OCCUPANT DENSITY AND DAYLIGHT ILLUMINANCE LEVEL FLUCTUATION FOR OFFICE BUILDING IN MALAYSIA

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Specially dedicated to my husband, children, parents, and family

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ABSTRACT

Daylighting has yet to be fully utilised in the office interiors even though Malaysia has abundant natural light throughout the year and highly dependent on artificial lighting. However, there is always fluctuation of illuminance in office spaces and this can cause problems to occupants which affect visual and work performance. The aim of this study is to investigate fluctuation in daylight illuminance that affects visual comfort and visual performance. This study also investigates the effects of occupant density in office space in a typical layout of office building. In the first phase of the study, a visual test has been conducted involving seventy two office workers and assessment using a questionnaires survey on one hundred and eighty one office workers. Experiment through visual test was conducted in the office space which involved groups of occupants in office buildings. Furthermore, four groups of office workers numbering five, ten, fifteen and twenty per group were subsequently assigned to the office to detect fluctuations by computer simulation using IES<VE> Software. The result of the experiment evidenced that the level of illuminance in the office was 300 lux to 400 lux while preferred illuminance level was 280 lux to 350 lux. However, the occupants performed their tasks well in higher illumination range of 400 lux to 600 lux. Findings from experiment of visual performance and daylighting simulation showed there was fluctuation influenced by the number of occupants. When occupancy was less than 50%, the fluctuation was acceptable for visual comfort. However, when the occupancy was more than 50%, it would lead to higher fluctuation and the illumination level of recommended standard (300 lux to 400 lux) was not achievable. The findings contribute towards the improvement of an acceptable visual comfort ranges for Malaysian Standard of lighting condition and assist architects and designers to have better understanding in quality and quantity of daylighting and strategies on energy saving.

ABSTRAK

Pencahayaan siang masih belum dimanfaatkan sepenuhnya di dalam ruang pejabat walaupun Malaysia mempunyai pencahayaan yang berlebihan sepanjang tahun dan amat bergantung kepada pencahayaan tiruan. Namun, sering terdapat iluminasi pencahayaan yang berubah-ubah di dalam ruang pejabat dan menimbulkan masalah kepada penghuni kerana mempengaruhi prestasi visual dan kerja. Tujuan kajian ini adalah untuk mengkaji keadaan berubah-ubah iluminasi pencahayaan siang yang memberi kesan kepada keselesaan serta prestasi visual. Kajian ini juga mengkaji kesan kepadatan penghuni pejabat di dalam ruang kerja terhadap susunatur piawai bangunan pejabat. Pada tahap pertama kajian, melalui ujian visual yang dijalankan melibatkan tujuh puluh dua orang pekerja pejabat dan penilaian menggunakan kajian selidik dari seratus lapan puluh satu pekerja pejabat. Kajian eksperimen melalui ujian visual di ruang pejabat melibatkan kumpulan penghuni telah dijalankan di bangunan pejabat. Tambahan pula, empat kumpulan pekerja pejabat yang berjumlah lima, sepuluh, lima belas dan dua puluh kemudiannya dimasukkan ke dalam pejabat untuk mengesan keadaan berubah-ubah oleh simulasi komputer dengan menggunakan Perisian IES <VE>. Keputusan daripada kajian lapangan kaji selidik membuktikan bahawa tahap iluminasi di dalam pejabat yang diperolehi dalam keadaan sedia ada adalah 300 lux hingga 400 lux sementara tahap iluminasi yang dikehendaki adalah 280 lux hingga 350 lux. Walaubagaimana pun, pencapaian penghuni adalah lebih baik dalam tugasan pada tahap iluminasi yang lebih tinggi iaitu 400 lux hingga 600 lux. Penemuan daripada eksperimen pencapaian visual dan simulasi pencahayaan semulajadi menunjukkan terdapat keadaan iluminasi yang berubah-ubah dipengaruhi oleh pertambahan bilangan orang di dalam pejabat. Impak daripada penghunian yang berkurangan dari 50% menunjukkan tahap keadaan yang berubah-ubah masih boleh diterima untuk keselesaan visual. Apabila penghunian yang melebihi 50% akan menyebabkan pertambahan keadaan yang berubah-ubah lebih tinggi dan tidak mencapai tahap iluminasi piawaian iaitu (300 lux hingga 400 lux). Penemuan ini menyumbang ke arah penambahbaikan julat keselesaan visual yang boleh diterima untuk keadaan pencahayaan dalam Piawaian Malaysia dan membantu para arkitek dan pereka untuk pemahaman yang lebih baik dalam kualiti dan kuantiti pencahayaan siang serta strategi penjimatan penggunaan tenaga.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis Of Variance
ASEAN	-	Association of South East Asian Nations
ASHRAE	-	American Society of Heating Refrigeration and Air Conditioning Engineers
BOCA	-	Building Officials and Code Administrators International
BPS	-	Building Performance Simulation tools
CIBSE	-	Chartered Institute of Building Service Engineers
CIE	-	Commission Internationale de L'eclairage
DF	-	Daylight Factor
DGI 22	-	Daylight Glare Index
EPU	-	Economic Planning Unit
IES	-	Illuminating Engineering Society
IESNA	-	Illuminating Engineering Society of North America
IES<VE>	-	Integrated Environmental Solutions <Virtual Environment>
JKR	-	Jabatan Kerja Raya
MJIIT	-	Malaysia-Japan International Institute of Technology
NRC	-	National Research Council of Canada
PWD	-	Public Works Department
SPSS	-	Statistical Package for the Social Sciences
TIMA	-	Tun Ismail Mohamad Ali Office
UBBL	-	Uniform Building By Law
UDI	-	Useful Daylight Illuminance
VC	-	Visual Comfort
VDT	-	Visual Display Unit
VP	-	Visual Performance
WWR	-	Window to Wall Ratio

LIST OF SYMBOLS

D_v/E_v	-	Diffuse to extraterrestrial illuminance ratio
E_i	-	Interior illuminance (lux)
E_x	-	Exterior illuminance (lux)
L	-	Luminance of the light source
WWR	-	Window to Wall Ratio

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Sustainable development strategies are an essential part of preserving the natural environment, and need to be incorporated in standard or recommended forms in order to achieve a balanced impact on the environment. The growth in awareness of sustainable energy consumption and its impacts in Malaysia have been reviewed to demonstrate energy efficient strategies. Starting with demand and the energy crisis of the 1990s, the application of energy efficiency focuses on energy consumption, especially in office buildings. Investigations from Kannan (1999) found offices and shopping complexes used more than 90% of total energy for lighting and air conditioning, while residences used less. A study from Zain Ahmed *et al*. (2008) found that overall energy consumption for Malaysia was 269 kWh/m^2/yr. This shows that energy consumption in Malaysia, especially in office buildings, has increased over the years. The standard in Malaysia, named as Malaysia Standard 1525:2014, was renewed to incorporate improvements for achieving sustainability in all buildings. Studies from local researchers, institutes and higher learning institutions on lighting efficiency are rising in order to fulfill the National Goal of Malaysia's 10^{th} plan - 12^{th} plan. The purpose is to encourage new buildings to be built with energy-efficient strategies without compromising human comfort. The current

Malaysian Standards and recommendations on lighting levels are regarded as an effective method of saving electricity and reducing energy consumption in office buildings. There is a need to clearly define these terms, particularly with regard to the effects of acceptable lighting conditions on occupants' visual comfort and performance in daylit office buildings. Awareness of the importance of indoor lighting research in office environments needs to be emphasized.

Aries *et al.* (2010) stressed the importance of lighting quality in indoor spaces, and examined how office lighting is influenced by architecture, which can be traced to studies by Chung *et al*. (2000) and Veitch *et al.* (1998) on light, the psychological effects thereof, and how it can affect work quality, levels of comfort, and satisfaction of office workers. Several studies have proved that demand for natural lighting is increasing when it affects human performance and comfort in indoor spaces (Heschong *et al*., 2003). Based on the International Energy Agency (IEA) Solar and Heating Cooling Program, Task 31; Daylighting Building in the 21st century, the building research community must understand the present occupant's needs and preferences in daylit spaces, and has an agenda to recognize user perspectives and requirements.

Nowadays, many office buildings in Malaysia have taken on a more cosmopolitan feel, with high-rise blocks constructed close to each other. They have adapted the sustainable approach in designing buildings, but the application of energy-efficient buildings and occupants' visual comfort still need to be clearly addressed. Many researchers have studied adjusting lighting conditions in offices to reflect occupants' requirements, since people spend most of their working time in office buildings (Aries *et al.,* 2010; Schweitzer *et al*., 2007; Boyce *et al*., 2003; Leech *et al.*, 2002). In Malaysia, efforts from local researchers have provided strategies to increase the availability of daylight and maximize the benefits of natural lighting in indoor areas, (Zain-Ahmed *et al*., 2002; Ossen *et al*., 2005; Loutzenhiser *et al.,* 2007). However, estimates of the preferred levels and occupants' satisfaction of lighting quality need to be standardized in order to tally with the standards and recommendations in Malaysia. According to Kandar *et al.* (2011) office buildings in Malaysia must not only comply with the Malaysia Standard 1525, but must also

search for solutions to improve lighting recommendations based on climate factors and office space requirements.

