

**THE DAYLIGHT AND LUMINOUS
ENVIRONMENT OF WORKING AREA IN
LIBRARY OF UNIVERSITY MALAYA**

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LIBRARY OF UNIVERSITY MALAYA**

by

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LIST OF SYMBOLS

R^2	Coefficients of Determination
Q^2	Predictive Relevance
f^2	Effect Size

LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
DGI	Daylight Glare Index
DGP	Daylight Glare Probability
ERC	Externally Reflected Component
FD	Feelings towards Daylight
GBI	Green Building Index
H	Hypothesis
IAQ	Indoor Air Quality
ID	Interior Design
IEQ	Indoor Environmental Quality
IRC	Internally Reflected Component
LC	Luminous Comfort
OES	Overall Environmental Satisfaction
P	Productivity
PE	Physical Environment
PLS-SEM	Partial Least Squares Structural Equation Modelling
PH	Psychological Health
Q	Question
UGR	Unified Glare Rating
UM	University of Malaya
VIF	Variance Inflation Factor
WWR	Window-to-Wall Ratio

**KESAN CAHAYA SIANG DAN PERSEKITARAN CAHAYA DI
KAWASAN KERJA DI PERPUSTAKAAN UNIVERSITI MALAYA**

ABSTRAK

Keadaan hidup awam dapat diperbaiki melalui beberapa parameter yang berbeza, yang berkesan dan penting. Pencahayaan siang adalah salah satu parameter yang paling ketara. Cahaya semula jadi dapat menembusi bangunan dengan menerapkan pencahayaan siang hari. Ini juga dapat menyebabkan peningkatan kondisi dan kesejahteraan hidup, termasuk kenyamanan akustik, kenyamanan termal, dan juga kenyamanan bercahaya. Oleh itu, salah satu masalah terpenting yang harus dipertimbangkan dalam kajian kesejahteraan bercahaya adalah kepuasan dengan cahaya siang. Walaupun, banyak kajian telah dilakukan mengenai pencahayaan siang hari di bangunan, pada masa lalu dan baru-baru ini, dalam beberapa kajian, kepuasan dengan pencahayaan siang hari telah dianggap sebagai elemen mengesankan utama dalam keadaan bangunan yang bercahaya. Perpustakaan adalah salah satu tempat paling kritikal di mana masalah siang hari harus dibimbangkan. Produktiviti dan kesihatan psikologi pengguna dapat ditingkatkan melalui keadaan bercahaya yang tepat di perpustakaan. Kurangnya kaedah pencahayaan semulajadi dapat dilihat dengan jelas di perpustakaan Universiti Malaya, di mana pengguna dan kakitangan perpustakaan tidak cukup berpuas hati dengan keadaan bercahaya. Kajian ini bertujuan untuk menyelidiki dan menentukan dengan jelas faktor-faktor kepuasan cahaya waktu siang yang memberi kesan kepada kesejahteraan bercahaya melalui beberapa konsep yang telah digunakan dalam kajian sebelumnya yang berkaitan dengan bidang ini. Usaha kemudian dilakukan untuk menguji kesan faktor-faktor ini terhadap kesejahteraan bercahaya dan kesan kesejahteraan bercahaya terhadap kesihatan dan produktiviti

psikologi penghuni. Untuk mencapai objektif ini, pendekatan kuantitatif berdasarkan tinjauan telah diterapkan. Pada mulanya, borang soal selidik dibina; dan kemudian, kajian rintis dibuat untuk mengesan kekurangan dan kelemahan dalam soalan yang ditetapkan. Tinjauan ini merangkumi 150 pengguna dan kakitangan di perpustakaan Universiti Malaya, Kuala Lumpur, Malaysia. Hasil kajian menunjukkan bahawa perasaan terhadap cahaya siang mempunyai pengaruh paling besar terhadap perbandingan keselesaan bercahaya dengan dua faktor lain; lebih-lebih lagi, perbezaan antara kesan keselesaan bercahaya terhadap produktiviti dan kesihatan psikologi yang sangat ketara. Kesimpulan yang dicapai diharapkan dapat menyumbang kepada peningkatan kaedah pencahayaan siang hari dan peningkatan persekitaran bercahaya di bangunan yang berlainan, terutamanya perpustakaan.

