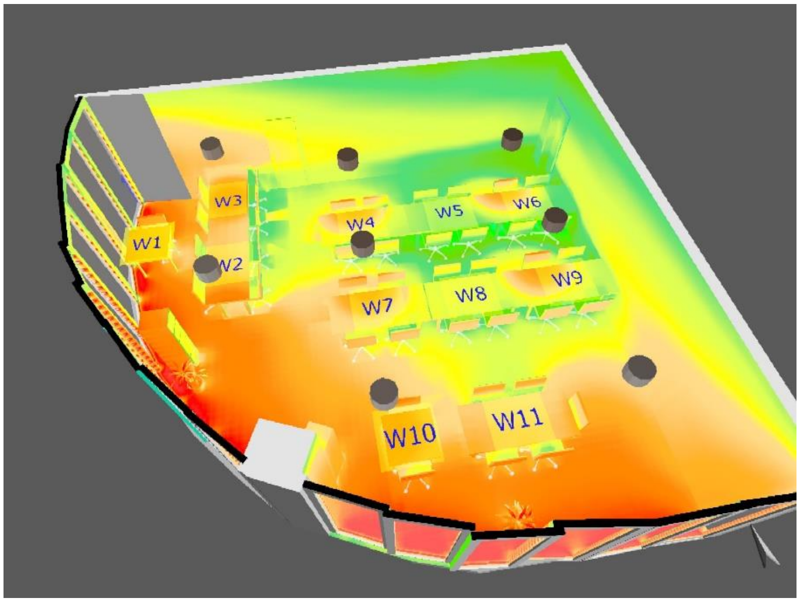


Figure 1.2 False Color Analysis

Table 4.2 shows the individual reading of the Daylight Factor (DF). According to tables 4.3 and 4.4, workspace 1 shows a value of 13.897%, which falls under an intolerable state for both lighting and glare. Workstation 2 shows 4.162% where it is tolerable for light but uncomfortable for glare. Workstations 3 and 4 records a value of 3.312% and 1.351%, both the records carry the same category where it is acceptable for lighting and glare condition. Workstation 5 and 6 shows a value of 0.972% and 0.787%, where for the lighting, it falls under perceptible and for glare, it is imperceptible. For workstations 7,8 and 9, the values taken are 1.952%, 1.522%, and 1.185%. These three workstations are in the range of acceptable for both lighting and glare. As for the other two workstations, 10 and 11, the value recorded are 5.004% and 3.912%, where their condition for lighting is tolerable and for glare is uncomfortable.

Table 4.2 Daylight Factor on Workstation

Number of workstations	Daylight Factor		
	Value (%)	Daylight Factor, Lighting (%)	Daylight Factor, Glare (%)
Workstation			
1	13.897	Intolerable	Intolerable
2	4.162	Tolerable	Uncomfortable
3	3.312	Acceptable	Acceptable
4	1.351	Acceptable	Acceptable
5	0.972	Perceptible	Perceptible
6	0.787	Perceptible	Perceptible
7	1.952	Acceptable	Acceptable
8	1.522	Acceptable	Acceptable
9	1.185	Acceptable	Acceptable
10	5.004	Tolerable	Uncomfortable
11	3.912	Tolerable	Uncomfortable

Table 4.3 shows Daylight Factor for the lighting category. The lighting category can be divided into Intolerable, Tolerable, Acceptable and Perceptible depending on the intensity. The result that has gotten from the analysis for DF to lighting was 2 (9.10) of them was under intolerable condition, 5 (22.70) for tolerable, 10 (45.50) for acceptable and 5 (22.70) for perceptible. The highest rating was rated for Acceptable, which concludes that the lighting in the workspace is acceptable but on the other hand, tolerable and perceptible shares an identical value as 5 (22.70). It can be said that the intolerable rate for DF in the workspace is very low as only 2 (9.10) has contributed to this.

Table 4.3 Overall DF for lighting category

Item	Frequency, n (%)
Daylight Factor, DF (Lighting)	
Intolerable	2 (9.10)
Tolerable	5 (22.70)
Acceptable	10 (45.50)
Perceptible	5 (22.70)

Table 4.4 shows Daylight Factor for the glare category. Both Daylight factor for glare and lighting shares the same reading, but they have a different scale. For DF glare, 10 (45.50) categorized as Acceptable and both Tolerable and Perceptible shows a score of 5 (22.70). A value of 2 (9.10) goes for intolerable.

Table 4.4 Overall DF for glare category

Item	Frequency, n (%)
Daylight Factor, DF (Glare)	
Intolerable	2 (9.10)
Uncomfortable	5 (22.70)
Acceptable	10 (45.50)
Imperceptible	5 (22.70)

The overall reading was calculated in terms of mean and standard deviation, as shown in Table 4.5 For both DF glare and lighting, the mean calculated was 5.837 with a standard deviation of 0.691. Based on the categorical data, it can be said the lighting and glare in the workplace are acceptable.