Previous designers have tended to neglect or overestimate the proportion of daylight and daylight availability in working areas, which is influenced by window size, people's preferences, and satisfaction. Recommended settings of lighting have not yet reached the needed levels for occupants. A range of illuminance levels is necessary for occupants to enhance visual performance. Efficient lighting is important, and under such lighting environments, especially in indoor spaces, adequate illuminance levels are needed. However, lighting conditions for offices during preliminary design and in post-occupancy evaluations reveal different levels. This scenario is only realized when the occupant feels visual discomfort, and more retrofitting work is needed for a more sustainable working environment. This is also due to daylight fluctuation in office buildings, which can cause unconscious visual discomfort due to absorption of lighting in components, which is transmitted to the interior surface.

This study identifies current office buildings in Malaysia with the integration of occupant density and daylighting performance, which both affect visual comfort. The research will begin with an investigation of current condition in daylighting and illuminance in offices where changes in daylight illuminance levels in a room affect visual comfort and performance. To accomplish the objective as specified above, the study will be conducted using four techniques: surveys, field measurements, visual test performance, and computer simulation. The findings of the study will be inserted in the lighting requirement, which can also be regarded as part of the criteria in the recommendation of lighting levels in Malaysia.

1.2 Problem Statement

Various sources on lighting conditions have been taken into consideration when developing current office buildings, by applying the Malaysian Standards and Recommendations on Lighting Levels. Even though several researchers have found that there is efficient tropical daylight in offices in Malaysia (Mohd Hamdan, 1996; Kandar *et al.*, 2011), daylighting designs are still not effective for occupants when global illuminance, being from a tropical sky, changes rapidly and results in unpredictable levels of indoor daylight (Ossen *et al.,* 2005; Lim *et al.,* 2012). Most of the research has concentrated on external solar shading and fenestration design (Lim *et al.*, 2010; Mansour *et al*., 2006; Ossen, D.R. *et al.*, 2005), and the study to illuminate the internal spaces for visual comfort in Malaysia had also conducted based on the parameters shading devices, floor depth, ceiling height, opening ratio, glass transmittance and material reflectance (Sadin *et al.*, 2014). Therefore, occupants' visual comfort parameter still lacked in the investigation (Kim and Kim, 2007) and various studies on systems has been introduced to decreased daylight penetration and adding additional light absorption (Fontoynont, 2014). This means that a simple system is more needed in most buildings to maximize daylight and provide an external view.

Studies carried out on a number of existing office buildings in Malaysia found that the existing daylighting condition in office building did not comply with Malaysian Standards 1525; 2014 (Lim *et al,*. 2012). The recommended illuminance level is still referring to 300-400 lux for office building, and this only concentrates on artificial illuminance levels to provide maximum energy consumption. The focus on illuminance level need to be further explored as this will contribute the office workers' productivity. Recently, solutions have been sought to satisfy the needs of occupants and contribute to energy saving by considering the illuminance of the working plane, windows, and automatically control systems using sensors. However, no study has yet been published focusing on the illuminance changes which affect the preferred illuminance level and acceptable level by occupants due to fluctuation illuminance in Malaysia.

When most of the office buildings especially government office buildings were found over illuminate or lack of illumination, it shows the designer should identify the significant parameter in lighting design during schematic layout till occupancy. This consideration and awareness can meet the acceptable illuminance level for occupants during performing the task less work for retrofitting such as de-lamping artificial lighting. Therefore, complaint by occupants on lighting distraction and too bright the illuminance level shows fluctuation of illuminance level occur frequently in indoor spaces. In addition, these may reduce visual comfort and performance. Furthermore, the fluctuation of daylight illuminance level which affects the acceptable indoor daylighting level is not highlighted in any visual comfort issue where it significantly changes the quantity of daylight levels. This unpredictable change in illuminance level happens more severely when the room is fully occupied, and it is also reported that dimming control systems may be affected due to this condition. Clarification is needed on whether lighting guidelines over or underestimate the preferred amount of light. Factors that influence illuminance changes in offices are not identified during the measurement of quantity of illuminance level. The occupants are not aware of the illuminance change, and this illuminance variation may contribute to visual discomfort and visual annoyance. (Lee *et al.*, 2013).

Based on the history of illuminance, recommendations from different countries at different times are evaluated for different activities in offices (Mills and Borg, 1999). Observations and investigations are undertaken to identify fluctuation ranges that meet the occupants' visual comfort and performance, which may contribute to the effectiveness of dimming controls on high productivity in the office. Currently, the Malaysian government is trying to refine assessment methods in daylighting conditions in order to retrofit existing government office buildings and achieve sustainable architecture building without compromising on visual comfort. The problem of daylighting and its potential in Malaysia is related to the adequacy of daylight in an interior space, which faces criticism when illuminance levels in existing offices in Malaysia do not meet the standards and recommendations. Due to this condition, a study on illuminance change in daylight conditions must be implemented in order to clarify the effect between daylight illuminance fluctuation and occupant density in the workplace.

The above description shows the obvious impact that lighting problems have in relation to visual comfort in an office space. It also reveals a need to improve recommendations on Malaysian Standard on Lighting Practice to provide an ideal design for office space without jeopardizing visual comfort for the occupants, as well as incorporating energy-saving strategies. This scenario can be improved through the stages of identifying the preferred illuminance level in daylight conditions, fluctuation based on occupant density of a room, and maximum occupancy density, which affects visual comfort. Subsequently, it is necessary to verify the acceptable range of daylight fluctuation based on the window to wall ratio, occupant density and distance in daylit office room.

1.3 Research Questions

1. What is the range of preferred daylight illuminance level for occupants in office buildings?
2. What are the parameters influencing the fluctuation in illuminance in office buildings?
3. Is the fluctuation of illuminance level affects visual performance and visual comfort?
4. What is the maximum occupant density among the selected variables by using simulation?

1.4 Research Aim and Objectives

This study aims to recommend an acceptable range of daylighting fluctuations for office occupants' visual comfort based on occupant density. To achieve this aim, the following objectives have been derived:-

1. To investigate the preferred illuminance level for office buildings in Malaysia.

2. To determine the effect of the illuminance level and visual performance due to occupancy density.

3. To examine the optimum fluctuation discomfort based on occupancy density.

4. To recommend the acceptable range of daylight fluctuations of different room configurations and occupant density.

1.5 Research Gap

Over the years, lighting level research has only focused on illuminance levels in artificial lighting environments, rather than on daylighting. The variables affecting daylight strategies indoors have been identified by several researchers, who consider the design criteria for windows, ceilings, workstation position, technology on skin façade, and shading. Brightness and illuminance is detected by the daylight availability through reflectance and transmittance from room furniture, office material, and layout settings (Ochoa *et al.,* 2012; Rahmani *et al*., 2012: Kandar *et al.,* 2011; Lim *et al*., 2011; Freewan *et al.,* 2009; Denan, 2004). Although many previous researchers have investigated indoor lighting and the characteristics of the architectural element, investigation of the factors that influence change in daylight illuminance needs to be conducted. The control system and window design of an office building will be more functional and practical when there is consideration of fluctuation in illumination in the workplace. It is believed that the estimation of lux level would fully benefit daylighting strategies and lighting conditions in the workplace. By knowing the occupancy's preferred illuminance levels and ranges of illuminance levels when performing tasks, we can improve in designing an efficient typical office space in Malaysia. In order to determine the illuminance levels needed according to Malaysian Standard Lighting Practice, the estimation of lux level in occupied rooms needs to be identified. Previously, researchers have only

concentrated on occupancy studies with fire escape routes through occupancy load, and determining spatial layout with occupancy pattern. Determining the appropriate illuminance levels according to occupancy density has never been factored into room design. Consideration of the maximum number of people in the workplace is a potential strategy for reducing fluctuation in illuminance levels and maintaining the recommended illuminance level.

It is necessary to investigate the reduction in illuminance levels, which can influence the illuminance range of visual discomfort. This situation changes the illuminance level, and also causes visual disruption. Araji (2008) assessed various lighting conditions alongside behavioral experiments, while Veitch *et* al. (2008) reviewed how human behavior contributes to higher tolerance, compared to the values indicated in guidelines and lighting standards or norms. The latest study only assesses occupants' preferences and satisfaction towards changes in illuminance, but there has been no study examining the occurrence of fluctuation of illuminance level due to the occupant density. In this study, a more detailed occupant density parameter will be used to determine that fluctuation of illuminance level affect visual performance.