**THE DAYLIGHT AND LUMINOUS ENVIRONMENT OF WORKING
AREA IN LIBRARY OF UNIVERSITY MALAYA**

ABSTRACT

Public living conditions can be improved through several different parameters, which are effective and important. Daylighting is one of the most significant parameters. Natural light can penetrate in buildings through implementing daylighting. It also can lead to improvement of living conditions and comfort, including acoustic comfort, thermal comfort, and as well as luminous comfort. Therefore, one of the most important concern that should be considered in luminous comfort studies, is satisfaction with daylight. Although, many studies have been conducted about daylighting in buildings, in the past and recent, in a few studies, satisfaction with daylighting has been considered as a main impressive element in luminous conditions of buildings. Libraries is one of the most critical places where daylight issue should be concerned. Users' productivity and psychological health could be boosted through the proper luminous conditions in the library. The lack of daylighting methods can be clearly observed in the University of Malaya library, where the users and staff of the library are not satisfied enough with the luminous condition. This study aimed to investigate and clearly define the factors of daylight satisfaction which have an impact on luminous comfort through some concepts that has been used in previous studies relating to this area. An attempt was then made to test the impact of these factors on luminous comfort and the effect of luminous comfort on occupants' psychological health and productivity. To achieve this objective, survey-based quantitative approach was applied. At first, a questionnaire was developed; and then, a pilot study was made to detect any deficiencies and weaknesses in the questions set. The survey comprises

150 users and staff at University of Malaya library, Kuala Lumpur, Malaysia. The results shows that feelings towards daylight have the most effect on the luminous comfort comparison with the two other factors; moreover, the difference between luminous comfort impact on productivity and psychological health is totally tangible. The achieved conclusions will hopefully contribute to upgrade of daylighting methods and improvement of luminous environment in different buildings, especially libraries.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The first part of this chapter discussed on the research background. Subsequently, the problem statement of this research described the issues originating from lack of daylight. Moreover, two research objectives are considered for this research, which lead to this study's main goal. Five research hypotheses have been considered based on the objectives. Additionally, in the scope of research, some information about the research area and location of the case study is provided. Then, the reasons which make this research important are described in the significance of the research. Following this, the research limitation is discussed. In the next part, the definition of terms has been provided. Furthermore, data collection and data analysis methods are explained in the research methodology. Finally, the last part is an overview of the chapters.

1.2 Research Background

Daylight as a valuable resource has benefits in building design. One of the most significant benefits is that it could conduct people to nature and improve people's mood and the circadian stimulus. In addition to this, appropriate exposure to daylight impacts on people's visual perception and promotes people's productivity and satisfaction (Acosta, Leslie, & Figueiro, 2017). In recent years, the provision of better-quality daylighting is a concern in some productive studies. Researchers have suggested the use of optical units (Whang, Wang, & Chen, 2009), light-pipes (H.W.Li, Tsang, Cheung, & Tam, 2010), atriums (Samant, 2010), remote-source lighting systems (I. Wong & Yang, 2012), and light shelves (Xue, Mak, & Cheung, 2014a) to

bring daylight into rooms more intentionally and efficiently. They also improve the indoor illuminance level while improving illuminance and comfort. Consciousness concerning comfort has increased. Therefore, it has aroused people's attention to their living conditions, such as acoustic comfort, thermal comfort, and luminous comfort (Xue, Mak, & Cheung, 2014b).

Daylighting, as a principal parameter in the architectural study, has been started in northern Europe since the late nineteenth century. However, the sun has been utilized since man's existence began. Our ancestors attempted to find shelter as a human habitat. These human habitats were the caves that have been warmed by sunlight. Therefore, sunlight as a key element has been remained in habitation design since then. They chose some areas to provide their habitat and worship places. The purpose of solar exposure is to make the best use by supplying cool, shade, and heat. They also wanted to be protected from the enemy. Therefore, they shaped their dwellings so that they carved openings within their walls and designed sunken courtyards. The sun was a major source to provide heating, comfort, and well-being for many of these communities. The Greek vernacular architecture's primary design component was the relation between light and shadows considered in ancient Greek architecture. The solar heat in winter and the coolness in the summer night was transferred into the interior through the buildings with thick walls, while the light was ushered into space by deep whitewashed wall apertures. In ancient Greek architecture, south-facing houses caused the penetration of sun into the porticos in winter. However, south-facing houses gained shade in the summer, so that the path of the sun was above the roof and right over occupants' heads. So, it was built the south side loftier to get the winter sun and the north side lower to keep out the winter winds. Besides being a source of heat, the Greeks believed the sun fostered good health. After that, in Rome's