Table 4.5 Overall DF Mean and Standard Deviation

Item	Mean (Standard deviation)
Daylight Factor, DF	5.837 (0.691)

Table 4.6 shows the individual UGR for all workstations, whereas table 4.11 shows the category for UGR. Workstation 4,6,7,9 has a UGR value of more than 30, which gives us an intolerable glare condition. But for Workstation 1, 2 and 3, the UGR values are 13.897, 10.700 and 3.312, which is imperceptible. Workstation 5 and 8 also is imperceptible with a result of 15.100 and 13.400. Workstations 10 and 11 contribute a rating level of 5.004 and 14.900, which can be said as imperceptible.

Table 4.6 Unified Glare Rating on Workstation

Number of workstations	Unified Glare Rating	
	Values	**Category**
Workstation		
1	13.897	Imperceptible
2	10.700	Imperceptible
3	3.312	Imperceptible
4	>30	Intolerable
5	15.100	Imperceptible
6	>30	Intolerable
7	>30	Intolerable
8	13.400	Imperceptible
9	>30	Intolerable
10	5.004	Imperceptible
11	14.900	Imperceptible

Table 4.7 shows the Unified Glare Rating score of the workspace. The scale for UGR is divided into 4 with the scale of Imperceptible, Perceptible, Disturbing, and Intolerable. The highest score for UGR is in the Perceptible category, where 9 (40.90) of them falls under this category. Intolerable records 8 (36.40) and imperceptible records 5 (22.70) overall. From this table, we can also conclude that even though the glare range in this workplace is perceptible, the intolerable rate here is almost the same. It records one value lower than perceptible. The balance has recorded 5 (22.70) as the condition is just imperceptible, and there is no record found for the state to be disturbing.

Table 4.7 Overall UGR Categorical

Item	**Frequency, n (%)**
Unified Glare Rating, (UGR)	
Imperceptible	5 (22.70)
Perceptible	9 (40.90)
Disturbing	0 (0)
Intolerable	8 (36.40)

The overall UGR rating is 4.450 for mean and 0.430 for standard deviation, as shown in table 4.8.

Table 4.8 Overall UGR Mean and Standard Deviation

Item	**Mean (Standard deviation)**
Unified Glare Rating, (UGR)	4.450 (0.430)

Table 4.9 shows the One Sample t Test for DF. The p-value shows 0.845 which can be said that it is not significant. This is because the values are calculated for Daylight and not with artificial lighting

Table 4.9 One Sample t Test: DF

Compare	**Mean**	**Standard deviation**	**t value**	**p value**
DF	5.864	3.241	-0.197	0.845

Table 4.10 shows the One Sample t Test for UGR. The p-value for this was <0.01, which is more significant. The value for UGR is greater even compared with DF because UGR calculates the overall glare and total illuminance that leads to glare.

Table 4.10 One Sample t Test: UGR

Compare	**Mean**	**Standard deviation**	**t value**	**p value**
UGR	4.450	2.017	-33.821	<0.01

4.3 To determine the discomfort of glare among office workers.

The discomfort of glare analysis was conducted with the aid of a questionnaire survey. The questionnaire consists of 4 sections, and section A is sociodemographic, section B is visual comfort, section C1 is general discomfort, and section C2 is health discomfort. For this objective, the response from sections B, C1 and C2 was taken. For this section descriptive analysis was performed. From section B, there were seven options given to answer one question. The question was, “Images of your workstation will be taken by the consultant. Please mark the positions on the View Diagram light direction which are distracting or uncomfortable at this current time”, as shown in figure 4.3.

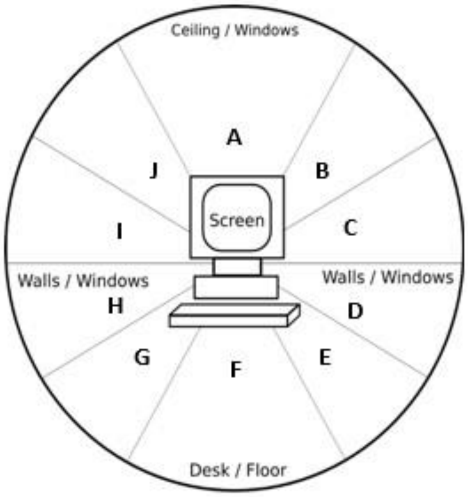


Figure 4.3 View Diagram

The respondent responded for each glare direction starting from A to J clockwise. The respondents will respond Yes if they experience glare from each direction and click on no if they do not experience any glare as shown in table 4.11. The recorded value for glare direction A was 15 (68.2%) with Yes and 7 (31.8%) with No, glare direction B has an equal number of 11 (50.0%) for both options. Glare direction C recorded a value of 10 (45.0 %) for Yes and 12 (54.5%) for No.