The overview in Table 1.1 shows the trend of research which carried out from the 1980's to the present period. In the 1980's, preference and satisfaction in daylighting condition were investigated by Heerwagen and Orians (1986), Dubois (2001), Boubekri (1991), while in the 2000's Boyce (2003), Aries (2005), Araji (2008), Wang (2009), Lee *et* al. (2013), studied the illuminance level in daylighting condition. From the beginning of 2000 to date, the issue of fluctuation in illuminance comes in to place which was studied by Lee, J.H. Yoon *et* al. (2012). A few research works were carried out on room configuration and physical variables like window and distance which relate to the daylight penetration to indoors. (Ghisi, 2005; Aries, 2010). The research on recommendation of lighting condition were carried out by Kandar *et* al. (2011) and Lim *et* al. (2011) which emphasized on daylighting, distance and WWR. The summary of previous research on daylighting, illuminance, fluctuation and visual comfort that are related to issue of present study is presented in Table 1.1.

Table 1.1: Past studies on lighting and illuminance level

	Design										**Perception**			**Environment**		**Method**		
Author and Year	Occupant Density	Illuminance	Task performance criteria	Work Plain Illuminance	Control System	Orientation	Window Wall Ratio/Window	Room Layout	Distance	Standard/Recommendation	Energy Efficiency	Artificial Lighting	Preference and Satisfaction	Glare	Daylighting	Fluctuation of Illuminance	Simulation	Remarks
Boyce, P. *et al.* (2003)		√	√	√								√			√	√		Offices
Gala Siu, A.D. *et al*. (2006)										√			√		√			Open plan office (experiment)
Kim, S.Y. *et al.* (2007)					√						√				√	√		Common Spaces (experiment)
Van Den Wymelenberg, K. G.,(2012).						√					√	√			√			Office (survey /questionnaire)
Aries *et al.*, (2010)		√	√	√								√			√	√		Offices (survey /questionnaire)
Kandar *et al.*, (2011)									√	√	√		√		√			Offices (survey)
Fontoynont, (2014)										√			√		√			Office
Lee, J.H. Yoon *et al.* (2013)		√	√	√			√	√				√			√	√		Offices
Ochoa, C.E *et al.* (2012)			√				√	√					√		√			Offices
Wang, N. (2009)		√		√		√							√		√			Offices
Ghisi, E *et.* al (2005)							√	√					√		√			Office
Araji, M.T (2008)		√					√	√					√		√			
Al-Tamimi *et al.* (2009)							√								√		√	
Fadzil and F.S.F.S.. (2004)							√								√			
Ahmed, A.Z. *et al.* (2007)										√					√			Offices

Dubois, M.C. *et al.* (2001)							√						√		√			Offices
Lim, Y. W et. al. (2011)				√			√	√		√			√		√		√	Offices
Boubekri, Hull and Boyer (1991)							√	√				√	√		√			Offices
Heerwagena nd Orians (1986)		√					√						√		√			
My Study (2015)	√	√	√					√	√	√			√		√	√	√	Office (experiment)

1.6 Scope of Study and Limitation

This study sets out to investigate illuminance change or fluctuation in illuminance levels in daylit office buildings and its relation to visual comfort in the office building. The acceptable illuminance level in daylighting condition and preferred illuminance level from the occupant in the workplace need to be identified in order to justify illuminance range in the task working area without jeopardizing visual comfort. This study integrates the issues and methods from previous researchers in order to evaluate valid samples and findings. The limitation of this study are only investigate the effect of fluctuation in illuminance levels in daylit indoor environments for office building. The investigation includes the variables of illuminance level in daylighting condition, windows to wall ratio which representing 70% of the wall opening, occupant density, distance and two types of room layouts ; deep and narror layout (as these are related to Malaysian Standard 1525; 2014 [recommended illuminance 300-400 lux] and the EPU standard). The focus is also only on quantity of illuminance level, work plane illuminance in office buildings, and assessing visual comfort in daylight conditions in Malaysia. The related variables that measure visual comfort and illuminance are based on window opening (WWR) 70, with typical room layout matching EPU standards and within the recommended illuminance level of Malaysian Standard 1525:2007. The study will not look at office arrangements, orientation of the room, control systems, control devices, color, glazing types, views, or privacy.

This research was also limited by experiments on visual test performance that only enhance the reading task in daylighting condition. Occupants spent about two hours in the selected office building. This research investigated the occupant density within distance, room distance, room layout, and window size. Daylight factor is also documented for existing empty room and occupied room. The development of techniques as part of the methodology which verify the calculation of occupant density in a room without jeopardize the quantity of illuminance level.

1.7 Significance of the Study

Most of the studies on visual comfort have been focusing on the glare and view. It is believed that determining the range of illuminance level would fully benefit daylighting strategies and lighting conditions in the workplace. By knowing the occupancy's preferred illuminance levels and ranges of illuminance level during task performance, energy-saving in lighting design can be achieved. In order to meet illuminance level according to Malaysian Standard Lighting Practice 1525;2014, the estimation of lux level in occupied room needs to be identified. The outcome of the study is to enhance the important of occupant density in the workplace as this will influence the reduction of the fluctuation in illuminance levels and affect visual performance. Furthermore, the result of optimum illuminance range of visual discomfort will provide a strategy to reduce energy consumption and meeting the target of Malaysian Standard 1525. An ideal number of occupants in workplace without jeopardizing the illuminance level and visual comfort in a working environment will enhance a quality space in office building.. This study can also be used as a supplement to lighting practice recommendations, where estimation of lighting conditions in a typical office room may be determined during the preliminary design stage.

1.8 Thesis Structure

This thesis is organized as follows:

Chapter One: Introduction. This chapter is made up of discussion on the introduction to the study, a description to the problem, the objectives of the study, the scope covered, the significance of the findings, and the organization of the study. Besides that, the limitations of the research are also reviewed in this chapter.

Chapter Two: Literature Review will briefly explain the theory that relates to this work, covering past research that has been done in relation to the study. The theoretical framework is discussed in this chapter to elaborate on and explain the related variables and parameters of the research. The benefit of daylighting is discussed in this chapter to elaborate on and explain the relationship of daylight in office buildings to workers and the environment, both physically and physiologically.

Chapter Three: Methodology includes a complete account of the research methodology used in this study. This chapter is divided into two main sections. The first section reviews the parameters of preferred illuminance levels in daylight office buildings. The characters of the element that influence the daylight availability are discussed. The second section reviews the relationship between illuminance changes with visual comfort of office building occupants by applying a simulation using IES software. This chapter will also explain the survey and experimental set-up under the research strategy. Surveys is divided into two main sections. The first section presents the building environment for conducting a survey by using questionnaires. The second section reviews the survey on selected office buildings for conducting visual tests to achieve the objective of the research, which focuses on preferred illuminance range, fluctuation in illuminance and task performance within the range of preferred and acceptable illuminance level of the working environment.

Chapter Four: Analysis and discussion 1 gives the results, analyses, and findings of all the objectives. This chapter gives results from survey and experiment 1 on the

ranges of preferred illuminance level, experiment 2 on fluctuation illuminance ranges based on user response analysis and visual test. The discussion will also presents a comprehensive study based on two selected office buildings to examine the optimum fluctuation discomfort based on occupancy density and compares the results of field measurement and computer simulation using IES<VE> Software. The findings from objective 3 will be used as a parameter for objective 4 which is using the computer simulation to examine the variables related to fluctuation based on occupanct density and recommend the acceptable range of daylight fluctuations.

Chapter Five concludes the acceptable ranges of daylight fluctuations and the maximum occupant density in typical office buildings, which will influence the recommended illuminance level for office building in Malaysia. This will be used as a supplement in determining the lighting indicator for office buildings in Malaysia. Finally, this chapter also suggests future research to complement the findings.

1.9 Conclusion

This chapter presents briefly the introduction of the study, and the framework of the research. The next chapter will illustrate the definition of the related theories and its parameters.