architecture classical, the technology of glass window coverings belongs to the Romans. Romans utilized this technology to trap and grab solar heat to warm their baths and homes. They are also the pioneer of rules and regulations for protecting citizens' access to sunlight and solar zoning legislation. Solar access legislation originated from increasing urban density in Roman cities. Following this, in the nineteenth century, a movement was launched to provide fresh air and bring sunlight to the slums, which negatively affected European cities. This movement was because of reformers' and planners' concern in terms of deficient urban sanitary circumstances. For the first time in British history, the Public Health Act of 1848 charged the government with responsibility for protecting and safeguarding public health and welfare. In the early part of the twentieth century, a new movement in the architecture world was created, which adopted modernity and refused the old designing buildings. In this movement, the windows with large expanses were considered to maximize fresh air and natural light. As one of the most well-known architects in the Modern Movement, Le Corbusier believes that there is a fourth physical dimension in any building in addition to the other three, which is nature. The fourth dimension provides sunlight, fresh air, and health to the occupants of the building (Mohamed, 2008).

Baker and Steemers (2014) defined daylight as 'the combination of the diffused light from the sky and sunlight'. In addition to this, Xue, Mak, and Huang (2016a) define people's satisfaction with the luminous environment as luminous comfort as subjectively evaluated by occupants.

Presently, there is very little research concerning the daylighting of libraries in Malaysia, which has a tropical climate. Based on the different researches around the world, most developed countries have considered the cutting-edge methods of

daylighting in their libraries. Accordingly, this study concentrates on a library in Malaysia. This scenario could improve the library design, especially in terms of daylighting and luminous comfort. Additionally, developing more research regarding daylight in libraries will positively affect towards the local guideline available for Malaysian buildings, e.g., Uniform Building By-law (2012).

1.3 Problem Statement

There are many factors that could have a significant impact on users' wellbeing in buildings. Recent researches demonstrate that one of these factors is daylight. In other words, the lack of daylight could have negative impacts on people's psychological health and productivity (Xue et al., 2014b). Our circadian system, which has an impact on our alertness and mood, is regulated by daylight (Plitnick, Figueiro, Wood, & Rea, 2010) (Webb, 2006). Daylight affects the desirability and appeal of spaces because it provides luminance and color variation (Lim, Hirning, Keumala, & Ghafar, 2017). Thus, occupant desire for a connection to the outside is satisfied by providing windows and boosting their mood (Galasiu & Veitch, 2006) (Heschong, 2003).

In Malaysia, some legislative requirements have been stated in Uniform Building By-law. In this statement, one of the issues which has been considered is lighting and ventilation. According to the uniform building by-law (2012), one or more windows must be provided in every room, which is designed and adapted for different utilizations such as business, residential or other purposes except schools and hospitals in order natural lighting and natural ventilation provision. The area of window should be 10% of the room's clear floor area and they should have openings capable of allowing airflow without any interruption. Moreover, in the Green Building Index

(GBI), one of the principles clearly emphasized is daylight. Hence, it is referred to daylighting promotion for building occupants (PAM, 2009).

Libraries are valuable places where students can retrieve indefinite data sources, documentation records, and information. Hence, library design can lead to promoting students' motivation to use it not only during exams but also in their free time (Kilic & Hasirci, 2011). Moreover, the interior design of a room could have a significant effect on human mood and social behavior. Hence, designing of study environment in a library is critical in terms of individual performance (Othman & Mazli, 2012). Accordingly, lighting is one of the architectural tools that significantly influences visual comfort and users' perception behavior in libraries. Therefore, in libraries as utilizable buildings should be provided proper conditions in terms of daylight. Despite the aforesaid hints, the daylighting concept is not considered in most of the library designs. Consequently, the users do not satisfy with the luminous environment (Kilic & Hasirci, 2011).

As a result, daylighting satisfaction is a fundamental factor in luminous comfort (Xue et al., 2014b). This factor incorporates three primary aspects:

- The physical environment (H.W.Li, Wong, Tsang, & Cheung, 2006)(H.W.Li & Tsang, 2008),
- The users' feelings towards daylight (Xue et al., 2014b),
- Interior design (Othman & Mazli, 2012).

Regarding these aspects, daylight impact on occupants' satisfaction with luminous environment will be evaluated in this research.

1.4 Research Objectives

The aim of this research is to evaluate the impact of daylight on luminous comfort.

Two major objectives are formulated within the described problem statement, which have mentioned below:

1. To evaluate the effect of satisfaction with daylighting on luminous comfort in University Malaya library.
2. To assess the impact of luminous comfort on psychological health and productivity in University Malaya library.

1.5 Research Hypothesis

Based on the research objectives, there are five research hypotheses, which have been provided below:

1. Physical environment significantly influences luminous comfort.
2. Feelings towards daylight significantly influence luminous comfort.
3. Interior design significantly influences luminous comfort.
4. Luminous comfort significantly influences psychological health.
5. Luminous comfort significantly influences productivity.