Glare direction D gives a reading of 15 (68.2%) for Yes and 7 (31.8%) for No, glare direction E recorded 4 (18.2%) response for Yes and 18 (81.8%) as No and glare direction F records a value of 5 (22.7%) as Yes and 17 (77.3%) for No. From glare direction F, 5 (22.7%) of them voted Yes and 17 (77.3%) of them voted No, for glare direction G 2 (9.1%) stated Yes and the rest which around 20 (90.9%) stated No and for glare direction H 15 (68.2%) choose Yes and 7 (31.8%). Finally, for glare direction I and J, the value was distributed evenly as 10 (45.5%) responded Yes and 12 (54.5%) responded No.

Table 4.11 Visual Comfort

Item	Frequency, n (%)
Glare direction A	
Yes	15 (68.2)
No	7 (31.8)
Glare Direction B	
Yes	11 (50.0)
No	11 (50.0)
Glare Direction C	
Yes	10 (45.5)
No	12 (54.5)
Glare Direction D	
Yes	15 (68.2)
No	7 (31.8)
Glare Direction E	
Yes	4 (18.2)
No	18 (81.8)
Glare Direction F	
Yes	5 (22.7)
No	17 (77.3)
Glare Direction G	
Yes	2 (9.1)
No	20 (90.9)
Glare Direction H	
Yes	15 (68.2)
No	7 (31.8)
Glare Direction I	
Yes	10 (45.5)
No	12 (54.5)
Glare Direction J	
Yes	10 (45.5)
No	12 (54.5)

Section C1, general discomfort of glare, consists of 31 questions, and they measure the discomfort of the workers from the study location. Based on table 4.12 preliminary: discomfort of glare, the recorded eye problem from the survey was Astigmatism and Myopia (Short-sightedness), where 3 (13.6%) respondents were diagnosed with Astigmatism, 4 (18.2%) with Myopia (Short-sightedness), and 15 (68.2) of them didn't have any medical history of eye problem.

For the light source, workers who prefer working in artificial light were 6 (27.3%), and with Daylight, preference was 16 (72.7%). 14 (63.6%) respondents are said to be sensitive to light, whereas 8 (36.4%) are not sensitive to light. The respondents were asked whether they work under the presence of multiple light sources or not and 13 (59.1%) of them responded Yes, whereas 9 (40.9%) of them is not under the influence of multiple light sources. As the distance of desk and window plays a role in this survey, we also consider the distance of their desk and window. Most of them with a respondent's rate of 12 (54.5%) has fewer than 2 meters from their window. The other 8 (36.4%) with 2-4 meters from the window and 2 (9.1%) with more than 4 meters.

Regarding the question above, the window's orientation was considered where 'I sit with back to the window' is 8 (36.4%) and 'I sit with my face to the window' 7 (31.8%). The option 'The window is located right to me' option was 3 (13.6%), and the 'The window is located left to me' was 4 (18.2%). Most of them with as many as 15 (68.2%) recorded that they experience glare, and only 7 (31.8%) of them recorded No. The respondents said high glare is experienced from 12.00 PM to 01.59 PM and 02.00 PM to 03.59 PM with a score of 12 (54.5%) and 10 (45.5%) for No. At 10.00 AM to 11.59 AM, 9 (40.9%) of them experience glare and 13 (59.1%) doesn't experience any whereas at 04.00 PM to 05.59 PM, 1 (4.5%) respondent experience glare and the rest 21 (95.5%) doesn't experience glow during that time. Finally, 21 (95.5%) respondents said that visual comfort is essential during work, and 1 (4.5%) responded No.

Table 4.12 Preliminary: Discomfort of glare

Item	Frequency, n (%)
Eye Problem	
No	15 (68.2)
Astigmatism	3 (13.6)
Myopia (Short-sightness)	4 (18.2)
Under what light source do you prefer to work?	
Artificial light	6 (27.3)
Daylight	16 (72.7)
Are you sensitive to intense light?	
Yes	14 (63.6)
No	8 (36.4)
Multiple light sources are used at workstations?	
Yes	13 (59.1)
No	9 (40.9)
How close is your desk to the nearest window? (Approx.)	
< 2 meters	12 (54.5)
2-4 meters	8 (36.4)
> 4 meters	2 (9.1)
How is your workstation oriented in relation to the window(s)?	

I sit with back to the window	8 (36.4)
I sit with my face to the window	7 (31.8)
The window is located right to me	3 (13.6)
The window is located left to me	4 (18.2)
Do you experience glare?	
Yes	15 (68.2)
No	7 (31.8)
At what time do you experience glare? (10.00AM to 11.59AM)	
Yes	9 (40.9)
No	13 (59.1)
At what time do you experience glare? (12.00PM to 01.59PM)	
Yes	12 (54.5)
No	10 (45.5)
At what time do you experience glare? (02.00PM to 03.59PM)	
Yes	12 (54.5)
No	10 (45.5)
At what time do you experience glare? (04.00PM to 05.59PM)	
Yes	1 (4.5)
No	21 (95.5)
Do you think visual comfort is important during work?	
Yes	21 (95.5)
No	1 (4.5)

