An Analysis on Role of Lighting Quality on Degree of Human Comfort in Public Buildings and Spaces

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***Abstract*—Lighting accounts for a significant amount of energy consumption in buildings especially public ones, up to 45% of the total consumed. This energy consumption can be reduced by as much as 60% through several design approaches as well as lighting control strategies. With particular focus on public buildings, where the application of this strategy is more challenging to apply due to differences in individual occupancy patterns, this paper covers and discusses items like role of lighting on comfort of occupants. Search terms were defined with use of three categories, namely 'occupancy patterns',' lighting control strategy' , and ' public space or building'. Relevant articles were selected by a structured search through key online scientific databases and journals.**

Although lighting currently tends to be controlled at workspace level or in public spaces, many aspects of the lighting strategies can be further developed; there is potential to further increase energy savings on lighting within open-plan public spaces.

***Index Terms*—architecture, comfort, space, lighting.**

I. Introduction

Light influence human vision. Lighting should provide visual conditions in which people can function effectively, efficiently, and comfortably. To predict human visual quality as a function of the lighting conditions, it is essential to understand the variables performances and discomfort of human visual system. Thus, the background of study highlights some of the basic relationships between light and vision. It provides some fundamental data that the designer of a building may find useful and calls attention to the factors that need to be considered when designing space, lighting and task for visual quality (performance and comfort) in the public buildings. The analysis is qualitative and limits in the public building area focus. [1].

Artificial lighting accounts for a significant fraction of global electrical energy consumption. In office and public buildings in particular lighting comprises 20 - 45% of their energy consumption. Earlier researchers have pointed to the importance of lighting in sustainable housing programs [2]. To promote energy savings on lighting use, aside from the use of more energy efficient luminaries such as LEDs [3], various lighting control strategies have been designed and implemented in public buildings. Examples of such strategies include daylight-linked automatic lighting control, dimming control and occupancy-based lighting control. Linking a light system with occupancy sensors is a cost-effective and easy solution for reducing lighting energy use. Their implementation has been demonstrated successfully in a number of studies, where energy used for lighting has been reduced by between 20% and 60%, depending on the configuration, type of space and type of occupancy sensor used [4]-[5].

Information gained by visualization of an object in a public space like gallery exhibition is becoming more common in public spaces such as galleries, museums and libraries. Public nature of these locations, however, requires special considerations in concerning the design of information visualization in terms of visual representations and interaction techniques [6]. According to Hinrichs et al., people's overall experiences of the visualization are highly influence by the interaction design. Visually appealing information and displays can be experienced negatively due to awkward interaction and techniques if it is hard to visualize. The interaction techniques for museum or gallery information visualizations should be as lightweight and intuitive as possible to ensure the visual quality toward the artworks. Other studies have revealed a significant relationship between gender and the extent of visual spatial elements as well as a significant difference between perceptions of different visual elements [7].

This study focusses on how lighting can be controlled more efficiently in relation to individual occupancy patterns in public buildings so that energy can be saved. Therefore, only characteristics related to this issue are considered. First of all, lighting energy use is affected largely by the used type of luminaires. Their spatial relationship to the objects and areas determine how efficiently the luminaires deliver lighting where it is needed, in other words, the object. Therefore, the number of luminaires per office space, the positioning of the luminaires (e.g. ceiling mounted, recessed), and the extent to which the luminaires are aligned to the position of the workspaces.

Manuscript received August 28, 2017; revised September 8, 2018.

doi: 10.18178/ijscer.7.4.400-404

II. Literture Review

A. Visual Quality

Human visual system involves the eye and brain working together to interpret the visual environment. The optical elements of the eye form an image of the environment on the retina by absorption of the light (spectrum). To form an image of the target on the retina, light has to be transmitted through the eye without excessive absorption and scattering, and the image of the target has to be focused on the retina. According to Lang (2012), visual quality is one aspect to assure that there is enough light for users to see and perform their daily tasks without eye strain. Lighting has a significant effect on how human perceive the world, and maintaining visual quality is a crucial factor in aiding human perception [8].

The human visual system is an image processing system. It involves the eye and brain working together to interpret the visual environment. The eye will form an image of the target on the retina from the optical components (the cornea, crystalline lens, and pupil). For this to occur, light has to be transmitted through the eye without excessive absorption and scattering, and the image of the target has to be focused on the retina [8]. Human visual system has to be functional well by adapting to the prevailing light condition. The human visual system able to process information over an enormous of luminance's, but not all at once. To cope with the light exposition from night to the sunlit, the human visual system changes its sensitivity through a process called adaptation. When the visual system is not completely adapted to prevailing retinal illumination, its capabilities are limited [9]. Human visual quality can be achieved in different conditions through visual performance and visual comfort.