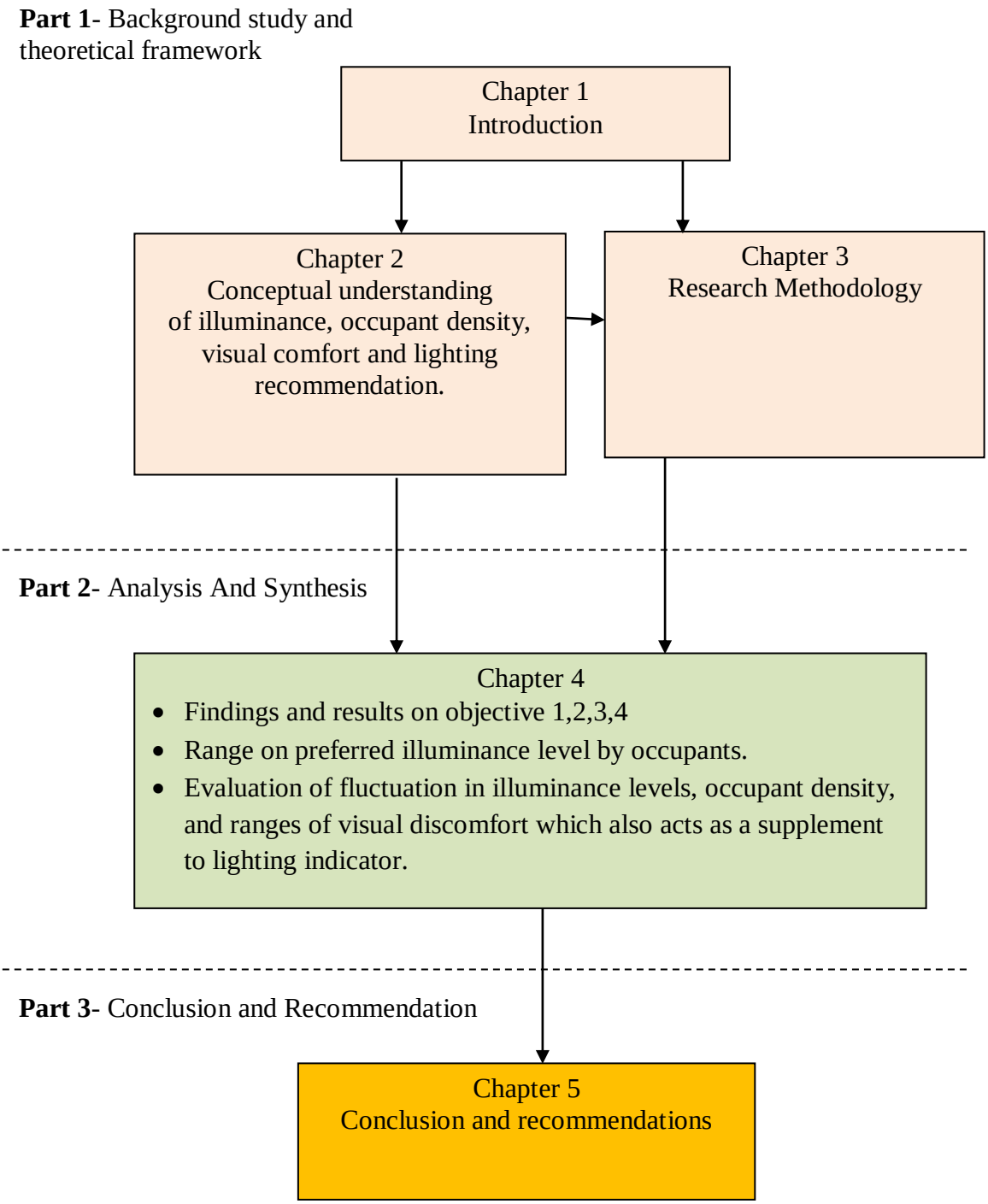

Figure 1.1: Summary of thesis structure

REFERENCE

Abdul Rashid, R. (2012). *Destination images and key factors influencing tourists' decision making visiting Sabah* (Doctoral dissertation, Universiti Teknologi Malaysia, Faculty of Built Environment).

Alshaibani, K. (2015). Average daylight factor for the ISO/CIE Standard General Sky. *Lighting Research and Technology*, 1477153515572939.

Alrubaih, M. S., Zain, M. F. M., Alghoul, M. A., Ibrahim, N. L. N., Shameri, M. A., and Elayeb, O. (2013). Research and Development on Aspects of Daylighting Fundamentals.*Renewable and Sustainable Energy Reviews,* 21, 494-505.

Al-Tamimi, N., Fadzil, S. F. S., & Abdullah, A. (2009). The Effect of Glazed Fenestration Area and Natural Ventilation on Thermal Performance in Residential Buildings in Tropical Region. In CIBW 107 International Symposium on Construction in Developing Economies (pp. 370-379).

Altomonte, S. (2009). Daylight for energy savings and psycho-physiological well-being in sustainable built environments. Journal of Sustainable Development, 1(3), p3.

Ander, G. D. (2003). Daylighting performance and design. John Wiley & Sons.

André, E., & Schade, J. (2002). Daylighting by optical fiber (Doctoral dissertation, MSc Thesis 2002: 260, Luleå University of Technology, Sweden).

Angelopoulou, E. (1999). The reflectance spectrum of human skin. *Technical Reports (CIS)*, 584.

Arabi, F., Husini, E. M., and Kandar, M. Z. (2012).Effect of Natural Light Glare on Passive Design in Malaysian Government Office Building.*American Transactions on Engineering & Applied Sciences.*

Araji, M. T. (2008). *Balancing Human Visual Comfort and Psychological Wellbeing in Private Offices.*ProQuest.Malaysia

Arendt, J. (2005). Melatonin: Characteristics, Concerns, and Prospects. *Journal of Biological Rhythms,* 20(4), 291-303.

Aries, M. B. C. (2003). *Retinal Illuminance: A New Design Parameter*..Publications-Commission Internationale De L Eclairage Cie,152, D3-52.

Aries, M. B. C. (2005). *Human Lighting Demands: Healthy Lighting in an Office Environment* (Doctoral dissertation, Technische Universiteit Eindhoven).

Aries, M. B., Veitch, J. A., and Newsham, G. R. (2010). Windows, View, and Office Characteristics Predict Physical and Psychological Discomfort. *Journal of Environmental Psychology,* 30(4), 533-541.

Astolfi, A. and Pellerey, F. (2008).Subjective and Objective Assessment of Acoustical and Overall Environmental Quality in Secondary School Classrooms.*The Journal of the Acoustical Society of America,*123(1), 163-173.

Attia, S., Beltrán, L., De Herde, A., & Hensen, J. (2009). "Architect friendly": A comparison of ten different building performance simulation tools. In 11th International Building Performance Simulation Association Conference and Exhibition. International Building Performance Simulation Association (IBPSA).

Battle Jr, E. F., & Soden Jr, C. E. (2009, June). The use of lasers in darker skin types. In *Seminars in cutaneous medicine and surgery* (Vol. 28, No. 2, pp. 130-140). WB Saunders.

Babbie, E. (2007). Quantitative data analysis. *The practice of social research, 11*.

Bechtel, R. B., Marans, R. W., & Michelson, W. E. (1987). Methods in environmental and behavioral research. Van Nostrand Reinhold Co.

Begemann, S. H. A., Van den Beld, G. J., and Tenner, A. D. (1997). Daylight, Artificial Light and People in an Office Environment, Overview of Visual and Biological Responses.*International Journal of Industrial Ergonomics,* 20(3), 231-239.

Bell, T. C., Cleary, J. G., and Witten, I. H. (1990).*Text Compression.* Prentice-Hall, Inc.

Berruto, E., Colombo, G., Monogioudis, P., Napolitano, A., and Sabatakakis, K. (1997).Architectural Aspects for the Evolution of Mobile Communications toward UMTS.*Selected Areas in Communications, IEEE Journal on,* 15(8), 1477-1487.

Blackwell, O. M. and Blackwell, H. R. (1980).Individual Responses to Lighting Parameters for a Population of 235 Observers of Varying Ages.*Journal of the Illuminating Engineering Society,* 9(4), 205-232.

Blackwell, H. R. (1946). Contrast thresholds of the human eye. *JOSA,36*(11), 624-643.

Bluyssen, P. M., Aries, M., and van Dommelen, P. (2011). Comfort of Workers in Office Buildings: The European HOPE Project. *Building and Environment,* 46(1), 280-288.

Borisuit, A., Linhart, F., Scartezzini, J. L., & Münch, M. (2014).Effects of realistic office daylighting and electric lighting conditions on visual comfort, alertness and mood.Lighting Research and Technology, 1477153514531518.

Boubekri, M., Hull, R. B., and Boyer, L. L. (1991).Impact of Window Size and Sunlight Penetration on Office Workers' Mood and Satisfaction A Novel Way of Assessing Sunlight.*Environment and Behavior,* 23(4), 474-493.

Bouchet, B. and Fontoynont, M. (1996). Day-lighting of Underground Spaces: Design Rules. *Energy and Buildings,* 23(3), 293-298.

Boulos, Z., Campbell, S. S., Lewy, A. J., Terman, M., Dijk, D. J., and Eastman, C. I. (1995). Light Treatment for Sleep Disorders: Consensus Report VII. Jet Lag.*Journal of Biological Rhythms,* 10(2), 167-176.

Boyce, P. R. (1973). Age, Illuminance, Visual Performance and Preference.*Lighting Research and Technology,* 5(3), 125-144.
.

Boyce, P., Hunter, C., and Howlett, O. (2003).*The Benefits of Daylight through Windows.* Troy, New York: Rensselaer Polytechnic Institute.

Boyce, P., Rea, M. S., Figueiro, M. G., White, R., and Kolberg, K. (2001).The Effects of Bright Light on Day and Night Shift Nurses' Performance and Well-being in the NICU.*Neonatal Intensive Care,*14(1), 29-32
.