In this part of the question Likert scale was given as an option for the workers to mark their discomfort rate. The scale starts with Never (0), Rarely (1), Sometimes (2), Often (3) and Always (4). Based on table 4.13, the first question from this section was "Does the natural daylighting distract the visible ability?" with results of 3 (13.6%) for Never, 4 (18.2) Rarely, 10 (45.5%) Sometimes, 4 (18.2%) Often and 1 (4.5%) Always. For the next question, "Does glare in office effects your work?" the response was Never 0 (0%), Rarely 2 (9.1%), Sometimes 12 (54.5%), Often 7 (31.8%) and Always 1 (4.5%). The next question was "You're comfortable with the current lighting condition in your workplace?", in this question, 15 (68.2%) said Often, 2 (9.1%) of them said it was Rarely, Sometimes and Always and Never was only 1 (4.5). The next three questions will be under the same umbrella based on "general lighting in your workspace" as if it is under the condition of Dim, Bright, and Glary.

Is the general lighting in your workspace is Dim? 13 (59.1%) of them said that they Rarely feel the workplace is dim, 5 (22.7%) of them recorded as never, 4 (18.2) said Sometimes, and 0 (0%) recorded Often and Always. For the bright condition, it was recorded 0 (0) Never, 1 (4.5) Rarely, 5 (22.7%) Sometimes, 10 (45.5%) Often, and 6 (27.3%) Always. However, for the glary category, the recorded response was 4 (18.2) for Never, 6 (27.3%) Rarely, 7 (31.8%) for Sometimes, 4 (18.2%) as Often and 1 (4.5%) recorded

Always. As an overall result, it can be said that for this question, the response for bright and glary is higher compared to dim. The adequacy of lighting arrangement in workstation was asked, only 1 (4.5%) of them responded Never and Rarely, 5 (22.7%) of them responded Sometimes, a greater number with 11 (50.0) responded Often, and 4 (18.2) was Always.

The next question was on difficulties with reading the computer screen; the response was 4 (18.2) of them choose never, 5 (22.7%) was recorded for Rarely and Often, 7 (31.8%) was Sometimes, and 1 (4.5%) of them was Always. “Are you satisfied with the amount of light for computer work?” this question priorities the illuminance on the assets being used, and 1 (4.5%) responded Never, 4 (18.2%) Rarely, 5 (22.7%) responded Sometimes and Always and 7 (31.8%) responded Often.

“Do you have difficulties with reading the documents on the desk?” this question was asked, even though they do not deal with documents as much as they do with the computer. It was asked to understand better the lighting settings as well, and the response was 13 (59.1%) for Never, 7 (31.8%) as Rarely, 2 (9.1%) as Sometimes, and for Often and Always, it was equally 0 (0). Moreover, the satisfaction rate for paper-based reading work was recorded as well. The result was 3 (13.6%) choose Never, 1 (4.5%) Rarely choose, 0 (0%) for Sometimes, 7 (31.8%) for Often, and 11 (50.0%) as Always. Laptop/computer screen also plays a role in glare; therefore, a question-related was asked: “Do you feel the laptop/computer screen causes glare to eye?”. The respondent responded as 8 (36.4%) of them shows no problem, 2 (9.1%) and 5 (22.7%) was Never and Sometimes, and 4 (18.2%) choose Often whereases 3 (13.6%) of them choose Always. Also, the experience of switching between a task which causes eyes to work hard was asked, and it turns out to be Never it was 5 (22.7%) of them, Rarely was 3 (13.6%), Sometimes records 8 (36.4%), Often and Always was 3 (13.6).

“The level of glare sensation experienced by you is high?” was also one of the questions, and the respondent response was 5 (22.7%) Never, 8 (36.4%) for Rarely, 3 (13.6%) for Sometimes, Often was 4 (18.2%) and Always was 2 (9.1%) response. The following question on “How often do you get distracted from your visual performances due to lighting level?” recorded the high response with 10 (45.5) for Sometimes, 7 (31.8) for Rarely, Never was 3 (13.6%), Often was 0 (0%) and Always was 2 (9.1%). “Does glare trigger your emotion and mood?” for this question, the respondents’ response was 10 (45.5%) said they Never felt it, 7 (31.8%) of them was Rarely, 3 (13.6%) of them was Sometimes, and 1 (4.5%) was for Often and Always. A stress-related question was added to understand whether the workers feel stress due to glare, and it turns out 7 (31.8) of them Never and Rarely had that issue, 6 (27.3%) experienced it Sometimes, and 1 (4.5%) either experienced it Often or Always. The workers were also asked whether they required blinds/curtains in their office, and 8 (36.4%) mentioned that they do prefer them Sometimes and Often, 2 (9.1%) will Never or Rarely require them and 3 (13.6%) always require them. The final question on this session was, “Do you prefer to move the desk location or view direction?”. It seems that 6 (27.3%) of them said it is Sometimes and Often, 3 (13.6%) of them said Never and Always, and only 4 (18.2%) choose Rarely.

