DAYLIGHTING AND VISUAL COMFORT STUDIES OF DESIGN STUDIOS IN INSTITUTIONAL BUILDINGS: A CASE STUDY OF KAED, IIUM

BY

SABREEN M. M. ELEYAN

A dissertation submitted in fulfilment of the requirement for the degree of Master of Science in Building Services Engineering

Kulliyyah of Architecture and Environmental Design

International Islamic University Malaysia

DECEMBER 2019

ABSTRACT

The high consumption of energy by educational buildings has been a subject of concern in recent decades. Lighting accounts for 25-40% of the energy balance of buildings and 19% of the worldwide energy consumption. Therefore, it represents a key driver for energy-saving efforts in many countries. Daylighting is an effective method in creating not only a comfortable visual environment, but it is a useful source of energy savings in university buildings as well. This study used a case study approach to investigate the daylighting condition and evaluations on visual comfort from three design studios in KAED, IIUM. Opinion survey and field measurements were carried out simultaneously in three studios with different orientations (north, south, and north-west). The daylighting analysis was made through field measurement using the Lux meter, and calculations of daylight factor were carried out. The results were compared with the Malaysian Standard (MS)1525: 2007. In addition, a questionnaire survey was distributed to the users of the studios to assess their visual comfort level. Further calculations were also made to assess the energy consumption level of the three design studios. The field measurement results showed that the lighting levels were not up to the required standard, but most of the users of the studios revealed that the lighting levels were sufficient and did not hinder them from staying longer inside their studio. The study proposed a more energy-efficient lighting solution to the present and the energy consumption calculation showed that by changing all lighting fittings of Fluorescent T8 lamps to LED (light-emitting diode) lamps yielded a 40% reduction. The study also proposed a more efficient lamp switching system where areas that received sufficient daylighting have the option of not using artificial lighting during the day. In this way, more savings were anticipated. Recommendations were finally proposed to enhance the visual comfort and lighting pattern of the design studios.

Keywords: daylighting, energy efficiency, visual comfort, university buildings

خلاصة البحث

يعتبر الاستهلاك العالي من الطاقة من قبل المباني التعليمية أمرا مهما في العقود الأخيرة. وتمثل الإضاءة ما بين 25 إلى 40٪ من رصيد الطاقة للمباني و 19٪ من استهلاك الطاقة في العالم. لذلك، فإنها تمثل محركًا رئيسيًا لجهود توفير الطاقة في العديد من البلدان .فكان ضوء النهار هو وسيلة فعالة ليس فقط لخلق بيئة بصرية مريحة، بل مصدر مفيد لتوفير الطاقة في مباني الجامعة. وقد استخدمت هذه الدراسة طريقة الدراسة الميدانية لتحري وضع ضوء الشمس وتقييمات الراحة البصرية في ثلاثة استديوهات للتصميم في كلية الهندية المعمارية (KAED) ، IIUM. لقد أجريت استطلاعات الرأي والقياسات الميدانية معا في ثلاث استديوهات باتجاهات مختلفة (الشمال والجنوب والشمال الغرب). وتم إجراء تحليل ضوء النهار باستخدام القياسات الميدانية باستخدام Lux meter ، وأجريت حسابات عوامل ضوء النهار. وتمت مقارنة النتائج أيضا مع المقياس الماليزيMalaysian Standard (MS)1525: 2007. بالإضافة إلى ذلك، تم توزيع استبيان على مستخدمي الاستوديوهات لتقييم مستوى الراحة البصرية لديهم . كما تم إجراء حسابات إضافية لتقييم مستوى استهلاك الطاقة لاستوديوهات التصميم الثلاثة. لقد بينت نتائج القياسات الميدانية أن مستويات الإضاءة لم تصل إلى الحد المطلوب، لكن معظم مستخدمي الاستوديو وجدوا أن مستويات الإضاءة كافية ولم تمنعهم من البقاء داخل الاستوديو الخاص بهم. اقترحت الدراسة حل إضاءة أكثر كفاءة في استهلاك الطاقة حتى الوقت الحاضر وأوضح حساب استهلاك الطاقة أنه من خلال تغيير كل مصابيح الأضاءة الفلورسنت T8 إلى مصابيح LED (الصمام الثنائي الباعث للضوء) إلى انخفاض بنسبة 40٪. تقترح الدراسة أيضًا نظام تبديل مصباح أكثر فاعلية حيث لا يكون اليوم طويلاً بما فيه الكفاية. وبهذه الطريقة ، تم توقع المزيد من المدخرات .تم اقتراح توصيات أخيرة لتعزيز الراحة البصرية وتصميم استوديوهات التصميم. اقترحت الدراسة أيضا نظام التبديل للإضاءة (lamp switching system) أكثر كفاءة حيث المناطق التي تستقبل ضوء نهار كاف لديها الخيار في عدم استخدام الإضاءة الصناعية خلال اليوم. وبهذه الطريقة، تم توقع المزيد من توفير الطاقة، وتم اقتراح توصيات أخيرة لتعزيز الراحة البصرية ونمط إضاءة لاستوديوهات التصميم.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