Brasche, S., Bullinger, M., Bronisch, M., and Bischof, W. (2001).Eye and Skin Symptoms in German Office Workers - Subjective Perception vs. Objective Medical Screening.*International Journal of Hygiene and Environmental Health,* 203(4), 311-316.

Brennan, A., Chugh, J. S., & Kline, T. (2002). Traditional versus open office design a longitudinal field study. Environment and Behavior, 34(3), 279-299.

Cantin, F. and Dubois, M. C. (2011). Daylighting Metrics based on Illuminance, Distribution, Glare and Directivity. *Lighting Research and Technology*, 43(3), 291-307.

Chakraborty, D. P. (2011, November). New developments in observer performance methodology in medical imaging. In Seminars in nuclear medicine (Vol. 41, No. 6, pp. 401-418). WB Saunders.

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. Journal of Economic Behavior & Organization, 81(1), 1-8.

Chel, A., Tiwari, G. N., & Chandra, A. (2009). A model for estimation of daylight factor for skylight: an experimental validation using pyramid shape skylight over vault roof mud-house in New Delhi (India). Applied Energy, 86(11), 2507-2519.

Christoffersen, J. and Wienold, J. (2005).*Monitoring Procedure for Assessment of User Reaction to Glare.* Report ECCO-DBUR-0303-01, Energy and Comfort Control for Building Management Systems (ECCO-Build), EU Commission (Contract No: ENK6-CT-2002-00656).

Chung, T. M. and Burnett, J. (2000). Lighting Quality Surveys in Office Premises.*Indoor and Built Environment,* 9(6), 335-341.

Clason, D. L., & Dormody, T. J. (1994). Analyzing data measured by individual Likert-type items. Journal of Agricultural Education, 35, 4.

Craig, A. and Cooper, R. E. (1992).Symptoms of Acute and Chronic Fatigue.*Handbook of Human Performance,* 3, 289-339.

Creswell, J. W. (2012). Qualitative inquiry and research design: Choosing among five approaches. Sage.

Creswell, J. W., Klassen, A. C., Plano Clark, V. L., & Smith, K. C. (2009). for the Office of Behavioral and Social Sciences Research (2011) Best practices for mixed methods research in the health sciences. National Institutes of Health. obssr. od. nih. gov/mixed_methods_research

Cuttle C. (2010). Towards the Third Stage of the Lighting Profession.*Lighting Research and Technology,* 42, 73-93.

Danielsson, C. B. and Bodin, L. (2008). Office Type in Relation to Health, Well-being, and Job Satisfaction among Employees.*Environment and Behavior,* 40(5), 636-668.

.

Denan, Z. (2004).*Assessment of Window and Lighting Design in Office Buildings under Daylight of a Hot-Humid Climate, Malaysia.* (Doctoral dissertation, The University of Wales College of Cardiff (United Kingdom))

.

Dodo, Y. A., Jibril, J. D., Enegbuma, W. I., & Medugu, N. I. (2014). Nigerian National Standards for Green Buildings: A Legislative Framework. IUP Journal of Structural Engineering, 7(2), 55.

Dubois, M. C. (2001). Impact of shading devices on daylight quality in offices. Simulations with Radiance.

Duval, C. L., Charles, K. E., & Veitch, J. A. (2002). Open-plan office density and environmental satisfaction

.

Edwards, L. and Torcellini, P. A. (2002).*A Literature Review of the Effects of Natural Light on Building Occupants* (p. 59). Golden, CO: National Renewable Energy Laboratory..

El Mohimen, M. A., Hanna, G., & Krarti, M. (2005). Analysis of daylighting benefits for office buildings in Egypt. Journal of solar energy engineering,127(3), 366-370.

Elzeyadi, I. (2002). Designing for Indoor Comfort: A Systemic Model for Assessing Occupant Comfort in Sustainable Office Buildings. In *Proceedings Of The Solar Conference* (pp. 485-498). American Solar Energy Society: American Institute Of Architects.

Estes Jr, J. M., Schreppler, S., & Newsom, T. (2004). Daylighting prediction

Fadzil, S. F. S. and Sia, S. J. (2004). Sunlight Control and Daylight Distribution Analysis: The KOMTAR Case Study. *Building and Environment,* 39(6), 713-717.

Ferreira, D. M., Zangaro, R. A., Villaverde, A. B., Cury, Y., Frigo, L., Picolo, G., ... & Barbosa, D. G. (2005). Analgesic effect of He-Ne (632.8 nm) low-level laser therapy on acute inflammatory pain. *Photomedicine and laser surgery*, *23*(2), 177-181.

Fairuz, S., Al-Tamimi, N. A., Abdullah, A., & Mariah, W. (2013). Wall Window Ratio (Wwr) And Its Influence On Internal Air Temperatures And Natural Light Level In Glazed Room In The Tropics.

Fisher, D. S. and Huse, D. A. (1991). Thermal Fluctuations, Quenched Disorder, Phase Transitions, and Transport in Type-II Superconductors. *Physical Review B,* 43(1).

Flynn, J. (1976). The Effects of Light Source Color on User Impression and Satisfaction: Preliminary Report: Cool White Fluorescent Color-Vs-High Pressure Sodium Color for Illuminating Engineering Research Institute, New York (No. 55). Pennsylvania State University, Department of Architectural Engineering.

Fontoynont, M. (Ed.).(2014). Daylight performance of Buildings.Routledge.

Fontoynont, M. Laurentin, C., and Bermtto, V., (2000).Effect of Thermal Conditions and Light Source Type on Visual Comfort Appraisal.*Lighting Research and Technology,*32(4), 223-233.

Foret, J., Daurat, A., & Tirilly, G. (1998). Effect of bright light at night on core temperature, subjective alertness and performance as a function of exposure time. *Scandinavian journal of work, environment & health*, 115-120.

Fotios, S. A. and Cheal, C. (2010). Stimulus Range Bias Explains the Outcome of Preferred-illuminance Adjustments. *Lighting Research and Technology,* 42(4), 433-447.

Fotios, S. and Cheal, C. (2012). Using Obstacle Detection to Identify Appropriate Illuminances for Lighting in Residential Roads. *Lighting Research and Technology*, 1477153512444112.

Freewan, A. A., Shao, L., and Riffat, S. (2009). Interactions between Louvers and Ceiling Geometry for Maximum Daylighting Performance.*Renewable Energy,* 34(1), 223-232.

Frontczak, M., Andersen, R. V., and Wargocki, P. (2012).Questionnaire Survey on Factors Influencing Comfort with Indoor Environmental Quality in Danish Housing.*Building and Environment,* 50, 56-64..

Frontczak, M., Schiavon, S., Goins, J., Arens, E., Zhang, H., and Wargocki, P. (2012).Quantitative Relationships between Occupant Satisfaction and Satisfaction Aspects of Indoor Environmental Quality and Building Design.*Indoor Air*, 22(2), 119-131.

Galasiu, A. D. and Veitch, J. A. (2006). Occupant Preferences and Satisfaction with the Luminous Environment and Control Systems in Daylit Offices: A Literature Review. *Energy and Buildings*, 38(7), 728-742.

Gardiner, K. and Harrington, J. M. (Eds.)(2008). *Occupational Hygiene.*John Wiley & Sons.

Ghisi, E. and Tinker, J. A. (2005).An Ideal Window Area Concept for Energy Efficient Integration of Daylight and Artificial Light in Buildings.*Building and Environment*, 40(1), 51-61.

Ghisi, E., & Tinker, J. (2001, August). Optimising energy consumption in offices as a function of window area and room size. In Seventh International Ibpsa Conference–International Building Performance Simulation association
.

Gifford, B. D., Zammuto, R. F., Goodman, E. A., & Hill, K. S. (2002). The relationship between hospital unit culture and nurses' quality of work life. Journal of Healthcare Management, 47, 13-26.

Gosling, S. D., Ko, S. J., Mannarelli, T., & Morris, M. E. (2002). A room with a cue: personality judgments based on offices and bedrooms. *Journal of personality and social psychology*, *82*(3), 379.

Guideline of Economic Planning Unit, "*Garis Panduan Dan Peraturan BagiPerancangan Bangunan Oleh Jawatankuasa Standard Dan Kos Unit Perancang Ekonomi, Jabatan Perdana Menteri, Edition* 2008.

Guth, S. K., & McNelis, J. F. (1969). Threshold contrast as a function of target complexity. American journal of optometry and archives of American Academy of Optometry, 46(7), 491.

Haapakangas, A., Helenius, R., Keskinen, E., & Hongisto, V. (2008, July). Perceived acoustic environment, work performance and well-being–survey results from Finnish offices. In Proceedings of 9th International Congress on Noise as a Public Health Problem (ICBEN) (pp. 434-441).