Table 4.13 General Discomfort of Glare

Item	Frequency, n (%)
Does the natural daylighting distract the visible ability?	
0 Never	3 (13.6)
1 Rarely	4 (18.2)
2 Sometimes	10 (45.5)
3 Often	4 (18.2)
4 Always	1 (4.5)
Does glare in office effects your work?	
0 Never	0 (0)
1 Rarely	2 (9.1)
2 Sometimes	12 (54.5)
3 Often	7 (31.8)
4 Always	1 (4.5)
You’re comfortable with the current lighting condition in your workplace?	1 (4.5)
0 Never	2 (9.1)
1 Rarely	2 (9.1)
2 Sometimes	15 (68.2)
3 Often	2 (9.1)
4 Always	
Is the general lighting in your workspace is Dim?	
0 Never	5 (22.7)
1 Rarely	13 (59.1)
2 Sometimes	4 (18.2)
3 Often	0 (0)
4 Always	0 (0)
Is the general lighting in your workspace is Bright?	
0 Never	0 (0)
1 Rarely	1 (4.5)
2 Sometimes	5 (22.7)
3 Often	10 (45.5)
4 Always	6 (27.3)
Is the general lighting in your workspace is Glary?	
0 Never	4 (18.2)
1 Rarely	6 (27.3)
2 Sometimes	7 (31.8)
3 Often	4 (18.2)
4 Always	1 (4.5)
Do you feel workstations are arranged with adequate lighting?	
0 Never	1 (4.5)

1 Rarely	1 (4.5)
2 Sometimes	5 (22.7)
3 Often	11 (50.0)
4 Always	4 (18.2)
Do you have difficulties with reading the computer screen?	
0 Never	4 (18.2)
1 Rarely	5 (22.7)
2 Sometimes	7 (31.8)
3 Often	5 (22.7)
4 Always	1 (4.5)
Are you satisfied with the amount of light for computer work?	
0 Never	1 (4.5)
1 Rarely	4 (18.2)
2 Sometimes	5 (22.7)
3 Often	7 (31.8)
4 Always	5 (22.7)
Do you have difficulties with reading the documents on desk?	
0 Never	13 (59.1)
1 Rarely	7 (31.8)
2 Sometimes	2 (9.1)
3 Often	0 (0)
4 Always	0 (0)
Are you satisfied with the amount of light for paper-based reading work?	3 (13.6)
0 Never	1 (4.5)
1 Rarely	0 (0)
2 Sometimes	7 (31.8)
3 Often	11 (50.0)
4 Always	
Do you feel the laptop/computer screen causes glare to eye?	
0 Never	2 (9.1)
1 Rarely	8 (36.4)
2 Sometimes	5 (22.7)
3 Often	4 (18.2)
4 Always	3 (13.6)
Does switching between task causes your eyes to work hard?	
0 Never	5 (22.7)
1 Rarely	3 (13.6)
2 Sometimes	8 (36.4)
3 Often	3 (13.6)
4 Always	3 (13.6)
The level of glare sensation experienced by you is high?	
0 Never	5 (22.7)

1	Rarely	8 (36.4)
2	Sometimes	3 (13.6)
3	Often	4 (18.2)
4	Always	2 (9.1)
How often do you get distracted from your visual performances due to lighting level?		
0	Never	3 (13.6)
1	Rarely	7 (31.8)
2	Sometimes	10 (45.5)
3	Often	0 (0)
4	Always	2 (9.1)
Does glare trigger your emotion and mood?		
0	Never	10 (45.5)
1	Rarely	7 (31.8)
2	Sometimes	3 (13.6)
3	Often	1 (4.5)
4	Always	1 (4.5)
Does glare leads to stress while working?		
0	Never	7 (31.8)
1	Rarely	7 (31.8)
2	Sometimes	6 (27.3)
3	Often	1 (4.5)
4	Always	1 (4.5)
Do you prefer to have blinds/curtains in your office?		
0	Never	2 (9.1)
1	Rarely	1 (4.5)
2	Sometimes	8 (36.4)
3	Often	8 (36.4)
4	Always	3 (13.6)
Do you prefer to move the desk location or view direction?		
0	Never	3 (13.6)
1	Rarely	4 (18.2)
2	Sometimes	6 (27.3)
3	Often	6 (27.3)
4	Always	3 (13.6)

Based on Table 4.14, health discomfort among the office workers was analyzed. We introduced seven symptoms that they may feel that can be caused by glare. The symptoms were asked based on how they feel for the past one week only. From the seven symptoms that have been analyzed, eye fatigue contributes more compared to the other symptoms. Around 8 (36.4%) reported it was Moderate, 4 (18.2%) has none, an equal number of 5 (22.7%) for Mild and Very Mild, and none has severe symptoms.

