Light Pollution and Health: Case Study of the Lighting Fixtures Applied on Penang Town Hall in George Town, Penang Island

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Abstract. Lighting design plays a central role in architecture and interior design. When it comes to heritage buildings, the case becomes even more sensitive and requires a delicate consideration of the light application. It is essential to conduct a good source of light to maintain a pleasant sustainable environment and to prompt a positive, healthy behavioural response. The objectives of this study are to outline the issues occur by the lighting application to the heritage building to learn the required factors to be considered in the lighting system as well as recognizing the association between the light pollution and health. The observations done around George Town on Penang Town Hall led to conduct the obstacles of the quality of light and building conservation. It is quite apparent that designers must meet the balance between the beauty of light and the appreciation of historical buildings in George Town

Keywords: Health & Light, historical building, Lighting Design, Conservation, Lighting Fixture, Art & History, Light Pollution, awareness.

1. Introduction

The importance and uniqueness value in the historical buildings in George Town - a UNESCO World Heritage Site - have been giving it the top priority for conservation, which has been applied within all aspects including lighting fixtures. However, designers, nowadays, tend to use extra light fixtures to emphasize the beauty of the heritage buildings and make it more standing for the tourists. Therefore, improper application can react negatively leading to harm those heritage buildings. This reason puts the responsibility on designers to maintain a balance in lighting design due to the extreme and unnecessary lighting application, which is leading to a negative impact, not only towards heritage buildings, but also it causes damage to humans, animals, and plants. The current paper is an attempt to present a case study investigation of the lighting fixtures applied to the Penang town hall in George Town. Thus, the methodology adopted in this research is the quantitative method theory by case study through collecting data from many related sources and analyzing it to get the final results, which are supported by personal observations, and visual data to examine the problems and questions in this research. The objectives of this study are to investigate the issues caused by the lighting applied to the heritage buildings as well as identifying the relationship between light pollution and the health aspect and finally, to study the necessary factors to consider in the lighting system. Research Method
The researchers collected primary data through the observation method, and they allocated the site observation at the area around the City Hall in George Town. George Town is the capital city of the Malaysian state of Penang Island. It has attained UNESCO’s Heritage City status and exposed to artificial lighting consideration by Penang State Government improvement plans [1]. The Penang state government has also studied it to measure the nature and extent of the building’s lighting issue [1]. Observation method was applied to study the problem of lighting design at this site. The observation was issued on daytime and nighttime to define the difference between the situation of the building being let out under daylighting and artificial light. Researchers studied the characteristic of the lighting fixture of Penang Town Hall building, the lighting fixtures arrangement and the lighting system functionality along with its impact on the building and the surrounding. Then, secondary data was acquired by library research method. Secondary data collection was by collecting information from a variety of sources such as books, journal, and Internet data based. Through detecting and locating related information, and analyzing what has found, the researchers developed and expressed ideas on how to solve the lighting issues. As stated previously, the quantitative method was used to collect the data. Quantitative data was collected and each one had its importance in firming the study and assisting the situations, which were further supported by visual proof. Researchers have focused on the investigation case study of the lighting fixtures applied on Penang Town Hall. The results of the discussion and analysis will be analyzed globally, and this will be beneficial for future in-depth studies on light and health in the context of Malaysian national health. The result quantified throughout the aid of measuring instrument, which were Lux meter, luminous flux meter, and luminance meter. In summary, the researchers summarized the research methods in the following diagram.

3. Light and human well-being

Light is crucial to human health. Light radiation affects the visual cortex, and also the performance and well-being [2]. According to (Flynn, Spencer et al. 1973, Flynn and Spencer 1977, Gibson 1979), both of the physiological and psychological aspects of an individual can be boosted by applying a proper lighting design [3]. Besides that, as its been known light enables people to see and observe their environment, as well as it induces Non-Image-Forming (NIF) effects, which consequently triggers the health [4]. NIF effects vary from hormone production and cell detachment to changes in behavior [5]. Studies on inferior-nasal retinal areas proved that when using melatonin (sleep hormone) as a biomarker, it is further capable in prompt of the NIF effects of radiation [6]. Disruption of the circadian rhythms with the 24h day/night cycle can play a role in mood disorders [7], cardiovascular disease [1], and even cancer [8, 9]. As stated, radiation has long-term effects, but at the same time it, short-term effects as well, such as emission of melatonin hormone and pupillary reflex [6]. According to Boivin (1996) and Czeisler CA (1989), one of the causes for a desynchronized pacemaker effect is bright light during the night hours, which can lead to harmful health consequences, such as severe impacts on the cardiovascular system and the kidneys [10]. The harmful impacts affect the biological system, mainly when the quality of light used at night does not meet the human health necessities [11]. The researchers conclude that light is an extremely crucial element to human well-being; therefore, it is required to apply the light following accurate design principal in order to avoid the negative impact on health.

