INTERIOR RETROFIT FOR EFFICIENT TROPICAL DAYLIGHTING IN HOME OFFICE WORKSPACES

SEYED MOHAMMAD MOUSAVI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Architecture)

Faculty of Built Environment
Universiti Teknologi Malaysia

NOVEMBER 2017

To the World without Border…

ACKNOWLEDGEMENT

My deepest gratitude goes to my main thesis supervisor Assoc. Prof. Dr. Tareef Hayat Khan and co-supervisor Dr. Lim Yaik Wah for their valuable advices, guidance, resources, encouragement, motivations, and friendship during the study. Without their continued support and interest, this thesis would not have been the same as presented here. I would also like to specially thank Assoc. Prof. Dr. Eka Sediadi and Mdm. Halimah Yahya for their advices, resources, assistances and friendships throughout the study.

I wish to sincerely appreciate the Malaysian Government and Ministry of Higher Education (MOHE) for the reward of Malaysian International Scholarship (MIS) and financial support during my Ph.D journey. I would also like to express my gratitude to the Department of Architecture, Faculty of Built Environment, Universiti Teknologi Malaysia for providing the resources, facilities and instruments needed for the study. My sincere gratitude also goes to those who have provided assistance in many ways at various occasions, especially Ms. Somaieh Asadi Harris my best friend in Malaysia, and also Rashidah binti Jimi Sham, Pearly Lim, Meena Gogila, Fifa, and Nabil.

My heartiest and utmost gratitude goes to my dear mother Sareh Parvin and the siblings Narges, Gholamhossein, Fatemeh, Hamzeh, and especially my brother Hossein Mousavi, for their patience, sacrifices, understanding, support and prayers during my study. I also would like to dedicate the thesis to the memory of my father Haj Morteza Mousavi and my uncle Haj Mahmoud Parvin, too unfortunate they cannot see me graduated. Finally, I thank God for giving me patience, courage, strength, mercy, guidance and blessings to face all challenges in life and to complete this thesis successfully.

ABSTRACT

Home office workspaces have substantially increased all over the world and Malaysia is not an exception. However, existing residential buildings (ERBs) in Malaysia have been designed mostly for the purpose of accommodation, but not for office working, as far as daylighting is concerned. This situation is even more critical here as it is a tropical country with intense solar radiation and excessive sky luminance. This causes discomfort glare in many typical ERBs, which are mostly without external shadings. Due to limited flexibility for modification of the existing residential units by residents, interior retrofit can play a significant role in improving the visual environment. Not much research has been done focusing on interior retrofit in ERBs regarding visual comfort. This thesis aims to optimize tropical daylighting efficiency through interior retrofit in home office rooms (HOR) located in the ERBs in Malaysia. A questionnaire survey was conducted to find out the current scenario of HORs in terms of interior design profile in 11 ERBs in Johor Bahru. Based on the findings, a base model was derived to simulate daylight using the Radiance program in the Integrated Environmental Solution-Virtual Environment (IES-VE) software. Prior to the simulation experiments, a field measurement in a typical room was conducted to validate the software under the tropical sky. Then different design parameters including furniture layout, window glazing film, surface reflectance, internal light shelf and venetian blind were experimented through daylight simulation. Estimated work plane illuminance (EWPI) and standard daylight zone (SDZ) were evaluated for quantitative performance, while work plane illuminance uniformity ratio (IUR), Guth visual comfort probability (GVCP) and CIE glare index (CGI) were considered for qualitative performance. Findings showed that partial blind at upper window was the optimum design model for efficient daylighting in a room with indirect or reflected sunlight for all cardinal orientations. However, integration of a light shelf with partial blind at lower window was the best in a room with direct sunlight. In conclusion, this study provides evidence that a dynamic integrated model of light shelf and partial blind can be an effective alternative to the conventional interior shading devices. The finding of the study has shown how to improve the visual environments in home office workspaces in ERBs by changing the pattern of internal shading device in tropical areas.