For headache, 11 (50.0%) them had no symptoms, 7 (31.8%) and 4 (18.2%) of them had Very Mild and Mild symptoms, and 0 (0%) was Moderate and Severe. The response for dry eyes is 10 (45.5%) for None, 5 (22.7%) for Very Mild, 6 (27.3%) was for Mild, only 1 (4.5%) for Moderate, and 0 (0%) for Severe. Symptoms of blurred vision were not like other symptoms where there was 0 (0%) response for Moderate and Severe, only 7 (31.8%) and 4 (18.2%) had Very Mild and Mild effects, and the rest was None with 11 (50.0%). The questionnaire also consists of 2 questions related to MSD as well, and those were Neck and back pain and Shoulders pain.

On the option for shoulders pain, 5 (22.7%) of them responded None, 9 (40.9) and 7 (31.8%) of them recorded Very Mild and Mild, 1 (4.5%) was Moderate, and 0 (0%) was Severe. On the other hand, for Neck and back pain for None and Very Mild the respondents equally responded with a response of 6 (27.3%), 7 (31.8%) as for Mild, 2 (9.1%) for Moderate, and 1 (4.5%) for Severe. From the overall result, it can be said that most of the symptoms such as Eye fatigue, Headache, Dry eyes, Shoulders pain, and Neck and back pain have Very Mild to Mild effects only, and hardly they become Moderate or Severe. Symptoms of Eye burning contributed to None with 15 (68.2%) response, Very Mild and Mild with3 (13.6%), 1 (4.5%) for Moderate, and finally 0 (0%) for Severe.

Table 4.14 Health Discomfort

Item	**Frequency, n (%)**
	Past 1 week
Eye fatigue	
None	4 (18.2)
Very Mild	5 (22.7)
Mild	5 (22.7)
Moderate	8 (36.4)
Severe	0 (0)
Headache	
None	11 (50.0)
Very Mild	7 (31.8)
Mild	4 (18.2)
Moderate	0 (0)
Severe	0 (0)
Dry eyes	
None	10 (45.5)
Very Mild	5 (22.7)
Mild	6 (27.3)
Moderate	1 (4.5)
Severe	0 (0)
Blurred vision	

None	11 (50.0)
Very Mild	7 (31.8)
Mild	4 (18.2)
Moderate	0 (0)
Severe	0 (0)
Eye burning	
None	15 (68.2)
Very Mild	3 (13.6)
Mild	3 (13.6)
Moderate	1 (4.5)
Severe	0 (0)
Shoulders pain	
None	5 (22.7)
Very Mild	9 (40.9)
Mild	7 (31.8)
Moderate	1 (4.5)
Severe	0 (0)
Neck and back pain	
None	6 (27.3)
Very Mild	6 (27.3)
Mild	7 (31.8)
Moderate	2 (9.1)
Severe	1 (4.5)

From table 4.15, It can be deduced that the general discomfort among the workers as per the survey done shows that the glare that the workers mostly facing Mid 19 (86.4%) discomfort.

Table 4.15 General Discomfort Category

Item	**Frequency, n (%)**
General Discomfort	
Low	2 (9.1)
Mid	19 (86.4)
High	1 (4.5)

When it comes to their health discomfort from table 4.16 due to glare, it shows Low category for 18 (81.8%) of them doesn't have any impact towards health as it does not affect them badly.

Table 4.16 Health Discomfort Category

Item	Frequency, n (%)
Health Discomfort	
Low	18 (81.8)
Mid	4 (18.2)
High	0 (0)

Therefore, the hypothesis is not accepted as the value that is shown in all 3 sections are not under the category of intolerable but they're tolerable.

4.4. To study the relationship between the intensity of glare and discomfort of glare among office workers.

In this section, few analyses were done between General discomfort, health discomfort and glare direction, DF and UGR. The study conducted was Spearman and Pearson correlation. This is because the DF scaled data is normal, and the UGR scaled data was not normal. Based on table 4.17, the significant value for DF and Glare Direction test was 0.780 for Glare Direction A, 0.406 for Glare Direction B, 0.280 for Glare Direction C,0.332 for Glare Direction D, 0.046 for Glare Direction E, 0.094 for Glare Direction F, 0.015 for Glare Direction G, 0.019 for Glare Direction H, 0.027 for Glare Direction I, and 0.668 for Glare Direction J. Values on direction E, G, H, I shows that it is significant as they have lower recorded value and the rest are not significant as they have higher significant value. This is because DF doesn't relate with the direction of glare, but it emphasizes more on the daylight factor such as the illuminance rate on top of the surface. Resulting from that we can say that the Glare direction E, G, H, and I have significant value as they tend to have more illuminance being illuminate on.

Table 4.17 DF and Glare Direction

Relationship	DF	
	p value	r value
Glare Direction A	0.780	-0.063
Glare Direction B	0.406	-0.187
Glare Direction C	0.280	-0.241
Glare Direction D	0.332	-0.217
Glare Direction E	0.046	-0.430
Glare Direction F	0.094	-0.366
Glare Direction G	0.015	-0.513
Glare Direction H	0.019	-0.495
Glare Direction I	0.027	-0.472
Glare Direction J	0.668	-0.097

Table 4.18 DF and General Discomfort

Relationship	DF	
	p value	r value
General Discomfort	0.304	0.230

The significant value showed in table 4.19 for DF and Health Discomfort test was 0.703.