……..
Noor Aziah Hj Mohd Ariffin
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

……..
Aliyah Nur Zafirah binti Sanusi
Internal Examiner

This dissertation was submitted to the Office of Deputy Dean (Postgraduate) and is accepted as a fulfilment of the requirement for the degree of Master of Science in Building Services Engineering.

……..
M. Zainora Asmawi
Deputy Dean (Postgraduate)

This dissertation was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for the degree of Master of Science in Building Services Engineering.

……..
Abdul Razak Sapian
Dean, Kulliyyah of Architecture
and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Sabreen M. M. Eleyan

Signature ..... Date .....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

DAYLIGHTING AND VISUAL COMFORT STUDIES OF DESIGN STUDIOS IN INSTITUTIONAL BUILDINGS: A CASE STUDY OF KAED, IIUM

I declare that the copyright holders of this dissertation are jointly owned by the student and IIUM.

Affirmed by Sabreen M. M. Eleyan

---------- ----------

Signature Date

ACKNOWLEDGEMENTS

Firstly, it is my utmost pleasure to dedicate this work to my dear parents and my family, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience. You are the most important people in my world.

I would like to express my special appreciation and thanks to my enthusiastic supervisor, Prof. Dr Noor Aziah Hj Mohd Ariffin, you have been a tremendous mentor for me. I would like to thank you for encouraging my research and for your continuous support and leadership, and for that, I will be forever grateful.

Sincere thanks to all my friends especially Aisha Nasr and Hind Alqattawi and my classmates for their kindness and moral support during my study. Thanks for the friendship and memories.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

AEC	Annual Energy Consumption
CIBSE	Charted Institute of Building Science Engineering Code
CIE	Standard General Sky
CO	Carbon Dioxide
De	The Exterior Reflected Component
DF	Daylight Factor
Di	The Internally Reflected Component
DPII	Daylight Performance Indicator Interpretation
Ds	The Sky Component
E	Illuminance level
EB	Electronic Ballasts
EC	Energy Consumption
$EC_{Existing}$	The Energy Consumption of Existing Lighting System
$EC_{Retrofitting}$	The Energy Consumption of Retrofit Lighting System
ES	Energy-Saving
ET	Electricity Tariff
EU	European Union
FL	Fluorescent lamp
FLT8	Fluorescent lamp Tube with Diameter 8
GHG	Green House Gasses
IES	Illuminating Engineering Society of North America Code
IIUM	International Islamic University Malaysia
JKR	The Malaysian Public Works Department Standard
KAED	Kulliyyah of Architecture and Environmental Design
Kw	KiloWatt
kWh	Kilo Watt per Hour
L	Lumen
LCC	Life Cycle Cost Analysis
LED	Lighting Emitting Diode
Lm	Luminous Flux
Lm/W	Lumen per Watt
Lx	Lux
MMD	Malaysian Meteorological Department
MS	Malaysian Standard 1525: 2007
MYR	Malaysian Ringgit
N	The Total Number of the Lamp
OC	Operating Cost
OH	Total Hours of Operation
PAY	The Payback Period
PSAL	Permanent Supplementary Artificial Lighting of Interiors
SHGC	Solar Heat Gain Coefficient of the Glazing
SPSS	Statistical Package for the Social Sciences
W	Watt
WFR	The Window-to-Floor Ratio
WWR	Window-Wall Ratio

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO THE RESEARCH

The dissertation is based on an analysis of lighting condition and visual comfort in design studios in The Kulliyyah of Architecture and Environmental Design (KAED) in the International Islamic University Malaysia (IIUM). This chapter will discuss the background of research, statement of the problem, aim, and objectives of the research, methodology of research, the scope of research, the significance of the research, structure of the dissertation and expected findings.

1.2 BACKGROUND OF THE RESEARCH

An indoor environment is highly influenced by the quality of installed lighting; this is much evident in learning institutions. Studies have shown how high-quality lighting is crucial to students' mood, their behaviour and ability to focus with learning (Musa, Abdullah, Che-Ani, Tawil, & Tahir, 2012). Furthermore, lighting is considered essential to the design and operation in all learning environments as its influence on the quality of an indoor environment is enormous (Michael & Heracleous, 2017).