ABSTRAK

Ruang kerja kediaman pejabat telah meningkat dengan ketara di seluruh dunia termasuk Malaysia. Bagaimanapun, bangunan kediaman yang sedia ada (ERBs) telah direka bentuk kebanyakkan untuk tujuan penginapan yang tidak berfungsi sebagai pejabat sebagaimana pencahayaan dititik beratkan. Situasi ini lebih kritikal di sini kerana merupakan negara tropika dengan sinaran suria yang sengit dan pencahayaan langit yang berlebihan. Ini menyebabkan ketidakselesaan silau dalam banyak ERBs biasa, yang kebanyakannya tanpa peneduhan luar. Oleh kerana kefleksibelan yang terhad untuk pengubahsuaian unit kediaman sedia ada oleh penduduk, retrofit dalaman boleh memainkan peranan penting dalam meningkatkan persekitaran visual. Tidak banyak penyelidikan yang telah dijalankan untuk memberi tumpuan kepada perubahan retrofit di dalam bangunan untuk memberikan keselesaan visual. Tesis ini bertujuan untuk mengoptimumkan kecekapan pencahayaan tropika melalui retrofit dalaman di bilik pejabat kediaman (HOR) yang terletak di ERB di Malaysia. Tinjauan soal selidik telah dijalankan untuk mengetahui senario HOR semasa dari segi profil reka bentuk dalaman di 11 ERB di Johor Bahru. Berdasarkan dapatan kajian, satu model asas telah diperolehi untuk mensimulasikan siang menggunakan program *Radiance* dalam perisian *Integrated Environmental Solution-Virtual Environment* (IES-VE). Sebelum eksperimen simulasi, ukuran lapangan di bilik khas telah dijalankan untuk mengesahkan perisian yang di bawah langit tropika. Kemudian parameter reka bentuk yang berbeza termasuk tata letak perabot, filem kaca tingkap, refleksi permukaan, rak cahaya dalaman dan sejenis bidai telah diuji melalui simulasi siang hari. Anggaran pencahayaan permukaan kerja (EWPI) dan standard siang zon (SDZ) telah dinilai untuk prestasi kuantitatif, sementara nisbah permukaan kerja pencahayaan keseragaman (IUR), Guth kebarangkalian visual keselesaan (GVCP) dan CIE indeks silau (CGI) telah dipertimbangkan untuk prestasi kualitatif. Penemuan menunjukkan bahawa sejenis bidai separa pada tetingkap atas adalah model reka bentuk optimum untuk pencahayaan yang efisien di dalam bilik dengan cahaya matahari yang tidak langsung atau pantulan cahaya matahari untuk semua orientasi kardinal. Walau bagaimanapun, penyepaduan rak ringan dengan sejenis bidai separa pada tingkap yang lebih rendah adalah yang terbaik di dalam bilik dengan cahaya matahari langsung. Kesimpulannya, kajian ini membuktikan bahawa satu model bersepadu dinamik rak ringan dan sejenis bidai separa boleh menjadi alternatif yang berkesan untuk peranti peneduhan dalaman konvensional. Dapatan kajian ini menunjukkan bagaimana untuk meningkatkan persekitaran visual di ruang kerja pejabat kediaman di ERBs dengan mengubah corak peranti teduhan dalaman di kawasan tropika.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3D	-	Three-dimensional
BLAST	-	Building Loads Analysis and System Thermodynamics
BGI	-	BRS (Building Research Station) Glare Index
BZ	-	Bright Zone (> 500 lux)
CIBSE	-	Chartered Institution of Building Services Engineers
CIE	-	International Commission on Illumination
CGI	-	CIE Glare Index
DF	-	Daylight Factor
DGI	-	Daylight Glare Index
DOE	-	Department of Energy, United States
DR	-	Daylight Ratio
DSL	-	Direct Sunlight
DZ	-	Dim Zone (< 100 lux)
EDB	-	Economic and Development Board
EPC	-	Energy Performance Certificates
ERB	-	Existing Residential Building
e-HBB	-	electronic Home-Based Business
EWPI	-	Estimated Work Plane Illuminance
FAB	-	Faculty of Built Environment
GBI	-	Green Building Index
GDGR	-	Guth Disability Glare Rating
GVCP	-	Guth Visual Comfort Probability
HB	-	High-rise Building
HBB	-	Home-based Business
HOR	-	Home Office Room
HVAC	-	Heating, Ventilation & Air-Conditioning