Table 4.19 DF and Health Discomfort

Relationship	DF	
	p value	r value
Health Discomfort	0.703	-0.086

From table 4.20, the significant value for UGR and Glare Direction test based on table 4.30 is 0.862 for Glare Direction A, 0.771for Glare Direction B, 0.358 for Glare Direction C, 0.728 for Glare Direction D, 0.081 for Glare Direction E, 0.047 for Glare Direction F, 0.022 for Glare Direction G, 0.106 for Glare Direction H, 0.152 for Glare Direction I, and 0.557 for Glare Direction J. This can be deduced that glare directions F and G record lower significant values than the rest. Only Glare direction F and G shows a significant value from the analysis that was made. This is because the surface tends to reflect more light so it is prone to be a spot with high glare rate.

Table 4.20 UGR and Glare direction

Relationship	UGR	
	p value	r value
Glare Direction A	0.862	-0.039
Glare Direction B	0.771	-0.066
Glare Direction C	0.358	-0.206
Glare Direction D	0.728	-0.079
Glare Direction E	0.081	-0.380
Glare Direction F	0.047	-0.428
Glare Direction G	0.022	-0.484
Glare Direction H	0.106	-0.354
Glare Direction I	0.152	-0.316
Glare Direction J	0.557	-0.132

Table 4.21 records the significant value for UGR and the General Discomfort test, and the recorded value was not significant with 0.327.

Table 4.21 UGR and General Discomfort

Relationship	UGR	
	p value	r value
General Discomfort	0.327	0.219

Based on table 4.22, the significant value for UGR and Health Discomfort test was 0.079.

Table 4.22 UGR and Health Discomfort

Relationship	UGR	
	p value	r value
Health Discomfort	0.079	-0.382

As an overall result concerning DF and other components, it can be said that DF and glare direction, general discomfort and health discomfort are not significant. As for UGR and glare direction, General discomfort, and health discomfort it is also concluded as there is not significant relationship. Therefore, the hypothesis is not accepted because there is no significant relationship between the intensity and discomfort of glare among workers.

5. Discussions

As of the first objective, the curved arc is entirely on the window panel, more lights are being reflected inside. This affects the workstation which is nearest to the window by showing a high value. Meanwhile, the corner of the workspace is green because the amount of lux in that area is acceptable, which shows green shades. Workstation 4,6,7, and 9 records the false color of orange as it is under the influence of direct/artificial lighting. From the overall result from the whole process of analysis, the intensity of glare, we can deduce that glare in the workplace is not under intolerable category. As the for DF lighting and glare in the acceptable range, it is considered perceptible even though the difference between intolerable and perceptible is low. From the table 4.9 and table 4.10 we can conclude that the One sample T test for both DF and UGR. It explains that UGR is significant, and DF isn't significant from the tested result, and this is because DF calculates the daylight effects and UGR will calculate every single illuminance being illuminated within the space. Glare increases with brighter lamps and poor background lighting, whereas it reduces with dimmer lamps and higher background lighting (Park, Augenbroe, and Messadi, 2003); The Daylight Factor (DF) is described as measuring the internal horizontal illumination on the work plane to the external horizontal illumination calculated under the CIE overcast sky (Gene-HarnLim, 2017). The DF and UGR are related to the Lux reading because the value has a relationship with the amount of illuminance on the workstation. From figure 4.2, we can see that the area covers by false color analysis and around the window panel, the results showed are red. UGR and DF increase when lux reading increases, which explains why the reading received from DiaLux evo is higher at specific workstations. Hence the hypothesis is accepted because there the intensity of glare among office workers is high.

For the 2nd objective, table 4.15, It can be deduced that the general discomfort among the workers as per the survey done shows that the glare that the workers mostly facing Mid 19 (86.4%) discomfort. The effect of illumination on performance is unclear. The challenge in discovering the correlations between lighting and efficiency is that many other variables influence human output simultaneously. These variables include motivation, employee-management relationships and the degree of personal influence over working conditions (Ružena Kr.likov et al., 2016). When it comes to their health discomfort from table 4.16 due to glare, it shows Low category for 18 (81.8%) of them doesn’t have any impact towards health as it does not affect them badly. They only experience one health discomfort mostly which is eye fatigue and even that is in moderate level. Due to their nature of job, which is mostly depending on computer related task, they tend to have eye fatigue frequently. As mentioned in (ASTIC,2015 Rachel Neuman and Karen Jacobs, 2010) over time, glare can cause eye strain, difficulty viewing papers, blurred vision, burning eyes, and even headache eye-focusing problems and tired eyes, contributing to an increased number of typing errors. Other than that, the health discomfort is either Never or Very Mild. Therefore, the hypothesis is not accepted as the value that is shown in all 3 sections are not under the category of intolerable but they’re tolerable.