1.6 Research Questions

Based on the research hypothesis, five research questions have been designed, which was mentioned below:

1. Does physical environment significantly influence luminous comfort?
2. Do feelings towards daylight significantly influence luminous comfort?
3. Does interior design significantly influence luminous comfort?
4. Does luminous comfort significantly influence psychological health?
5. Does luminous comfort significantly influence productivity?

1.7 Research Scope

The growth of the population in Malaysia is increasing significantly. Therefore, the need for buildings is also rising accordingly (Yee, Rahim, & Mohamed, 2015). Aiming at a variety of construction around the world, such as different types of offices (Lim et al., 2017) (H.W.Li & Tsang, 2008) (Berardi & Anaraki, 2015), residential buildings (Vaisi & Kharvari, 2019) (Xue et al., 2016a) (Xue et al., 2014b) (H.W.Li et al., 2006) and shopping malls (El-Abd, Kamel, Afify, & Dorra, 2018), scholars have already conducted series analyses in order post-occupancy evaluation about indoor environment quality which involved luminous comfort and daylight.

All profit-making buildings, which are mentioned in the previous paragraph, are extremely concerned about satisfying occupants with luminous environment.

However, non-profit buildings, for example, the library, are slightly concerned with luminous comfort (Frontczak & Wargocki, 2011). Their multipurpose feature and landmark functions lead to having an enormous impression on universities. Moreover, they are generally open to the public. Few studies have concentrated on the libraries daylighting having the most effect on luminous comfort.

Some libraries have been evaluated and observed in the research process such as Raja Tun Uda Library and Penang Digital Library. Since the UM library has more critical conditions of daylighting in comparison with the other libraries, which need to be improved in terms of daylighting. Accordingly, this study concentrates on the University of Malaya Library at Kuala Lumpur, Malaysia, which it is located in the oldest university of Malaysia. This university is a century old and dates back to 1905 when it was first established in Singapore. The UM library was established in 1959. This library is a primary place in order to do learning and research activities at the University of Malaya (Janaki & Mohamed, 2007). It is supposed to evaluate daylight impact on user's satisfaction with luminous environment of the university library. Therefore, a valid Partial Least Squares Structural Equation Model should be developed in which the post-occupancy evaluation theory is used.

1.8 Research Significance

It is anticipated that this study may help the government to set up proper standards and guidelines which also help researchers and designers to understand how to boost design properties and provide occupants with better luminous environments. In other words, this study could be useful to provide some indications associated with the daylight and occupant's satisfaction with luminous environment in libraries. Thus, this research contributes to knowledge within the fields of daylight in libraries. It could

also serve as a reference, including some solutions in order to provide luminous comfort for users. Moreover, this study could motivate people to use the library and stay longer at this place.

1.9 Research Limitation

The study must be conducted during the daytime. Moreover, it should be done on sunny weather conditions due to daylighting as the main area of this study. It is also noticeable that during the survey and observation in the library, artificial lighting cannot be switched off because it will disturb the library functions.

1.10 Definition of Terms

Daylight- Daylight originates from solar radiation and is emitted by the sun. It is also perceived during daytime and visible to the human eye (Aries, Aarts, & van Hoof, 2015).

Luminous comfort- Luminous comfort is defined as the people's satisfaction with the luminous environment, as subjectively evaluated by occupants (Xue et al., 2014b).

Physical environment- In the present study, the physical environment can be considered based on the key building parameters including floor level, orientation, external obstruction, window area, and shading affect (H.W.Li et al., 2006).

Feelings towards daylight- In this study, feelings towards daylight can be considered based on some factors including skylight, sunlight, and the perception of uniformity (Xue et al., 2014b).

Interior design- In the present study, interior design can be considered based on some elements, including seating layout, circulation area, and bookshelves arrangement (Othman & Mazli, 2012).

Psychological health- Psychological health has been conceptualized as a lack of psychological distress or psychopathology (Dunn & O'Brien, 2009).

Productivity- Productivity refers to the measured output of a person within a specified period of time (Segun-Adeniran, 2015).

1.11 Research Methodology

The research methodology contains different parts, including the data collection method, pilot study, and sampling and data analysis method.

In this research, a questionnaire will be prepared in order to be filled by students using the library of the university with the aim of collecting data. The questionnaires distributed are structured closed-ended questions. Therefore, in this study, a quantitative method will be used in order to collect data.

