DAYLIGHTING PERFORMANCE WITH COURTYARD DESIGN VARIANT ON OCCUPANT WELLBEING IN A TROPICAL CLIMATE.

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DEDICATION

This thesis is dedicated to my family, who have loved and supported me wholeheartedly throughout my graduate school journey. This dissertation is also dedicated to my supervisor and university friend for their encouragement and assistance during this dissertation period, and during the Covid-19 pandemic, we have striven to complete this dissertation together.

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ABSTRACT

In a tropical climate, the abundance of natural daylighting can illuminate an internal space, and it is an effective passive design strategy that provides energy savings for buildings. Natural daylighting was widely used in all building settings before the innovation of artificial lighting, due to this innovation most buildings have transitioned and adopted artificial lighting to illuminate the interior of the building. Due to this, high dependency on artificial lighting causes a poor indoor environment for user health and an increase in energy consumption in the building. A courtyard is a universal design element that has been practised for thousands of years globally. Its design has become an area of interest in the tropical climate, which improves daylighting performance in buildings. Courtyards with a proper design are key in providing sufficient daylighting for the indoor environment, as well as major energy savings in electric lighting. This research aims to explore the daylighting performance with courtyard design variant on occupant wellbeing. The objective is to identify and evaluate the courtyard design variant and the impact of the daylighting performance done toward occupant wellbeing. The methodology used in this research is the comparative analysis method which analyses the simulation data result that produces the recommended courtyard design, which is optimum for the occupant wellbeing in daylighting performance. The daylighting performance studies are done using SketchUp and Velux Daylight Visualizer software. The result from the findings will provide the optimum courtyard design variant and daylighting performance for occupant wellbeing. The result of the finding will contribute as a guideline for courtyard implementation in a tropical climate for occupant wellbeing.

ABSTRAK

Dalam iklim tropika, banyak pencahayaan semula jadi boleh menerangi ruang dalaman, dan ia merupakan strategi reka bentuk pasif yang berkesan yang menyediakan penjimatan tenaga untuk bangunan. Pencahayaan siang semula jadi digunakan secara meluas dalam semua tetapan bangunan sebelum inovasi pencahayaan buatan, disebabkan oleh inovasi ini kebanyakan bangunan telah beralih dan menggunakan pencahayaan buatan untuk menerangi bahagian dalam bangunan. Disebabkan ini, kebergantungan yang tinggi pada pencahayaan buatan menyebabkan persekitaran dalaman yang buruk untuk kesihatan pengguna dan peningkatan penggunaan tenaga dalam bangunan. Halaman adalah elemen reka bentuk universal yang telah diamalkan selama beribu-ribu tahun di seluruh dunia. Reka bentuknya telah menjadi kawasan yang menarik dalam iklim tropika, yang meningkatkan prestasi pencahayaan siang hari dalam bangunan. Halaman dengan reka bentuk yang betul adalah kunci dalam menyediakan pencahayaan siang yang mencukupi untuk persekitaran dalaman, serta penjimatan tenaga utama dalam pencahayaan elektrik. Kajian ini bertujuan untuk meneroka prestasi pencahayaan siang dengan varian reka bentuk halaman terhadap kesejahteraan penghuni. Objektifnya adalah untuk mengenal pasti dan menilai varian reka bentuk halaman dan kesan prestasi pencahayaan siang yang dilakukan terhadap kesejahteraan penghuni. Metodologi yang digunakan dalam penyelidikan ini ialah kaedah analisis perbandingan yang menganalisis hasil simulasi dan mengesyorkan reka bentuk halaman yang optimum untuk kesejahteraan penghuni dari segi prestasi pencahayaan siang. Kajian prestasi pencahayaan siang dilakukan menggunakan perisian SketchUp dan Velux Daylight Visualizer. Hasil daripada penemuan akan memberikan varian reka bentuk halaman dan prestasi pencahayaan siang yang optimum untuk kesejahteraan penghuni. Hasil dapatan itu akan menyumbang sebagai garis panduan untuk pelaksanaan halaman dalam iklim tropika untuk kesejahteraan penghuni.