Daylight is light that is transmitted via sunlight, which is then reflected on a surface before illuminating into space or a place. It is also a primary architectural strategy within the design of excessive-performance schools, which impacts on students' and teachers'wellbeing that improves their academic performance in the educational environment (Mathalamuthu & Nik Ibrahim, 2014).

In recent decades, the study of daylighting in institutional buildings has been a subject of interest. The design of daylighting in educational buildings has been proven to be more important than any other building types. Researches have shown the importance of daylighting in the educational environment on several occasion (Boyce, Hunter, & Howlett, (2003); Mahone et al., (1999); Plympton et al., (2000); Nicklas, Michael, Bailey, (1996) & Task, (2000). For example, the authors stress that daylighting creates a pleasant environment and promotes better health: Mahone et al., (1999) and Plympton et al., (2000) asserted that daylighting enhances academic performance. Nicklas, Michael, Bailey, (1996) and Task, (2000), emphasise its potential of energy-saving, especially when combined with other daylighting responsive control systems. Thus, the importance of daylighting in the educational sector has been recognised globally, due to the reasons mentioned above and, it has served as a primary design tool for practitioners such as architects and interior designers.

Visual comfort has been an essential issue in institutional buildings as it is directly related to the students' wellbeing and learning process (Baker & Steemers, 2014; Michael & Heracleous, 2017). Similarly, energy efficiency and its related effects, such as energy generation and consumption cost, is an important issue. Thus efforts to overcome these problems include saving energy and switching to renewable sources which further reduce environmental hazards.

According to a study from the European Union (EU), buildings contribute around 40% of the energy consumed and emission which comes from traditional lighting (Mahlia et al., 2011). Thus, there are needs to find a solution to decrease energy usage, which is influencing global warming (Becchio, 2013). According to a study by Jamaluddin (2012), the government paid over MYR 2.7 billion for electricity bills from government universities and hospitals.

On a global scale, 25-40% energy balance of a building is on lighting, reaching 19% on worldwide energy consumption. Lighting thus becomes a key reason for energy efficiency research in various countries (Elena, 2013). One would see in commercial buildings such as universities, and lighting can cost more than the budget of computers and books combined reaching up to 42% of the total electricity supplied (Mahlia et al., 2011).

Although, harnessing daylight had been a primary architectural strategy within the design of excessive-performance schools to cut the cost further, improve impact on students' and teachers' health which also increases their performance in the learning environment (Olson & Kellum, 2003; Mathalamuthu & Nik Ibrahim, 2014). Lighting optimisation research thus becomes the target in energy efficiency. The inclusion of lighting control devices has shown good energy savings potential (Elena, 2013). Replacing existing lighting systems with energy-efficient lamps such as Lighting Emitting Diode (LED) has similarly reduced energy cost and GHG emissions.

However still lacking, a need to further research on suitable solutions that would reduce energy consumption for lighting to further reduce non-renewable energy consumption leading to GHG emission, which is highly influential towards global warming (Becchio, 2013).

The present study aims to investigate the present lighting scenario and visual comfort in three design studios in KAED in IIUM. The method adopts for this research are field measurements, questionnaire survey, and energy consumption calculation. Furthermore, this research proposes potential improvements to provide better visual comfort and to minimise energy consumption due to artificial lighting usage.

1.3 STATEMENT OF THE PROBLEM

Lighting plays a crucial role in the environment of a design studio. Incorporating the dynamics of daylight into a studio improves concentration that ensures alertness in young minds. It further enhances a healthy attitude towards learning (Olson & Kellum, 2003). A significant part of the energy consumption at institutional buildings is spent in illuminating its interiors.

The artificial light is used for visual comfort in institutional buildings, which is at the cost of higher energy consumption (Inan, 2013). This artificial lighting is most active throughout the day and night, which further increased the utility bill (Tang, 2012).

At one of the universities in Perak, Malaysia, their electricity record has shown a significant 8% bill increase for every additional architectural studio in that university (Mirrahimi et al., 2013). Studios in frequent use would contribute higher consumptions of electric energy from the concurrence of lighting and air-conditioning (Abdelatia et al., 2014). Therefore, the need to prioritize daylighting is more evident in studios to ensure efficient energy consumption.

Following the rise in energy costs, more effort has gone into minimizing its consumption from lighting installations (Olson & Kellum, 2003). Daylight has been the most apparent contributor for energy saving, especially during the daytime, where sun rays are the most abundant source of light available to us (Inan, 2013). An essential path towards sustainable and energy-efficient buildings would be reducing energy loads from artificial lighting.