Once the questionnaire parts are ready, a pilot study will be conducted to evaluate the questionnaire. The pilot study aimed to highlight problems and test the validity and reliability of the questionnaire among a small group of respondents. Therefore, the questionnaire is accomplished with 50 occupants who use the UM library.

The next step is to determine the samples of the study. There are different methods of sampling. In this study, quota sampling, as one of the non-random sampling designs, is implemented to select the samples. When the number of the study

population is unknown, or it cannot be individually identified, non-random sampling designs are applied (Kumar, 2019). Hence, regarding the unknown study population of this research, this method could be useful.

Finally, for achieving the objectives of this study, Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS software will be created to analyze the relationships between the daylight and luminous comfort, which demonstrated the positive impact among the latent variables.

1.12 Overview of the Chapters

This thesis is divided into six chapters.

Chapter 1 briefly describes the introduction of this thesis, the background of research, thesis aims and objectives, and its scope and limitations. This chapter also highlighted the significance of the research and then briefly described the research methodology used.

Chapter 2 will discuss the related literature review. The literature review will be provided according to the problem and objectives. Thus, this chapter discusses the satisfaction with daylight, which is a significant element in luminous environment. It is also provided the aspects which have an impact on satisfaction with the daylight parameter. In addition to this, the definitions related to safety and health are explained. As well as this, it will be assessed the benefits of luminous comfort for the occupants. Then, the previous researches associated with this study will be reviewed, and a summary of these researches will be provided as a theoretical framework in this chapter.

Chapter 3 outlines the methodology method applied in this research. Thus, the methods of collecting and analyzing data for achieving the aims of the research are explained.

Chapter 4 discusses the data analysis and findings of the study. The findings are related to the research objectives which direct the study. They are expressive of daylight effect on occupants' satisfaction with luminous environment based on the questionnaire.

Chapter 5 discussed the importance of analysis results and the findings considering the research problem, which has already been described.

Finally, Chapter 6 summarised and concluded the thesis with major findings and subsequently proposed recommendations for future research.

1.13 Summary

This chapter depicted the features and outline of the research by clarifying the problem, the objectives, and the research hypothesis and significance. It briefly discussed the daylighting impact on luminous comfort, especially in libraries. Moreover, the aspects of daylighting satisfaction have been provided. They will be further discussed in chapter 2.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to suggest an approach to evaluate daylight impact on occupants' satisfaction with luminous environment. The literature review discusses the key concepts relating to this research, such as daylight, daylight in the library, and luminous environment. Subsequently, it investigates the luminous comfort significance among the OES (Overall Environmental Satisfaction) aspects. In addition to this, it provides references and evidence to evaluate the relationship between daylight and luminous comfort according to some effective factors. Finally, the conceptual framework is displayed at the end of this chapter.

2.2 Lighting Quality

Before considering how good quality lighting might be made available to all it is necessary to define what lighting quality is. Unfortunately, defining lighting quality is not easy. A number of different approaches have been suggested; from single-number photometric indices calibrated by subjective responses (Bear & Bell, 1992); to the results of a holistic design process based on lighting patterns (Loe & Rowlands, 1996); to the lighting conditions which have desirable impacts on task performance, health and behavior (Veitch & Newsham, 1998); to lighting which enhances the ability to discriminate detail, colour, form, texture, and surface finishes without discomfort (Cuttle, 2008).

Veitch and Newsham proposed that lighting quality exists when the luminous conditions support the behavioural needs of individuals in the lit space (Veitch &

Newsham, 1998). This definition has the merit of being measurable, but it only considers the immediate consequences of the luminous conditions on the individuals. More accurately, this definition should be expanded to include architectural and economic considerations, as well as individual well-being (Veitch, 2001) (Figure 2.1). Lighting system characteristics such as individual control, indirect lighting, and the use of daylight are also thought to contribute to good quality lighting (Veitch, 2001).