Finally, based on table 4.18, the significant value for DF and the General Discomfort test was 0.304. DF and General discomfort records higher values; therefore, it is not significant. This is because the recorded response value was only moderate and wasn’t high. Most of the contributing factors towards general discomfort were low or none. The significant value showed in table 4.19 indicates a higher reading; hence it is not significant. For health the scale shows lower value only where they’re not affected by any of the symptoms that was listed. They also tend to have a balanced and casual work environment from the observation that was done among the office workers. From table 4.30, This can be deduced that glare directions F and G record lower significant values than the rest. Only Glare direction F and G shows a significant value from the analysis that was made. This is because the surface tends to reflect more light so it is prone to be a spot with high glare rate. Table 4.21 value shows 0.327 because the recorded response value was only moderate and wasn’t high. Most of the contributing factors towards general discomfort were low or none. So, it couldn’t produce the targeted result. Based on table 4.22, the significant value for UGR and Health Discomfort test was 0.079 because the studied parameter (Health discomfort) doesn’t contribute to any severe result from the analysis done or the respondent didn’t respond that they encounter a situation that gives health discomfort from their current employment. As an overall result concerning DF and other components, it can be said that DF and glare direction, general discomfort and health discomfort are not significant. As for UGR and glare direction, General discomfort, and health discomfort it is also concluded as there is not significant relationship. Therefore, the hypothesis is not accepted because there is no significant relationship between the intensity and discomfort of glare among workers.

6. Conclusions, Implications and Recommendations

This chapter concludes the study findings in line with the objectives, with the research's validity, expressed clearly and explained the recommended measures that can be carried out. Overall, occupants were at ease with the level of daylighting available in their rooms (N.D. Dahlan et al., 2008) even though some of the workstations were brighter and had more glare. Research is needed to determine the relative threshold of occupants' dim and bright expectations or the glare level with focusing Hopkinson's conjecture that a view More with a great deal of interesting information may reduce discomfort from a glare source of light, in particular a window (Hopkinson, 1970, 1972).

5.1. Conclusion

Firstly, the first objective, "To calculate total illuminance in the office workplace", was tested with descriptive analysis and One Sample t Test. It comes out that the value was generated significant, and the hypothesis was accepted. It can be said that the workstations in the workplace aren't projected with an adequate level of illuminance. This is because some workstation is aligned along the window panels and dome under the influence of direct lighting, which gives a higher reading of lux when lux measurement was taken. The penetration of daylight via window panels and artificial lighting provides more lighting or illuminates more light onto the surface of the workstation, which leads to direct and indirect glare. Hence, the workplace doesn’t achieve the standard lux that is stipulated in lighting guidelines and Malaysian standard.

The second objective, “to study the relationship between total illuminance in the office workplace and glare discomfort among office workers”, used the Chi-square test as it was between categorical data. The hypothesis was not accepted as the result was not significant. The total illuminance in each workstation records higher and lower lux reading. It can be said that the reading fluctuates according to the workstation. However, for the discomfort variable, we can conclude that the results weren’t leading towards the glary situation even though there were chances to do so. As the data didn’t support both the variables, it was concluded as it was not helping the finding of this objective.

The third objective was to study the relationship between the total illuminance and the intensity of glare in the office workplace. This objective was tested with Spearman and Pearson correlation. Even though there is a high relationship between the lux reading and DF and UGR, the recorded value for this paper was not appealing. The result may have gotten better with more than 30 or 40 respondents as a baseline, but due to the current pandemic situation, there was a reduction due to the mode of working. The respondents are primarily from the workstation, which has lesser reading and records a lower value of DF and UGR; this was unable to relate with the lux reading produced by the DialuxEvo software.

5.2. Study limitation

Due to the current pandemic situation of the Covid19 Outbreak, several parameters weren't calculated. Several parameters such as DGP, DGI and VCP weren't calculated because of the closure of the study location. These parameters were supposed to be computed using Aftab Software's aid by capturing and generating HDR Images.

The research was held with 22 respondents, which is half of the total sample of 44 respondents. This is also due to the current situation where workers are working from home. Requesting those workers who work from home to complete the questionnaire will lead to false information or bias as they might forget the condition of their workplace. Also, it is highly recommended to have more respondents complete the survey and interview/observe more workers for better results.

5.3. Recommendation

I. Future researcher

As for future researchers, we can choose more parameters to study the relationship and the glare. Due to the current pandemic situation, specific planned tests weren't conducted due to the movement-controlled order by the government. However, future researchers may study the parameters such as DGP, DGI, VCP, and others. Will be prone to have better results on the research. Considering the usage of AftabSoft (evalglare) will benefit the researchers as they can find more detailed results from their findings. The researcher also needs to fulfil the sample size given or make the sample size higher or bigger to get more accurate results from the study being conducted.

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