B. Visual Performence

Review from the IESNA Lighting Handbook (2000) stated, visual performances are concerns with the limits and visible of the visual system's capabilities. The quality of visual performance depends significantly on the characteristic of the lighting speed and accuracy, and the visual system of the observer. Lighting position is relates with the display type, display setting, ceiling height and amount of displays. In normal practice, spaces like art gallery exhibition installed with ceiling mounted light either direct or indirect light. For vertical display, ceiling mounted light is installs in 30 º angle position with specific formulate distance of ceiling height - the human eye level + 577 mm. This calculation creates a minimum distant parameter for the viewer for good visual experience. However, for freestanding display it is easier where the ceiling mounted installed at the center of the display position as shown in Fig. 1.

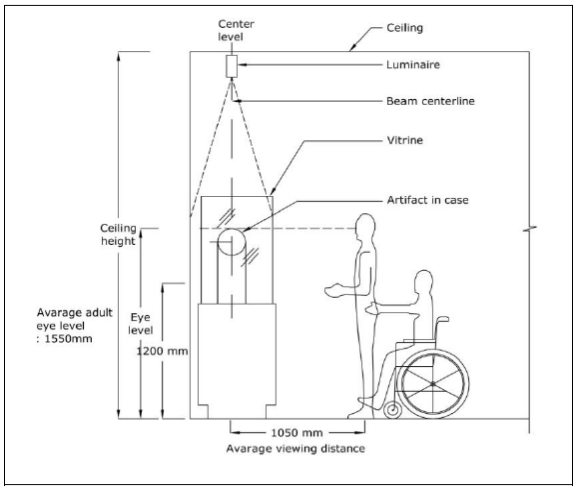

Figure 1. Normal Position for Freestanding Display

Visual targets that are larger than the minimum size but have the same luminance as the immediate background is zero luminance contrast. It can still be discerned by differences in color. Color difference can be highlighted between the colors of the objects like artwork and the immediate background (wall and partition). Additionally, such as cognitive factor as perception and expectation affect the measurement of the detect ability and recognition of the target. Despite visual performance, visual comfort is a key factor in human visual quality. Visual comfort can prevent symptoms and cause of visual discomfort - red, sore, itchy, and watering eyes; headaches and migraine attacks. There are many different of lighting that can cause visual discomfort. Insufficient light is an obvious problem of visual discomfort such as - glare, shadows, and veiling reflections. According to Rutter (1997), as shown in Fig. 2, most commonly reported display-design problem is glare and contrast as most of these complaints came from the age of 40 and above crowds [10].

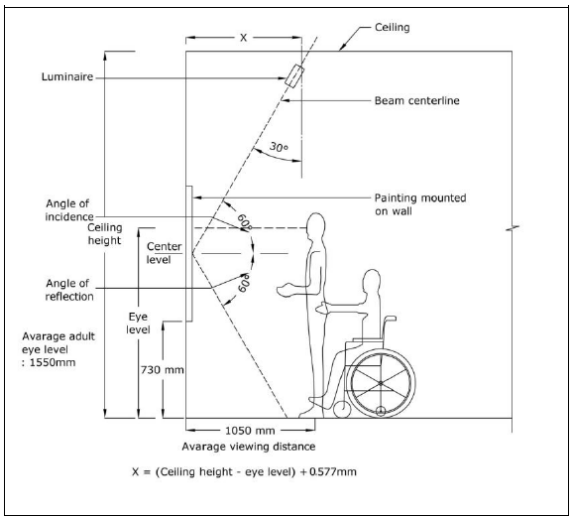

Figure 2. Solution for Glare.

III. Research Methodology

This study employs the observational and visual analysis on human visual quality towards the objects of a public space like art gallery exhibition.

This research was done based on a methodology designed in several stages:

Stage 1: Study the variables of visual performances and visual comfort in visual quality characteristic.

Stage 2: Analysis on literature reviews from proceedings paper, journal, books, internet webpage and unpublished thesis. Screen the variables to define the factors of human visual quality in the public building like art gallery exhibition.

Stage 3: Walkthrough observations were conducted for two days duration, recorded using note pad and digital camera. The observation focusing on space planning, luminance effect and interior and material finishes in several public building including some art galleries.

All recorded data and all images taken were analyzing to identify possible result. The data were justified after extract related sources and explore linkages among analysis. Finally, analyzed components with different factors defines human visual quality in public spaces like commercial buildings and art exhibition galleries.

IV. Action of Lifht In Architectural Space

Lights that passed through the need to comfort the eye of a person to prevent eye strained. Human visual sensory received certain information, it enunciated by feelings and emotions. When illumination and design elements are combining, the luminance of the light is visible. The quality, appearance and color of the light will differ giving different interactions.

Lighting does give certain effects to the artworks because lighting has a different wavelength that is call visible light waves. The visible light waves are the only electromagnetic waves human can see as the colors of a rainbow which corresponds to a different wavelength. When light passes through in the wall that is paint white, all of the spectrum of colors will refract back giving the actual image of the artworks. When the light passes through in a wall that has a red color painted on the wall, the spectrum of colors will refract all of the colors but without the red. As the result, the red wall become more dominant than the artwork and become a focal point [11].