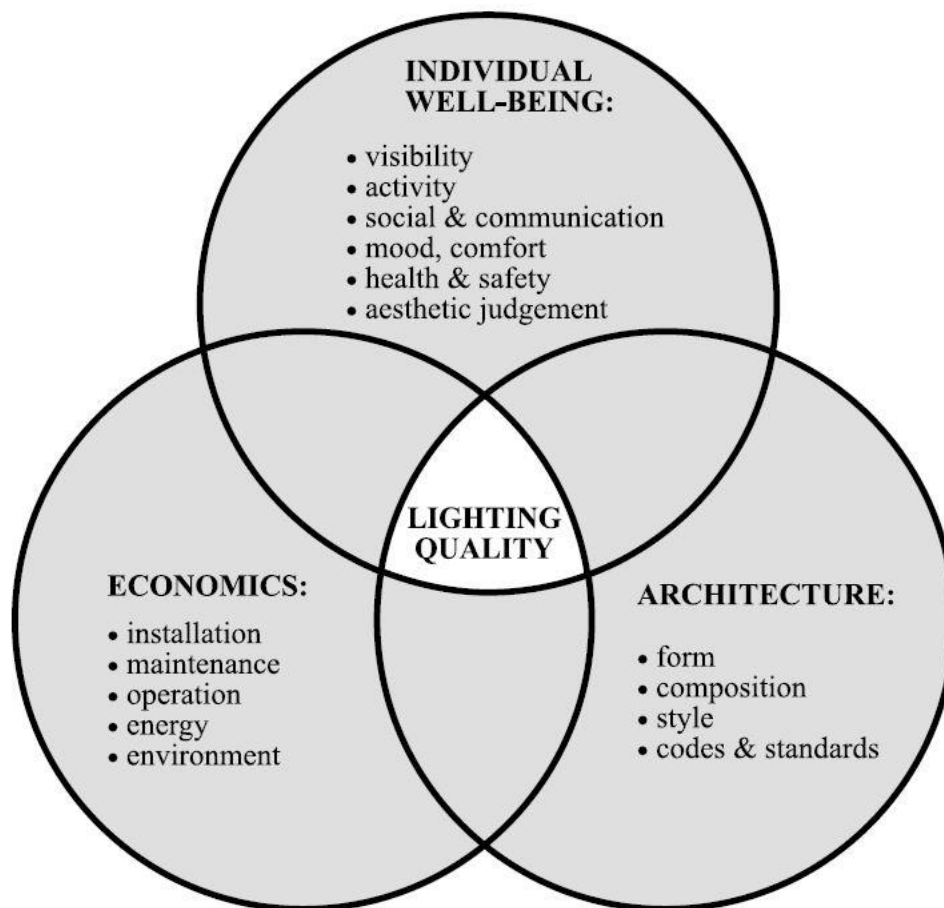


Figure 2.1 The integration of individual well-being, architecture, and economics.

Source: (Veitch, 2001)

2.3 Daylight

2.3.1 Daylight Definition

Manning (2006) indicated that daylighting is a method which could lead to natural light penetration into a room with the purpose of artificial lighting replacement or supplement. Moreover, it is defined as a vehicle that impresses users' perception of the environment, controls the given information by the environment's visual field and affects well-being (Cheung & Chung, 2008). Furthermore, daylight originates from the solar radiation and emitted by the sun. It is also perceived during daytime and visible to the human eye (Aries et al., 2015). Daylight is also the primary source of illumination of indoor spaces by natural light (Webster, 2015).

2.3.2 Daylight Significance

Daylight has lots of significance in terms of different aspects such as occupant comfort, the arrangement of spaces, attractive and pleasing atmosphere, architectural decisions, energy-saving, and good visual work. Chel (2014) believes that daylighting is considered as a remarkable concern in modern architecture, which influences occupant comfort (visual and thermal), structure, the functional arrangement of spaces, and energy use in the building. Moreover, daylight is regarded as the best source of light because it is the one light source that matches human visual response mostly. It is also functional for good color rendering. Additionally, Muneer (2007) discusses that daylight produces cheeriness and brightness sense, which have a considerable positive effect on the people. Furthermore, daylight penetration in a building through window openings comprises of two functions. Firstly, daylight in the indoor environment can

cause to create a pleasing and attractive atmosphere. Secondly, it allows people to have visual contact with the outside world. From Singh's point of view, architectural daylighting deals with natural light in buildings and forms part of architectural physics. Architectural daylighting is applied to satisfy demands for healthy and high-quality visual work environments by providing the best illumination in a building (Singh, 2018).

Daylight is explained as a significant part associated with architectural decisions, including facades, forms, functions, orientation, design concepts, and even materials (Eltaweel & Yuehong, 2017). In addition to these, Zain-Ahmed et al. (2002) notice that using daylighting strategies alone can cause energy saving. The more energy-saving could be provided if both shading and daylighting strategies are utilized in the design of passive solar buildings without visual requirements compromise. Another significance of daylight is reducing the artificial lighting requirements of non-domestic buildings (Crisp & Crisp, 1988). Daylight is also considered as an elementary design component that provides visual comfort, best illumination performances, and enhances indoor spaces (Iommi, 2019).