According to Weintraub (2000), the energy efficiency of a lighting system is attributed to an accurate reduction in lighting power density and usage of the lighting systems itself. A reduction in lighting power density, defined as the ratio of total lamp

wattage in a room to its floor area, is readily achieved through the use of energy-efficient lamps, luminaries, and associated equipment. However, this energy-efficient equipment widely available does not provide for energy savings by itself (Weintraub, 2000). Thus, a lighting design considering the user's requirement is to be planned and carried out. In brief, one need not only use energy-efficient equipment but also requires an energy-efficient lighting design. The latter could be optimized through the use of control systems and also through the effective integration of daylight. Such an approach could decrease energy loads and promote energy efficiency in the building.

Incorporating daylight to good design would significantly reduce electric energy consumption by minimizing the use of artificial lighting during the day (Mirrahimi et al., 2013). Although, it has seen in various research where proper daylighting strategies made by increasing daylight usage had improved students' comfort thereby increased performance (Olson & Kellum, 2003). However, there exists little research focusing on the effectiveness of daylighting strategies and their energy savings potential in educational buildings. Hence, this study is looking to affirm the benefits of combining daylighting with new efficient lamp strategies for better energy savings in educational settings.

1.4 RESEARCH AIM AND OBJECTIVES

The study aimed to investigate the daylighting performance and visual comfort condition of three design studios in KAED, IIUM and to propose recommendations for creating a comfortable studio environment to achieve energy consumption and improve visual comfort, are the overriding aims.

There are three objectives of this study, as follows:

1. To study the daylighting performance and visual comfort in the institutional

buildings.

2. To investigate the daylighting performance, visual comfort, energy consumption and savings on lighting in the design studios of the institutional buildings.
3. To recommend potential improvements to achieve better daylighting performance, visual comfort and energy saving in the design studios.

1.5 RESEARCH QUESTIONS

Focusing on daylighting and visual comfort, the study attempts to address the following research questions:

1. Why are the daylighting performance and visual comfort important in the institutional buildings?
2. Does daylighting in the three design studios in KAED provide:
    - Acceptable indoor lighting (natural and artificial)?
    - Satisfactory levels of visual comfort for the students?
    - Energy Efficiency?
3. What are the improvements that can be implemented to achieve better visual comfort and energy saving in the design studios?

1.6 OUTLINE OF RESEARCH STRUCTURE

The method of research was conducted in three main parts, which used complementary research instruments. Part 1 sought to answer Research Questions 1 in the reviews of literature regarding the subject matter concerned: daylighting, visual comfort and energy efficiency, while Part 2 is intended to answer Research Question 2 and Part 3 sought to answer Question 3. Part 1 is about the literature review, which provides the

appropriate method to achieve the aim and objectives of the research. Part 2 uses the general measures of the lighting performance, such as field measurement which covers lighting levels to know the levels of illuminance (E) and daylight factor (DF). The equipment used in this field is the lux meter. Part 2 also uses a questionnaire survey to correlate the data obtained from the monitoring with the feedback of those who regularly use the studios. Part 2 also uses the lighting energy consumption calculation and simple payback period for both existing and proposed lamps. Part 3 is the analysis of results, as summarised in Figure 1-1.