Hamza, T. H., Zabetian, C. P., Tenesa, A., Laederach, A., Montimurro, J., Yearout, D and Payami, H. (2010). Common Genetic Variation in the HLA Region is Associated with Late-onset Sporadic Parkinson's Disease. *Nature Genetics,* 42(9), 781-785.

Handbook, *IESNA Lighting.* (2000). New York: IESNA.

Hayduk, L. A. (1983). *Personal Space: Where We Now Stand. Psychological Bulletin,* 94(2), 293.

Heerwagen, J. H. (1998, March). Design, Productivity and Well-being: What are the Links. In*AIA Conference on Highly Effective Facilities, Cincinnati, Ohio, March*(pp. 12-14).

Heerwagen, J. H. and Heerwagen, D. R. (1986).Lighting and Psychological Comfort.*Lighting Design and Application,* 16(4), 47-51.

Heschong, L. (2002). Day lighting and student performance. ASHRAE J, 44, 65-67.

Heschong, L., McHugh, J., Manglani, P., & Dee, R. (2003).*Draft Protocol: Modular Skylight Wells for Suspended Ceiling.*

Hoffmann, G., Griesmacher, A., Bartenbach, C., & Schobersberger, W. (2010). *Modulation of lighting intensities and color temperature: Effects on melatonin and cognitive performance. Occupational Ergonomics,* 9(1), 27-39.

Hopkinson, R. G. (1963). Architectural Physics: Lighting.

Hopkinson, R. G. (1965). A proposed luminance basis for a lighting code.Lighting Research and Technology, 30(3 IEStrans), 63-88.

Hopkinson, R. G., Petherbridge, P., and Longmore, J. (1966).*Chapter 21: Daylight and Sunlight in Tropical Regions, Daylighting.*

Hughes, P. and McNelis, J. (1978).Lighting. Productivity, and the Work Environment, *Lighting Design + Application,* 8(12), 32-39.

Humphreys, M. (2005).Natural Resources, Conflict, and Conflict Resolution Uncovering the Mechanisms.*Journal of Conflict Resolution,* 49(4), 508-537.

Husin, S. N. F. S., & Harith, Z. Y. H. (2012). The performance of daylight through various type of fenestration in residential building. Procedia-Social and Behavioral Sciences, 36, 196-203.

Husini, E. M., Arabi, F., and Kandar, M. Z. (2011). On Post Occupancy Evaluation of the Preferred Luminous Environment and Occupants' Satisfaction for Office Buildings in Malaysia: A Survey. *OIDA International Journal of Sustainable Development,* 2(8), 47-58.

Hygge, S., & Löfberg, H. (1999). Post occupancy evaluation of daylight in buildings. Center for the Built Environment, Sweden, for IEA Solar and Heating Program Task, 21.

Hygge, S., & Lofberg, H. A. (1997). User evaluation of visual comfort in some buildings of the daylight Europe project. In Right Light (Vol. 4, No. 2).

Ibrahim, N., & Zain Ahmed, A. (2006). Energy saving due to daylighting: a simplified rediction tool for wall envelope design of air-conditioned office buildings in Malaysia.

Ibrahim, N., & Zain-Ahmed, A. (2007, September). Daylight availability in an office interior due to various fenestration options. In 2nd PALENC Conference and 28th AIVC Conference on Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, Crete island, Greece.

Iversen, A. C., Fear, N. T., Ehlers, A., Hacker Hughes, J., Hull, L., Earnshaw, M., and Hotopf, M. (2008).Risk Factors for Post-traumatic Stress Disorder among UK Armed Forces Personnel.*Psychological Medicine,* 38(04), 511-522.

Iversen, A., Roy, N., Hvass, M., Jørgensen, M., Christoffersen, J., Osterhaus, W., & Johnsen, K. (2013). Daylight calculations in practice..

Jacobs, A., & Solomon, J. (2004). MSc in Energy, Architecture and Sustainability: European Masters in the Integration of Renewable Energies into Buildings, RADIANCE Course (Advanced).

Jamaludin, A. A., Hussein, H., Keumala, N., & Ariffin, A. R. M. (2015).The dynamics of daylighting at a residential college building with the internal courtyard arrangement. International Journal of Architectural Research: ArchNet-IJAR, 9(3), 148-165.

Joarder, M. A. R., & Ahmed, Z. N. (2007). An observation on daylight inclusion in the lighting of offices in Dhaka.

Juslén, H. T., Wouters, M. C. H. M., and Tenner, A. D. (2005).Preferred Task-Lighting Levels in an Industrial Work Area without Daylight.*Lighting Research and Technology*, 37(3), 219-231.

Kandar, M. Z., Sulaiman, M. S., Rashid, Y. R., Ossen, D. R., Abdullah, A. M., Wah, L. Y., and Nikpour, M. (2011). Investigating Daylight Quality in Malaysian

Government Office Buildings Through Daylight Factor and Surface Luminance. *Engineering and Technology,* 59.

Kandaswamy, U., Adjeroh, D. A., Schuckers, S., and Hanbury, A. (2012). Robust Color Texture Features under Varying Illumination Conditions.*Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on,* 42(1), 58-68.

Kannan, K. S. (1999). Strategies for promotion and development of renewable energy in Malaysia. *Renewable Energy*, *16*(1), 1231-1236

Kensek, K., & Suk, J. Y. (2011).Daylight Factor (overcast sky) versus Daylight Availability (clear sky) in Computer-based Daylighting Simulations.Journal of Creative Sustainable Architecture & Built Environment, 1.

Kim, J. J., & Wineman, J. (2005). Are Windows and Views Really Better?. A Quantitative Analysis of the Economic and Psychological Value of Views, Daylight Dividend Program, Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY.

Kim, S. Y. (2005). Analyses of fluctuating light on visual comfort for the applications of daylight dimming control systems. University of Michigan..

Kim, S. Y. (2008). Analysis on Dimming Control Effect by Algorithm Variation for Direct/Indirect Lighting in a Small Office. Journal of the Korean Solar Energy Society, 28(5), 36-48.

Kim, S. Y. and Kim, J. J. (2007).Influence of Light Fluctuation on Occupant Visual Perception.*Building and Environment,* 42(8), 2888-2899.

Kim, S. Y., & Yum, S. K. (2005). Optimum control of a photoelectric dimming system in a small office with a double skin envelope. Architectural Research, 7(2), 47-54.

Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International.

Krarti, M., Erickson, P. M., & Hillman, T. C. (2005). A simplified method to estimate energy savings of artificial lighting use from daylighting. *Building and Environment*, *40*(6), 747-754.

Lee, J. H., Yoon, Y., Baik, Y. K., and Kim, S. (2013). Analyses on Human Responses to Illuminance Variations for Resident-friendly Lighting Environment in a Small Office.*Indoor and Built Environment,* 22(3), 535-550.

Lee, J. H., Moon, J. W., & Kim, S. (2014). Analysis of Occupants' Visual Perception to Refine Indoor Lighting Environment for Office Tasks. *Energies*,*7*(7), 4116-4139.

Leech, J. A., Nelson, W. C., Burnett, R. T., Aaron, S., and Raizenne, M. E. (2002). It's about Time: A Comparison of Canadian and American Time-activity Patterns. *Journal of Exposure Analysis and Environmental Epidemiology,* 12(6), 427-432.

Leslie, R. P. (2003). Capturing the daylight dividend in buildings: why and how?. Building and Environment, 38(2), 381-385.

Li, D. H. (2010). A review of daylight illuminance determinations and energy implications. Applied Energy, 87(7), 2109-2118
.

Li, D. H., & Tsang, E. K. (2005). An analysis of measured and simulated daylight illuminance and lighting savings in a daylit corridor. Building and Environment, 40(7), 973-982
.

Li, J., Lam, K., and Qian, G. (2001). Does Culture affect Behavior and Performance of Firms? The Case of Joint Ventures in China.*Journal of International Business Studies,* 115-131.

Likert, Rensis (1932). *A Technique for the Measurement of Attitudes*. Archives of Psychology 140: 1–55.

Linney, A. S. (2008). Maximum Luminances and Luminance Ratios and their Impact on Users' Discomfort Glare Perception and Productivity in Daylit Offices: Testing the Hypothesis: Maximum Luminance and Ratio Recommendations For Visual Comfort Should be Specific to the Luminous Conditions and by Accounting For the Impact of Adaptation, the Recommendations Will be More Accurate.

Lim, Y. W. (2011). *Internal Shading for Efficient Tropical Daylighting in High-Rise Open Plan Office* (Doctoral dissertation, Universiti Teknologi Malaysia, Faculty of Built Environment).

Lim, Y. W., & Mohd Hamdan, A. (2010, November). Daylight and users' response in high rise open plan office: a case study of Malaysia. In 3rd International Graduate Conference on Engineering, Science, and Humanities, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia (pp. 1-10).

Lim, Y. W., Kandar, M. Z., Ahmad, M. H., Ossen, D. R., and Abdullah, A. M. (2012).Building Façade Design for Daylighting Quality in Typical Government Office Building.*Building and Environment,*57, 194-204.