2.4 Strategies of Daylighting for Openings in Tropical Area

A daylighting system should be selected according to climatic characteristics (Ruck, 2000), however daylighting devices are usually designed and tested for European/temperate climates, and their performance for tropical and subtropical climates is still not well understood by designers (Garcia Hansen, Isoardi, Hirning, & Bell, 2012). According to the conducted research about selection of appropriate daylighting solutions for building in tropical and subtropical regions, electrochromic

windows provide the best solution against glare according to the simulations (Garcia Hansen et al., 2012).

In addition to this, the local daylighting strategies in tropical coastal areas use a jalousie window (Figure 2.2) that can filter the light from glare and from direct heat gain. A recent strategy to reduce glare involves using ray-ban glass in addition to an interior shading element, such as curtains. This element is very popular among houses in tropical climates for both protecting occupant privacy and providing aesthetic ornamentation. Moreover, the use of external shading elements, such as continuous roof eaves, is required in tropical coastal area to avoid direct sunlight (Fitriaty, Shen, & Achsan, 2019).



Figure 2.2 Jalousie Window
Source: (C, 2014)

2.5 Daylight in Library

Since the beginning of the construction history, architects have seen daylight as a tremendous prime factor of design (Baker & Steemers, 2014). In the development of building form, it is not always possible for the architect to consider daylighting as a

fundamental consideration. However, the daylight criterion is rising on the list of priorities when daylight benefits were realized in terms of the psychological and physical environment. Therefore, new technologies in window construction and glazing for daylight harvesting control systems were regarded as a primary issue due to energy utilization more sustainability (Baker & Steemers, 2014).

Libraries can be designed as an inviting, comfortable, and attractive place. It should also include social spaces, integrated technology, and flexible connections of learning so that the full range of library users with different study demands should be satisfying to stay as long as they need (Kan, 2009). For instance, users' satisfaction at the main library of Dundee University depends on two important factors, including daylight and outside view. For their satisfaction, the users desire to study under controlled daylight with the aid of low partitions. The controlled daylight, which is not too bright and glare, leads to satisfying users because it provides them comfort (Kilic & Hasirci, 2011). It is preferred to have indirect sunlight in libraries. It is due to that the sunlight transmission through a window or skylight brings glare and heat energy to space (Othman & Mazli, 2012) .

2.5.1 Selected Libraries According to Their Use of Daylight

This part emphasizes the daylight of some libraries which are classified into libraries in the USA, Europe, and Asia. In other words, the ways of daylight application in these libraries are assessed. The first part discusses the University of Michigan Law Library and Free University's Faculty of Philology Library. The second part is about the National Library in Singapore and Library of Liangzhu Village in China (see Table 2.1).

Table 2.1 Daylighting Methods in Libraries

Libraries	Completed Year	Daylighting Methods
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The University of Michigan Law Library	1981	<p>Triangular opening as v-shaped glass trench, makes lighter the underground space and provide users a view of Gothic tower in the basement (American Library Association, 1985).</p> <p>The mirror-mullions reduce the amount of direct sunlight and glare entering the space (Anderson, 1982).</p>
Free University's Faculty of Philology Library	2004	<p>A striking curved translucent enclosure includes a number of openings which provide defuse and even daylight and natural ventilation in the space (Foster and Partners, 2005) .</p>
National Library in Singapore	2005	<p>An atrium separated the two blocks of the building from each other.</p> <p>The building orientation is away from the East-West pivot to prevent exposure afternoon sun (Mutuli, 2016).</p> <p>Sun shading blades have been placed onto the facades of library to prevent immoderate glare and heat (Mutuli, 2016).</p>
Liyuan Library	2011	<p>Sun shading blades have been fixed onto the facades of the building. It aids to avoid excessive heat and glare (Vathupola, 2012).</p> <p>Other facades also have glass panels due to daylight penetration.</p> <p>Wooden bars helps to shade the building during the hotter summer months (Vathupola, 2012).</p> <p>The longer walls of building are facing east and west, hence, much of the direct sunlight comes from the smaller southern side (Vathupola, 2012).</p>

2.5.1(a) Evaluation of Libraries in USA and Europe according to their use of daylight

2.5.1(a)(i) The University of Michigan Law Library

Gunnar Birkerts & Associates constructed new underground addition in the University of Michigan Law Library in 1981, so it has won awards for the supreme

architectural design in the 11th Library Buildings Award Program (American Library Association, 1985). The addition illustrates the innovative glass trench, which makes lighter space. Therefore, the triangular opening has been applied as another source of light (Kan, 2009) (see Figure 2.3).