4. The relationship between light pollution and health aspect

Nowadays, light pollution has become more noticeable and seen as a significant threat by many institutions and organizations. Its occurrence is connected with adverse effects, such as sky glow, light trespass, glare, and the hindering of astronomical observations [7]. Different kinds of technical reports [12, 13], standards, and legal regulations, related to the control and reduction of this phenomenon, have recently been developed in all regions of the world. Light pollution identified as luminous pollution, is the excessive and misallocated use of artificial lighting. Light pollution is not a new term. Light trespass is one of the light pollution types and it occurs when unwanted light passes in one’s property; for example, in this research light trespass could be identified as the unwanted light towards
Penang Town Hall, which reflects from the surrounding buildings. Another type of light pollution is the sky glow, which is the glow effect over populated areas. Sky glow happens when the light is produced directly into the atmosphere, accidentally or intentionally, where it is distributed by dust and gas, creating a dome-like orange glow that covers the night sky. Light pollution brings serious health issue to living beings. The circadian clock is defined as the physiologic processes effect in almost all beings. When the circadian clock disrupts, it leads to numerous medical disorders in humans, including depression, insomnia, cardiovascular disease, and cancer [14]. Serotonin is a hormone produced during the day; serotonin converts to melatonin only in darkness, while Melatonin, is a type of hormone produced during the night and its identified to be helpful in regulating the body’s biological clock [15]. The body produces melatonin at night, while melatonin levels can drop impulsively in the existence of artificial or natural light [4]. Several scientific research studies indicated that decreased melatonin production leads to higher risks of breast cancer in women. On the other hand, animals can be confused by artificial lighting, leading to disrupting their breeding cycles. Moreover, the photosynthetic cycles of plants can be negatively affected when exposed to artificial light during the nighttime lights [16]. Finally, when it comes to the environment, excessive lighting causes wastage and harm to the environment. The International Dark-Sky Association states that additional lighting during nighttime wastes more than $1.5 billion in energy and electricity costs yearly around the world besides discharging of upwards of 12 million tons of carbon dioxide into the atmosphere [17].

5. Description of Heritage Building
This research is focusing on one of the most significant heritage buildings in George Town, Penang Island, which is the Penang Town Hall. British Army engineers designed the building, and it is completed in the 1880s. It is the city's oldest municipal building, as it once housed the Municipal Commission of George Town [18]. It also functioned as a venue for social events for the European elites, but in 1903, its administrative function was taken over by the City Hall, and it has been a historical monument since 1993 [6].

6. Findings and discussion

6.1. Characteristic of the visual environment
The appearance of a building depends on the visual qualities, which rely on the features of form, light, color, and materials that affect them [9]. One of the beautiful colonial buildings to appreciate is the old Penang Town Hall building. This famous two story building in George Town is known for its classical Victorian style. An impressive building situated next to the coastline with lush public gardens at the front with the value of the attractive facade and exterior that worth a look-see. A drop of shadows helps to render forms and textures of the Penang Town Hall building. The researchers’ site observation leads to an understanding point about the uniform ambiance of daylight in the day and uniformly illumination during the night. In the daytime, the building is clearly letting out with the natural lighting. On the other hand, during the night time, the installation of lighting fixtures does create a focus on specific areas of the buildings. However, the arrangement of the lighting project has caused glare from the reflection on the white surface of the columns, which affects the details of the historical buildings and makes them hard to be distinguished. Key design factors and criteria of lighting systems

The type of lighting fixture that has been installed on the Town Hall is floodlight. The color of the projected light is white color light. According to the guidelines given by UNESCO on heritage buildings, floodlights used on the building must be natural white light. The perceived color indicates the wavelength of light being reflected. In this case, white light contains all the wavelengths of the visible spectrum therefore, when the color white is being reflected, that means all wavelengths are being reflected, and none of them is absorbed, making white the most reflective color. The full spectrum that forms white light is listed in the table below.
The observation concluded that it is unnecessary to use highlight intensity floodlight to give impact on the details of the building facades only. Uniformly projected lights, such as daylight, are more than enough to enhance the beauty of the details on the facades by the contrary effect of light and shadows. The light illuminance level for the day can meet up to 9,000 lux. However, it might be slightly different in the situation at night. According to illuminance level, which is collected using the lux meter, the illuminance from the spotlight on the field shows an illuminance level of 28 lux depending on the distance from the source. The ambiance of the building was softly illuminated and faded gradient along the distance. From the researchers’ point of perspective, the illuminance level of 50 lux on the area is already sufficient for the eyes to distinguish the building and the details and shadows of facades. It is undoubtable that the daylight has its uniqueness to enhance the beauty of the building beside its aspects in the virtual comfort, and then energy saving. Therefore, there are some design considerations when implementing floodlight into designs, which are the type of light source, reflectivity, color, texture of the projection surface, a distance of the surface from the light source, and color filter used. One of the sources that also affects the floodlight projection is the distance of the surface from the light. Closer distances of the surface from the light source will lead to an increase of the illuminance level towards the surface. On the other hand, the researchers suggest using Polaroid to reduce 50% of the light intensity towards the surface of the building. In order to reduce the glaring effect in addition to the eye comfort leading to differentiate the detail of the building facades, making it enjoyable without the glaring discomfort.

7. Conclusion
From the discussions above, the researchers conclude with the question of what are the characteristics necessary to successfully implement “good” light art projects for historical build necessary characteristics in George Town and, which part needs to be illuminated and which architectural element should be left dark? As it is described previously about the Town Hall, the only illuminated part during the night time is the columns, while the top of the building is dark. Therefore, the answer is somewhat complicated. In general, the layout of lights alone is not sufficient to make a building aesthetically pleasing. An analysis of the surrounding area needs to be carried out, and the illumination of historic buildings needs to be planned comprehensively, by taking into consideration how the building interacts with its surroundings and moreover expanding the concept of lighting to cover this broader scope. Thus, visual comfort and glare are two priority areas that must be addressed. It is vital to consider the environmental and biological factors that hugely have impact on the lighting effects. In the future, designers will not face the danger of ignorantly using the lighting design as it is seen nowadays as a source of inspiration, without regard to the critical aspects presented above.

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