Loutzenhiser, P. G., Manz, H., Felsmann, C., Strachan, P. A., Frank, T., and Maxwell, G. M. (2007).Empirical Validation of Models to Compute Solar Irradiance on Inclined Surfaces for Building Energy Simulation.*Solar Energy,* 81(2), 254-267.

Mahdavi, A., Rao, S. P., & Inangda, N. (2013). Parametric Studies on Window-To-Wall Ratio for Day lighting Optimisation in High-Rise Office Buildings in Kuala Lumpur, Malaysia. *Journal of Design and Built Environment*, *12*(1)

Malaysian Standard 1525: 2014, *Code Of Practise On Energy Efficiency And Use Of Renewable Energy For Non-Residential Buildings, Second Revision*, Department of standard Malaysia.

Manning, P. (1965). Office Design: A Study of Environment.

Mansour, A., Sopian, K., Zain-Ahmed, A., and Reimann, G. (2006).Daylight Distribution of a New Design for Future Commercial Office Building in Malaysia.*ISESCO SciTechnol Vis*, 2(1), 53-6.

Marans, R. W. And Spreckelmeyer, K. F. (1982).Evaluating Open and Conventional Office Design.*Environment and Behavior,* 14(3), 333-351.

Marans, R. W. and Yan, X. Y. (1989). Lighting Quality and Environmental Satisfaction in Open and Enclosed Offices. *Journal of Architectural and Planning Research,* 118-131.

Marquie, J. C., & Foret, J. (1999). Sleep, age, and shiftwork experience.*Journal of sleep research*, *8*(4), 297-304.

Mazloomi, M. (2010). Horizontal distribution of daylight factor with reference to window wall ratio in pendentive dome buildings in tropics, case of Kuala Lumpur. *World Applied Sciences Journal*, *10*(10), 1247-1254.

Mardaljevic, J., Heschong, L., and Lee, E. (2009).Daylight Metrics and Energy Savings.*Lighting Research and Technology,* 41(3), 261-283.

McKennan, G. T. and Parry, C. M. (1984).An Investigation of Task Lighting for Offices.*Lighting Research and Technology,* 16(4), 171-186.

Mileva, Y., Bruhn, A., and Weickert, J. (2007). Illumination-robust Variational Optical Flow with Photometric Invariants. In *Pattern Recognition* (pp. 152-162).Springer Berlin Heidelberg.

Mills, E., and Borg, N. (1999). Trends in Recommended Illuminance Levels: An International Comparison. *Journal of the Illuminating Engineering Society,* 28(1), 155-163.

Mohd Hamdan, A. (1996). *The Influence of Roof Form and Interior Cross Section on Daylighting in the Atrium Spaces in Malaysia.*Doctor of Philosophy, University of Manchester.

Mohd Husini, E., Arabi, F., Ossen Dilshan, R., Kandar, M. Z., and Mat Lajis, N. (2013). Daylight in Office Buildings in Malaysia: A Pilot Study on Occupants' Satisfaction and Luminous Environment. Spaces & Flows: An International Journal of Urban & Extra Urban Studies, 3(1).

Moore, F. (1991). Daylighting: six Aalto libraries. Solar Today;(United States), 6(1).

Moore, T., Carter, D. J., & Slater, A. I. (2002). A field study of occupant controlled lighting in offices. Lighting Research and Technology, 34(3), 191-202.

Mukae, H. and Sato, M. (1992).The Effect of Color Temperature of Lighting Sources on the Autonomic Nervous Functions.*The Annals of Physiological Anthropology*,11(5), 533-538.

Mustonen, T., Törn, L., and Häkkinen, J. (2002, May). P-12: The Effect of Character Size and Contrast on Performance in Pseudo-text and Letter-search Tasks. In *SID Symposium Digest of Technical Papers*, 33(1), 240-243. Blackwell Publishing Ltd.

Nabil, A. and Mardaljevic, J. (2005). Useful Daylight Illuminance: A New Paradigm for Assessing Daylight in Buildings.*Lighting Research and Technology*,37(1), 41-57.

Näsänen, R., Karlsson, J., & Ojanpää, H. (2001). Display quality and the speed of visual letter search. *Displays*, *22*(4), 107-113.

Ne'Eman, E., & Hopkinson, R. G. (1970). Critical minimum acceptable window size: a study of window design and provision of a view. Lighting research and technology, 2(1), 17-27.

Neuman, W.L. 2006. *Social Research Methods*: *Qualitative and Quantitative Approaches.* New York: Pearson Allyn and Bacon.

Newsham, G. R. and Veitch, J. A. (2001).Lighting Quality Recommendations for VDT Offices: A New Method of Derivation.*Lighting Research and Technology*, 33(2), 97-113.

Ng, T. H. R. (2011).*A Multi-criteria Daylighting Performance Assessment Method for Cellular Offices* (Doctoral dissertation, The Hong Kong Polytechnic University).

Nussbaum, E. L., Van Zuylen, J., & Jing, F. (2007). Transmission of light through human skin folds during phototherapy: effects of physical characteristics, irradiation wavelength, and skin-diode coupling.*Physiotherapy Canada*, *59*(3), 194-207.

Ochoa Morales, C. E., Aries, M. B. C., Aarts, M. P. J., Loenen, V. E., & Hensen, J. L. M. (2011). Integrating Visual and Energy Criteria for Optimal Window Design in Temperate Climates.

Ochoa, C. E., Aries, M. B., and Hensen, J. L. (2012). State of the Art in Lighting Simulation for Building Science: A Literature Review. *Journal of Building Performance Simulation*, 5(4), 209-233.

Oldham, G. R., Cummings, A., & Zhou, J. (1995). The spatial configuration of organizations: A review of the literature and some new research directions. Research in personnel and human resource management, 13, 1-37.

Olgyay, V. and Olgyay, A. (1963).*Design with Climate: Bioclimatic Approach to Architectural Regionalism.*

Ossen, D. R., Hamdan Ahmad, M., and Madros, N. H. (2005).Optimum Overhang Geometry for Building Energy Saving in Tropical Climates.*Journal of Asian Architecture and Building Engineering*, 4(2), 563-570.

Pansky, S. H. (1985). *Lighting Standards-tracing the Development of the Lighting Standard from 1939 to the Present.*

Park, C. S. (2003).*Occupant Responsive Optimal Control of Smart Façade Systems*(Doctoral dissertation, Georgia Institute of Technology).

Pellegrino, A. (1999). Assessment of artificial fighting parameters in a visual comfort perspective. Lighting Research and Technology, 31(3), 107-115.

Peretti, P. O. (1977). Effects of controlled illumination levels upon verbal response latency in a color-word interference task. The Journal of psychology, 95(2), 189-193.

Poirazis, H. (2005). *Single Skin Glazed Office Buildings-Energy Use and Indoor Climate Simulations.*Report EBD-T--05/4.

Rahman, A. M. A., Samad, M. H. A., Bahauddin, A., and Ismail, M. R. (2009). *Towards A Low-Energy Building for Tropical Malaysia.* Malaysia: Universiti Sains Malaysia, 2009.

Rahmani, B., Kandar, M. Z., and Rahmani, P. (2012). How Double Skin Façade's Air-Gap Sizes Effect on Lowering Solar Heat Gain in Tropical Climate?.*World Applied Sciences Journal*, 18(6), 774-778.

Rashid, M. and Zimring, C. (2008).A Review of the Empirical Literature on the Relationships between Indoor Environment and Stress in Health Care and Office Settings Problems and Prospects of Sharing Evidence.*Environment and Behavior*,40(2), 151-190.

Rea, M. S. (2012). The Trotter-Paterson Lecture 2012: What Ever Happened to Visual Performance?.*Lighting Research and Technology*.

Rea, M. S., Ouellette, M. J., and Kennedy, M. E. (1985).Lighting and Task Parameters Affecting Posture, Performance and Subjective Ratings.*Journal of the Illuminating Engineering Society*,15(1), 231-238.

Robbins, C. L., & Hunter, K. C. (1986). Daylighting data compendium.Passive Sol. J.;(United States), 3(2).

Robinson, J., & Fielder, A. R. (1992). Light and the immature visual system.*Eye*, *6*(2), 166-172.

Roufs, J. A. and Boschman, M. C. (1997). Text Quality Metrics for Visual Display Units: I. Methodological Aspects. *Displays*, 18(1), 37-43.

S. Veeramas and C. Chuntamara, "The evaluation of lighting energy saving in open-plan office building with Daylight-linked system in Bangkok: an experimental study," in 2nd Chulalongkorn University Architectural Design Symposium (CU:ADS, 2011), pp. 1-19.

Saari, S. (2006, August). Productivity. theory and measurement in business. In Espoo, Finland: European Productivity Conference.