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LIST OF ABBREVIATIONS

UTM	-	Universiti Teknologi Malaysia
DF	-	Daylight Factor
MS1525	-	Malaysian Standard 1525:2014
NI	-	Monthly Nebulosity Index
SCN	-	Suprachiasmatic nuclei
BPS	-	Building Performance Simulation software
B.C	-	Before Christ
IES	-	Energy Modelling Software

LIST OF SYMBOLS

°	-	Degree
%	-	Percentage
Lx	-	Illuminance
$E_{internal}$	-	Internal Illuminance
$E_{external}$	-	External Illuminance
M^2	-	Meter Square
GWh	-	Gigawatt hours
ktoe	-	Kilo tonne of oil equivalent

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Daylight has an impact on human health and performance, it permits visual tasks, bodily control, mood and perception, and important chemical responses in the body (Roy *et al.*, 2020). The development of fluorescent lighting in the 1930s, allowed architects to design deep buildings without having to rely on natural light (Strong et al., 2014). The outcome of this development has reduced building dependency on natural daylight in illuminating the building interior, which causes an increase in energy consummation uses. Various survey-based studies have shown preferred of daylight to electricity lighting (Knoop et al., 2020), and one study shown in the tropic indicates also the occupant prefers to work under daylight as well (Hirning et al., 2017).

Unlike electric lighting, daylight is highly dynamic, changing within and across the days, throughout the year, and with weather conditions intensity, colour, diffuseness, and direction (Knoop *et al.*, 2020). Numerous architects are considering inventive ways to utilize the benefits of daylight without the negative effects associated with solar overheating due to the challenges related to daylight deprivation and a revived interest in the use of daylight in the construction of low-energy, sustainable buildings (Strong et al., 2014).

The courtyard is one of the daylight-enhancing ways to bring light into the interior and minimize the active zone (Elsiana *et al.*, 2018). Courtyards are a prominent feature in buildings throughout the world and have been employed as a conventional architecture feature by both ancient and contemporary architects. Due to a lot of factors, the courtyard system has undergone a significant alteration in contemporary architecture such as; advancements in technology, modern construction

materials, social and cultural transformations, changes in belief systems, lifestyle changes, changes in building regulations, and so on (Gupta et al., 2021). The courtyard design is critical for providing adequate daylight inside buildings as well as significant cost savings in artificial lighting. (Acosta et al., 2018).

To propose the design element of a courtyard, a study needed to be done to analyse the courtyard characteristics through concept, theory, typology, function, and so on (Lee et al., 2015). The appropriate application of the courtyard proportions and dimensions could effectively improve or mire its potential for improved environmental performance (Markus, 2016). In this study, the passive daylight performance is investigated to find the suitable courtyard design variant by using computer simulation for occupant wellbeing in tropical climates.

1.2 Problem Statement

The tropical climate receives both sun and rain in abundant, variability of daylight, however, poses a challenge when attempting to characterize the sky and develop models of daylight availability (Chirarattananon *et al.*, 2003). In Malaysia specifically, buildings consume a total of 48% of the electricity generated in the country, where commercial buildings consume up to 38,645 Gigawatts (GWh) and Residential buildings consume 24,709 Gwh (Hassan et.al, 2014). As electricity in Malaysia is supplied mainly from power stations, it is reported that from non-renewable energy resources such as coal (47.2%), natural gas (40.4%), hydropower (10.8%), diesel oil (0.8%), and fuel oil (0.3%) meanwhile from renewable sources (0.3%) gave 33, 134 ktoe of energy input in power stations (MCE, 2015).