Everything that is designed for a human shall take into account the peculiarities of its visual perception. Conscious and science-based formation of a visually comfortable environment as one of the main targets of modern design involves the studies of psychology, physiology, videoecology; since the mechanism of visual perception is extremely complex and can be represented as an active-learning process aimed at transforming visual sensations (signals) into a visual image which carry information about the shape, color and spatial movement of an object. Perception model of the design object is composed of three basic processes [12].

The research of peculiarities of visual perception enables to predict the effect of the designed objects on an individual. In the field of design education, attention is drawn to the harmony of a composition and the integrity of a form. However, as it has been shown in our research, it is not always suffice, as it does not specify the psychology of the perception of the visual image which can be "correct" in terms of the laws of form design, though destructive to the psyche. In terms of recommendations which are logically derived from our research, when making a project of design objects it is necessary to regard those semantic components of the image which create the emotional coloring and a harmonious semantic space [13].

V. Analysisi of Findings

Telecommunication, electronic environments, digital technology and global networks increasingly affect the physical world we live in. Rapid advances in this technology will overthrow the regime of time and space that are familiar to us today. It is constructing interactions and dialogues between two different realms, one is the physical reality on a global scale, the other is the virtual reality of infinite construction site in cyberspace [14]. From the observations conducted in several public buildings and space including art galleries and exhibitions, findings indicate there are various factors generated from main components of visual quality towards the better understanding of the space. The factors help to understand how lights react to a different character of material and finishes by giving positive and negative effect through human vision and visibility. The increase of visual performance and visual comfort can be achieved from technical understanding of lighting system on the luminaire type, angle and position.

The issues on reflective glare and shadow can be avoided by better understanding of the lighting techniques and specifications. Technical requirements of luminaires installation can be resolved through consultation of lighting designers or lighting specialists. Among factors mentioned, it has discovered that the distance between elements need to identify in every especial public space like art gallery design.

Besides, distance creates in invisible parameter or space for the viewer to viewing towards objects in comfort way. Technically, the material and finishes of the display partition and wall also determine the visual quality in an interior space or area. The glare happens from reflection of light on the partition or wall surface where the white color is refract to environment causing visual discomfort for the users. The reflected glare issues can be solved by proposing a matte material or light absorbing material on the surface. The findings call the need of improvement on the human visual quality in public interior spaces like commercial spaces and art gallery exhibition areas. The improvement on the human visual quality should be parallel with the value of objects and physical beauty of the space and surrounding materials. Directly, it creates a harmony between the object presentation, ambient of the space or gallery and visitor visual perception on the objects. At last, the findings indirectly signify the important role of the

architect or designer to identify the suitable materials, color and character of finishes to enhance the visual quality in an interior space.

Moreover, during this literature review, it was investigated to which extent in multi-occupant offices and public buildings, individual occupancy-based lighting control has been applied, developed, and evaluated. First of all, although the research was rather extensive, it only resulted in only few eligible studies conducted before. The topic was investigated by other more studies, but again few were found to be performed in public offices or buildings. The other limited number of studies only calculated the energy savings in buildings that could be gained by implementing an occupancy-based lighting control strategy. These however did not consider the design of the occupancy-based lighting control strategy and its application to the real office or public building environment.

Among other studies identified as eligible, first the study design as well as office characteristics were discussed which provides an answer to some research questions, or in other words, future research directions are provided through the concluded information. Then, it was explained to what extent the lighting system characteristics and lighting control design consider individual occupancy patterns in a public or office building. Subsequently, future directions for the development of individual occupancy-based lighting control shall be covered in order to approach the data necessary for design of comfortable spaces and environments. Finally, suggestions are provided for a design approach that could be taken into consideration in an interior space intended to be lighted towards human comfort.

VI. Conclusions

As discussed before, the evaluation of the occupancy-based lighting control systems in buildings is currently focusing on energy savings. For a user-centered design approach in public building users are to be directly involved in the design and maintenance process. This approach can be implemented through qualitative user tests during design process, such as focus groups and interviews, or quantitative user tests like measuring task performances, and the results can applied in the design process.

The main purpose of improving visual quality in a public interior space like a commercial space or art gallery exhibition is to enable the visitor to perform their activity comfortably, relaxing, safely and easily. To achieve this aim, it is necessary to provide lighting that people are operation on good visual performance and visual comfort. These can be done by improving the characteristics of the task as well as the lighting. In order to improve the task and lighting the following items shall be considered:

- Standard viewer distance must be calculated and kept empty area.
- Scale of artwork or any displayed object must be appropriate with the viewer distance.
- Use diffuse reflectors material (e.g. matte finishes) for wall and display partition.
- Maintain the luminance contrast light all over the space and area.
- Ensure luminance position and angle to follow the standard technical requirements of the public space.
- Control color contrast on wall, ceiling and the floor.
- Design the lighting that is free from disability glare and veiling reflection.

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