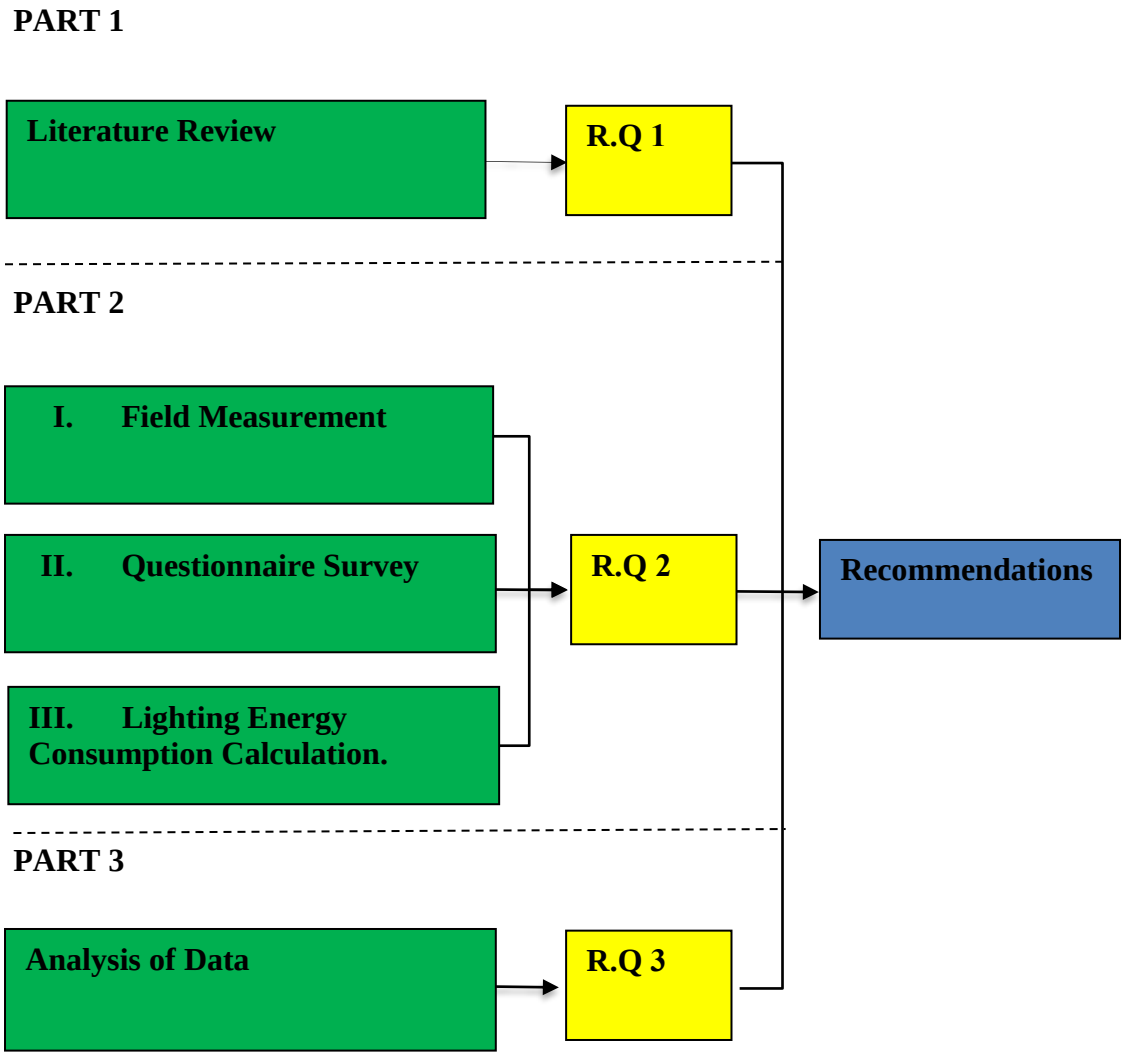

Figure 1.1 :The Research Structure

1.7 SIGNIFICANCE OF THE STUDY

A significant reduction in energy consumption through this study whilst ensuring good visual comfort is beneficial to the government. It stresses the importance of daylighting to reduce electricity consumption from a building. Proposed strategies from this study may aid in incorporating daylighting controls in existing building leading to a reduction in energy consumption and emissions of GHG to sustain the eco-friendly environment. These design strategies should be beneficial to the owners, stakeholders, and particularly to the whole environment. Furthermore, it is expected to increase awareness among building owners at minimizing energy consumption, while providing greater visual comfort for her users, ensuring their productivity.

1.8 SCOPE AND LIMITATIONS OF THE STUDY

The scope of this study will focus on the analysis of lighting condition and visual comfort of three design studios but of various solar orientations. All studios were located on the second floor of the KAED building in IIUM. This research only focused on energy saving in a lighting system at KAED, through the using of daylighting and new efficient lighting lamps. The other strategies of energy-saving are not considered in this study.

1.9 STRUCTURE OF THESIS

This dissertation comprises of five chapters where each one included many topics. In brief, **Chapter One** discusses the background of research, statement of the problem, followed by the aim and objectives of the research, and methodology of research, It then further states the scope which the research is based on and finally diving into study significance and research structure of the dissertation and expected findings.

Chapter Two reviews literature related to this thesis. It discusses daylighting, visual comfort and saving energy. Moreover, this part of the research highlights the critical impacts of daylighting on visual comfort and energy efficiency in buildings.

Chapter Three presents the methodology of the research, which utilises three data collection techniques: questionnaire survey; field measurements and energy savings calculation. Each method is discussed in detail and finally, the data analysis techniques to extract the results of the experiments are elaborated.

Chapter Four is the analytical chapter which presents the analysis and results of the field measurements, questionnaire survey, and energy consumption calculation to answer the research questions and to achieve the aim of the study.

Chapter Five is the final part of the dissertation, which summarises the overall thesis objectives, questions posed and main findings, followed by recommendations and future research for energy saving in the design studios in IIUM.