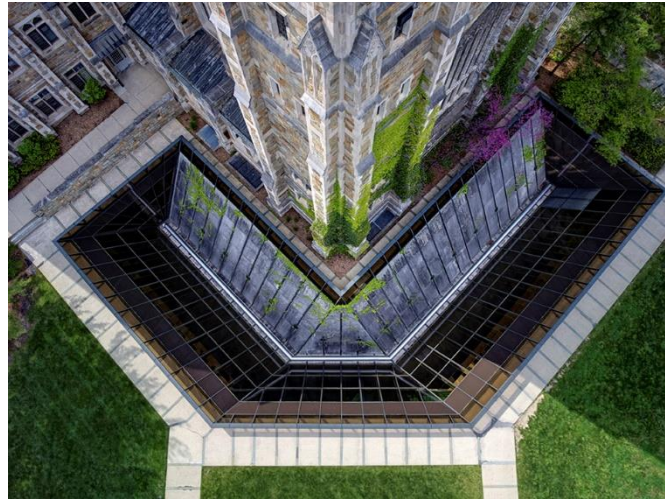


Figure 2.3 The University of Michigan Law Library, V-Shaped Glass
Source:(James Haefner Photography, 2017a)

V-shaped glass generates light flow into this underground structure, which reflects the original building and provides users a view of the Gothic tower (American Library Association, 1985).

In the underground of the building, the sky lighting as a triangular opening is the only connection to the outdoors. The underground addition comprises study areas, book stacks, a lounge, and space for future expansion. In the long skylight, yard deep mirrors set perpendicular to mullions, which creates a long row of stained glass windows that capture colorful and changing images of the sky and gothic details of the mother building. Functionally, the mirror-mullions operate as baffles to reduce the amount of direct sunlight and glare entering the space (Anderson, 1982), as shown in Figure 2.4. Library Director Margaret A. Leary explained that the library staff are happy with some features in this underground structure, including air and daylight quality, the

satisfaction of the library, the views of the sky and, trees and Gothic building, which make it a successful design (American Library Association, 1985).



Figure 2.4 The Mirror-Mullions Reducing the Amount of Sunlight and Glare
Source: (James Haefner Photography, 2017b)

2.5.1(a)(ii) Free University's Faculty of Philology Library

A campus library of Free University in Berlin was designed by Foster and Partners and completed in December 2004. This library has earned the Berlin Brain nickname due to its cranial form, as illustrated in Figure 2.5. A striking curved translucent enclosure encompasses the four floors of the library, which diffuses daylight dramatically. It is also naturally ventilated for more than half of the year. The building is arranged on a radial geometry, which includes clad in aluminum and glazed panels. Dispersed transparent openings provide users sunlight glimpses and the sky view, while an inner fabric membrane of glass fiber filters the daylight (see Figure 2.6).



Figure 2.5 Berlin Brain
Source: (Gorner, Nigel, & Rudi, 2005)



Figure 2.6 Free University's Faculty of Philology Library
Source:(Gorner et al., 2005)

On each floor, the book stacks were placed at the center of it. The reading desks were also arranged around the perimeter (Foster and Partners, 2005).

The creative double-layered skin of the library causes diffuse and even daylight circumstances and direct air through a number of openings in the transparent enclosure, which enables natural ventilation (Foster and Partners, 2005).

2.5.1(b) Evaluation of Libraries in Asia according to their use of daylight

2.5.1(b)(i) National Library in Singapore

One of the most famous environmentally aware architects is Ken Yeang. Sustainable design was required for the National Library Building in Singapore, which would consider as a landmark for the area (see Figure 2.7). The client asked two requirements, including a facility as a cultural center and an enjoyable civic space for Singaporeans (Mutuli, 2016). This project was completed in 2005.



Figure 2.7 National Library in Singapore
Source: (Mutuli, 2016)



Figure 2.8 Atrium in the Library
Source: (Mutuli, 2016)

An atrium has been designed in the building, which has separated the two blocks of the building from each other. The atrium is semi-enclosed as well as fully daylight, as shown in Figure 2.8. Hence, it causes penetrating light into the various parts of the building. It also helps facilitate ventilation. The two blocks are linked in the atrium through the bridges. The larger block gives accommodation to the library, which is placed at the civic plaza and is open to the sky, so it is ventilated naturally. The smaller block comprises all the noisy activities such as an auditorium, an exhibition, and a multi-media space (Mutuli, 2016).

The building orientation is away from the East-West pivot to prevent exposure to the afternoon sun. The southwest side of the building has a solid wall that permanently avoids penetrating direct sun rays into the building (Mutuli, 2016).