Sadin, M. F. M. A., Ibrahim, N. L. N., Sopian, K., and Salleh, E. I. (2014, July).The Effects of Different Depth of Floor towards Internal Daylighting and Rules of Thumb for Office Room.In *Advanced Materials Research* (935, 92-96).

Sa'id, E. N. A., Dodo, Y. A., Khandar, M. Z., and Ahmad, M. H. (2014).Correlating Visual Comfort with Green Building Index in an Open Plan Office Space.*Life Science Journal*, 11(10).

Sakaran, U. (2003). Research Method for Business A skillJBuilding Approach, fourht Internet Advertising. Interactive Marketing, 13(3), 34.

Salkind, N. J. (2000). Statistics for people who hate statistics.

Sarey Khanie, M., Stoll, J., Mende, S., Wienold, J., Einhäuser, W., & Andersen, M. (2013). Uncovering relationships between view direction patterns and glare perception in a daylit workspace. In LUXEUROPA (No. EPFL-CONF-188436).

Schakib-Ekbatan, K., Wagner, A., & Lussac, C. (2010, April). Occupant satisfaction as an indicator for the socio-cultural dimension of sustainable office buildingsdevelopment of an overall building index. In Proceedings of Conference: Adapting to Change: New Thinking on Comfort.

Schiler, M. E., & Japee, S. A. (1997). Interior Illuminance, Daylight Controls and Occupant Response. Vital Signs Curriculum Materials Project.

Schiler, M. E., & Japee, S. A. (2001). VITAL SIGNS: Interior illuminance, daylight controls and occupant response. Vital Signs.[Online]. Available: http://www. arch. ced. berkeley. edu/vitalsigns/, res/downloads/rp/daylight/day1_sml. pdf.

Schweitzer, F. and Farmer, J. D. (2007). Brownian Agents and Active Particles: Collective Dynamics in the Natural and Social Sciences. *Springer Science & Business Media.*

Shamsuddin, S. (1997). Identity of place: a case study of Kuantan town centre, Malaysia (Doctoral dissertation, University of Nottingham).

Shamsuddin, S. (2011). *Townscape Revisited: Unravelling the character of the historic townscape in Malaysia*. Penerbit UTM Press.

Shao, L., Elmualim, A. A., & Yohannes, I. (1998). Mirror lightpipes: daylighting performance in real buildings. Lighting Research and Technology,30(1), 37-44.

Shikakura, T., Morikawa, H., and Nakamura, Y. (2003).Perception of Lighting Fluctuation in Office Lighting Environment.*Journal of Light & Visual Environment*, 27(2), 75-82

.

Slater, A. I., Perry, M. J., & Carter, D. J. (1993). Illuminance differences between desks: Limits of acceptability. Lighting Research and Technology,25(2), 91-103.

Stokols, D. (1972). On the Distinction between Density and Crowding: Some Implications for Future Research. *Psychological Review,* 79(3), 275.

Stone, P. T., Clarke, A. M., and Slater, A. I. (1980).The Effect of Task Contrast on Visual Performance and Visual Fatigue at a Constant Illuminance.*Lighting Research and Technology*, 12(3), 144-159.

Störring, M., Andersen, H. J., and Granum, E. (2001). Physics-based Modelling of Human Skin Colour under Mixed Illuminants. *Robotics and Autonomous Systems,* 35(3), 131-142.

Szokolay, S. V. (1980). *Environmental Science Handbook for Architects and Builders.*Construction Press.

Tague, N. R. (2004). Seven basic quality tools. The Quality Toolbox. Milwaukee, Wisconsin: American Society for Quality, 15.

Tang, C. K., & Chin, N. (2013). Development Of Jkr/Bseep Technical Passive Design Guidelines For Malaysian Building Industry.

Taylor, A. E. (2000). *Illumination Fundamentals.*Lighting Research Center, Rensselaer Polytechnic Institute.

Taylor, L. H., Sucov, E. W., and Shaffer, D. H. (1975).Office Lighting and Performance.*Lighting Design and Application,* 5(5), 30-36.

Tragenza, P. and Wilson, M. (2011). *Daylighting Architecture and Lighting Design,* Routledge Taylor & Francis Group.

Tsang, K. W. (2010). An analysis of daylighting performances in office buildings and applications of light-guide system coupled with redirecting device.

Ulrich, R. S., Zimring, C., Quan, X., & Joseph, A. (2004). The role of the physical environment in the hospital of the 21st century. Report sponsored by the Robert Wood Johnson Foundation and the Center for Health Design.

Ünver, R., Öztürk, L., Adıgüzel, Ş., & Çelik, Ö. (2003). Effect of the facade alternatives on the daylight illuminance in offices. Energy and buildings,35(8), 737-746.

Van Den Wymelenberg, K. G. (2012). *Evaluating Human Visual Preference and Performance in an Office Environment Using Luminance-based Metrics*.University of Washington.

Veal, A. J. (2006).*Research Methods for Leisure and Tourism: A Practical Guide.*Pearson Education.

Veitch, J. A. and Newsham, G. R. (1998).Lighting Quality and Energy-efficiency Effects on Task Performance, Mood, Health, Satisfaction, and Comfort. *Journal of the Illuminating Engineering Society*, 27(1), 107-129.

Veitch, J. A., & Newsham, G. R. (1996). Determinants of lighting quality II: Research and recommendations.

Veitch, J. A., Charles, K. E., Farley, K. M., and Newsham, G. R. (2007). A Model of Satisfaction with Open-plan Office Conditions: COPE Field Findings. *Journal of Environmental Psychology,* 27(3), 177-189.

Veitch, J. A., Newsham, G. R., Boyce, P. R., & Jones, C. C. (2008). Lighting appraisal, well-being and performance in open-plan offices: A linked mechanisms approach. Lighting Research and Technology, 40(2), 133-151.

Veitch, J. A., Newsham, G. R., Boyce, P. R., Jones, C. C., Heerwagen, J., Myer, M., and Hunter, C. M. (2006). Lighting Quality and Office Work: Two Field Simulation Experiments.*Lighting Research and Technology,*38(3), 191-223

Velds, M. and Christoffersen, J. (2001).*Monitoring Procedures for the Assessment of Daylighting Performance of Buildings.* Daylighting in Buildings: A Source Book on Daylighting Systems and Components.

Vine, E. L., Sathaye, J. A., & LeFranc, M. N. (1997). The monitoring, evaluation, reporting, and verification of climate change mitigation projects: discussion of issues and methodologies and review of existing protocols and guidelines. Energy Analysis Program, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory.

W Creswell, J. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* SAGE Publications, Incorporated.

Wang, N. (2009). *In Broad Daylight: An Investigation of the Multiple Environmental Factors Influencing Mood, Preference, and Performance in a Sunlit Workplace.*ProQuest.

Wienold, J., & Christoffersen, J. (2005). Towards a new daylight glare rating. Lux Europa, Berlin, 157-161.

Wilson, D., & Haglund, B. (2003, September). Workplace performance monitoring: analysing the combination of physiological and environmental sensory inputs. In Eurowearable, 2003. IEE (pp. 17-22). IET.

Wurtman, R. J. (1975). The Effects of Light on the Human Body.Scientific American,233(1), 68-77

Yeang, K. (1998). Lighting research in daylighting. In Proceedings in daylighting conference (pp. 11-13).

Yearout, R. and Konz, S. (1989). Visual Display Unit Workstation Lighting.*International Journal of Industrial Ergonomics*, 3(3), 265-273.

Yun, G. Y., Shin, J. Y., and Kim, J. T. (2010).Influence of Window Views on the Subjective Evaluation of Discomfort Glare. *Indoor and Built Environment*.

Zain Ahmed, A. (1999). A study on the potential of solar irradiation as a source of natural lighting in buildings and its implication on energy-efficiency

Zain-Ahmed, A. Z. N. I. (2000). Daylighting and shading for thermal comfort in Malaysian buildings. Department of Engineering, University of Hertfordshire.

Zain-Ahmed, A., Rahman, S., and Sharani, S. (2005, September). Natural Cooling and Ventilation of Contemporary Residential Homes in Malaysia: Impact on Indoor Thermal Comfort. In *The 2005 World Sustainable Building Conference, Tokyo, 27-29 September 2005 (SB05Tokyo)* (pp. 1597-1604).

Zain-Ahmed, A., Sopian, K., Abidin, Z. Z., and Othman, M. Y. (2008).Renewable Energy, Buildings and the Fuel Crisis.In *Proceedings of International Conference on Construction and Building Technology* (pp. 13-24).

Zain-Ahmed, A., Sopian, K., Zainol Abidin, Z., and Othman, M. Y. H. (2002).The Availability of Daylight from Tropical Skies-A Case Study of Malaysia.*Renewable Energy*, 25(1), 21-30.

Zhou, X., Yan, D., Ren, X., & Hong, T. (2012). Data analysis and modeling of lighting energy use in large office buildings. submitted to Building Research and Information.