Before the 1940s, daylight was the primary light source in buildings; artificial lights supplemented the natural light but in the short span of 20 years, electric lighting had transformed the workplace by meeting most or all of the occupants' lighting requirements. However, benefits from daylighting extend beyond architecture and energy. The psychological and physiological aspects of natural light should also be considered. The comforting space and connection to the environment provided to

building occupants provide benefits as significant as the energy savings to building owners and managers (Edwards et.al, 2002). To mitigate this reoccurring cycle of problems, courtyards are being used in the building element to improve both wellbeing and daylighting performance in the building.

The potential of the courtyard is repeated in various research and case studies, Aldawoud, (2008) has stated that courtyard integration is shown to be energy efficient in all climates, particularly hot deserts and hot humid ones. A courtyard's psychological potential has been repeatedly stressed, in addition to its environmental benefits. It can be concluded that many past performance studies have investigated courtyards applied in low-rise residential type conditions, An empirical study on courtyards in non-domestic buildings under hot humid climate conditions is very limited (Almhafdy *et al.*, 2013).

1.3 Research Aim

To explore the daylighting performance of courtyard design variants on occupant wellbeing in a tropical climate.

1.4 Research Question

The questions of the research are:

(a) What is the impact of daylight and visual comfort on occupants' wellbeing?

(b) What is the effective design variant of courtyard design and its impact on passive daylighting performance?

(c) What is the optimal courtyard design required for occupant wellbeing on passive daylighting performance?

1.5 Research Objectives

The objectives of the research are:

(a) To study the impact of daylight and visual comfort requirements for occupant wellbeing in tropical climates.

(b) To evaluate the design variant of courtyard design and the impact of daylighting performance.

(c) To determine the optimum courtyard design requirement for passive daylighting performance for occupant wellbeing.

1.6 Significant of the Research

Courtyards play an important role in shaping the physical, psychological, and climatic environment in building (Sthapak *et al.*, 2014). In response to numerous elements as well contextual needs such as site constraint and specific uses, courtyards have acquired more dynamic forms other than the rectilinear shape of the classic footprint. As a result, new and modern shapes such as the 'U', 'L', 'T', and 'Y' have emerged (Almhafdy *et al.*, 2013). However, courtyard design implementation in a tropical climate is not as rigorous as in the country and climate.

In the context of tropical climate, courtyard studies in daylight performance are not quite as advanced as the climate which adopted a variant of courtyard design in their building design scheme. The outcome of this research can provide a significant result on daylighting performance in tropical climate courtyards and also provide a guideline for designing a courtyard that benefits the occupant's wellbeing. Thus, it will reduce the dependency on using artificial lighting and concurrently reduce the energy consumption needed for artificial lighting.

1.7 Scope and Limitation

The scope of the research is to understand the effect of daylighting performance of courtyard design variants on occupant wellbeing in tropical climates. The courtyard stimulation is done in a site located in Putrajaya, where it is limited to a 4 to 5-story building model and adjacent to the lake on the west facade. The limitation of the study is the utilization of only one stimulation study which is, Velux Daylight Visualizer software which studies the daylighting performance and calcite the amount of illuminance and daylight factor during the simulation. Other aspects of the courtyard aspect such as solar heat gain, energy consumption, and thermal comfort are not considered in this research.

1.8 Research Methodology

The research is to study the daylighting performance in the tropical climate, how is the impact of daylight and visual comfort requirements for occupant wellbeing, the design variant of courtyard design and the impact of daylighting performance, what is the optimum courtyard design requirement for daylighting performance for occupant wellbeing based on literature review and simulation studies. The comparative analysis method was used to analyse the simulation result and recommend the optimum courtyard design variant for occupant wellbeing in terms of daylight performance.

1.9 Thesis Framework

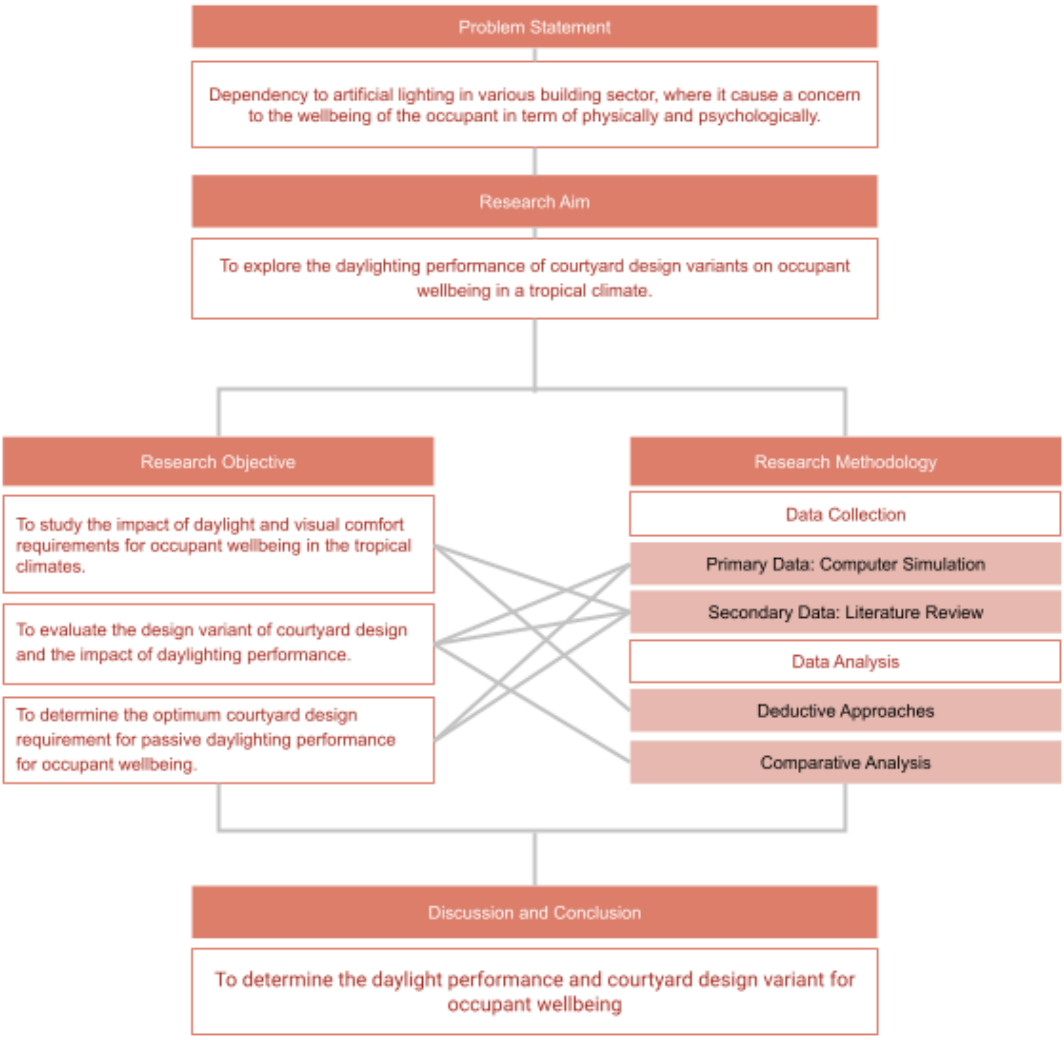

Figure 1.1 Thesis Framework

1.10 Summary

Overall, this chapter discusses a brief overview of the research framework and the criteria that surround the issue of dependency on artificial lighting which creates a poor indoor environment and the effect it brings to occupant wellbeing. Integration of courtyards play an important role in various aspect of the building cycle and it impacts the physical, psychological, and climatic environment in the building. Hence, the

research intends to explore the courtyard design variable and the effect on daylighting performance in the build.

Alas, this research will serve as a guideline and research paper for other researchers and architects to explore the possibilities that the courtyard brings toward the passive design strategy. Other criteria will be explained further in the following chapter, where various methods and past research findings will help shape the courtyard variable and produce an optimum courtyard that satisfies the need for occupant wellbeing.

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