IEQ	-	Indoor Environmental Quality
IES <VE>	-	Integrated Environment Solution <Virtual Environment >
IESNA	-	Illuminating Engineering Society
IUR	-	Illuminance Uniformity Ratio
IT	-	Information Technology
JB	-	Johor Bahru
LEED	-	Leadership in Energy and Environmental Design
LSR	-	Light Shelf Depth Ratio
MS	-	Malaysian Standard
MUFL	-	Mostly-Used-Furniture-Layout
NGO	-	Non-Governmental Association
NI	-	Nebulosity Index
RD	-	Relative Difference
RGB	-	Red/Green/Blue
RNC	-	Residential New Construction
SAZ	-	Suitable Area Zone
SDZ	-	Standard Daylight Zone (100 – 500 lux)
SHGC	-	Solar Heat Gain Coefficient
SOHO	-	Small Office Home Office
SR	-	Surface Reflectance
THO	-	Technopreneur Home Office Scheme
UBBL	-	Uniform Building By Laws
UGR	-	Unified Glare Rating
UTM	-	Universiti Teknologi Malaysia
VDT	-	Video Display Terminal
VELUX DV	-	VELUX Daylight Visualizer
VLT	-	Visible Light Transmittance
VT	-	Visible Transmittance
WFR	-	Window-to-Floor Ratio
WPI	-	Work Plane Illuminance
WWR	-	Window-to-Wall Ratio

LIST OF SYMBOLS

B	-	Blind
Ds	-	Depth of Shelf
E	-	External Illuminance
E_1	-	Incident Light
E_2	-	Reflected Light
E_{min}	-	Minimum Work plane Illuminance
E_{avg}	-	Average Work plane Illuminance
E_M	-	Measured Daylight Indicator
E_S	-	Simulated Daylight Indicator
Hc	-	Clerestory Height
Ho	-	Height from sill
hr	-	Hour
Hs	-	Height of sill
klx	-	Kilo Lux (1000 Lux)
L	-	Light shelf
LB	-	Integrated Light shelf and Blind
M	-	Measurement
P	-	Measurement Point
Rgh	-	Roughness
S	-	Simulation
Spec	-	Specularity

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.0 Introduction

The prospect of working from home has gained credibility over the years. Nowadays, due to the rapid development of communication technology, including computer capabilities, Internet services, and digital drawing, many people moved their own offices into their residential units (Whitehead, 2009). Home office workspace is a space inside a house that can be used for desk-related tasks (computer work, paperwork, study, etc.). This workspace can be exclusively devoted an entire room or may be occupied other spaces in a house (Kanarek, 2001). Home has many benefits for home office workers, such as saving time and money, decreasing expenses of daily commuting and furniture, increasing productivity, flexibility, and independence during working, reducing vehicular and human traffic, etc. (Bateman, 2000; Kanarek, 2001; Sulaiman and Shariff, 2012; Sulaiman et al., 2009). In this thesis, home office worker referred to a person who performs at least a type of desk-related tasks at his/her home office workspace during daytime.

There can be various terms used for home office tasks, such as home-based business, while each one may be formally or informally operated, all run from the owner's home office. Working from home has remarkably increased worldwide and is taken much more serious in recent years. According to different conservative estimations, one in ten households in the UK, Australia, and the USA operates a home business (Dwelly et al., 2006; Pratt, 2000; Walker et al., 2008; Walker and Webster, 2004). In Singapore, the government took some measure, such as Technopreneur Home Office Scheme (THO), to encourage entrepreneurs to use their dwelling as home offices (Rahim, 2010). Home office is also a new focus initiative of the Malaysian government to persuade people working from their homes. Accordingly, business associations, non-governmental associations (NGOs), private agencies such as Johor Corporation are also playing a major role in developing the concept of home office (Rahim, 2010; Sulaiman, 2011).

1.1 Background of Study

Due to increase of computer services and video display terminals (VDT), visual comfort has become a significant issue for the design of office workplaces (Guzowski, 2000). The quality of daylight is an essential reason to employ daylighting in order to design home office workplaces. Kanarek (2001) remarked that natural lighting is a vital part of any home office workspace since poor lighting can cause eyestrain, fatigue and irritability. The significance of daylighting is also highlighted for residential constructions in the Green Building Index (GBI, 2013). In this case, daylighting as well as air quality, has been devoted the highest points in the category of indoor environmental quality (IEQ) for residential sectors. Thus, efficient daylighting design needed to be investigated in order to improve visual comfort for home office workers in residential constructions. An esteemed American architect, Louis Kahn defined:

> *"…Natural light is the only light that makes architecture, architecture."*
>
> (Louis I. Kahn, 1966)

The visual world can be experienced by human being through the presence of light. Previous research showed that the development of human eye is indeed based on daylight (Gugliermetti and Bisegna, 2006; Wang, 2009). Daylight as the natural source of light is the combination of sky light and sunlight. It is the visible electromagnetic radiation that allows human to perceive luminous environment subjectively (Ander, 2003). Daylighting as a passive architectural design strategy has many benefits, such as saving energy by reducing the dependency on electric lighting (Ander, 2003; Robbins, 1986). Daylighting does not only contribute towards designing more energy-conscious buildings, but it can also influence human physiology and psychology. It provides healthy indoor environments, higher productivity and lower absenteeism for users (Athienitis and Tzempelikos, 2002; Bluyssen, 2010; Konis, 2013). Daylight as an aesthetical design element can also create sense of spaciousness to a building (Lechner, 2014). Daylight tends to produce less heat for the same amount of light compared with electric lighting because of its higher quality of luminous efficacy (Lam, 2000; Lam and Li, 1998). Thus, daylighting is a significant design strategy for many architects.

While daylighting is an effective way to save energy, poor daylighting installations may cause unwanted solar heat gain and glare problems. This is even more critical in tropical climate with extremely high daylight availability that the outdoor illuminance can be as high as 140,000 lx (Zain-Ahmed et al., 2002a). Intense sunshine, dynamic cloud formation within a few minutes, and excessive outdoor illuminance of tropical sky can create unpredictable indoor daylight availability and visual discomfort for occupants (Lim et al., 2008a; Mohd Hamdan, 1996; Tzempelikos, 2005). Therefore, tropical daylight needed to be utilised in order to avoid intense solar heat gain, non-uniform daylight distribution and glare problems in buildings. Zain-Ahmed et al. (2002b) indicates that at least 10 % energy savings can be achieved by using daylighting strategies alone.

In tropical climate, big windows that directly exposed to sky can cause thermal discomfort and glare problem. On the other hand, small windows or extreme use of shading devices can ignore daylight distribution that resulted in gloomy indoor environment. This increases dependency on electric lighting for illuminating interior spaces in buildings. Previous daylighting research in tropical regions focused on preparing sufficient amount of daylight (Chaiwiwatworakul et al., 2009; Shahriar and Mohit, 2007; Sharifah and Sia, 2004). However, in order to have energy efficient and architectural designs, it is essential to keep the balance between the daylight harvesting and the prevention of solar heat gains in buildings (Lim, 2011). In tropical climates with the high outdoor illuminance, daylight efficiency is not just providing high daylight quantity, because it cannot promise acceptable daylight quality for visual comfort and may cause glare problem (Lim and Mohd Hamdan, 2010). Consequently, both quantitative and qualitative performances of tropical daylighting needed to be controlled in order to increase daylighting efficiency in buildings (Lim et al., 2009; Tzempelikos and Athienitis, 2007).

1.2 Problem Statement

The fast development of IT and computer services all over the world, resulted in increase of home office workspaces (Kanarek, 2001). This made a number of office workers to transfer their workplaces from office buildings to their homes. Because of the growing trend of home office, a residential unit should not be used only as a bedroom, but also a place for home office workers to do their desk-related tasks. However, existing residential buildings were not designed for office working but only planned for accommodation. In addition, existing residential buildings do not have potentials to cover various human’s need, especially visual comfort that is significant to be provided for home office workers in their residential units. Kanarek (2001) claimed that natural lighting is a vital part of any home office workspace since poor lighting causes eyestrain, fatigue and irritability. Thus, efficient daylighting strategies needed to be investigated in residential buildings in order to provide visual comfort for home office workers.

Excessive global illuminance, high sky luminance, and dynamic cloud formation of tropical skies resulted in non-uniform distribution of daylight in buildings. Malaysia is located in equatorial region; hot, humid and cloudy with dull grey sky condition that causes heat and glare problems for occupants (Sharifah and Sia, 2004; Zain-Ahmed et al., 2002a). However, high availability of tropical daylight is not optimised in the existing buildings in Malaysia. This is even more serious in the buildings without external shadings or well-designed shading devices on their facades that causes direct penetration of sunlight into such buildings. However, the use of electric lighting and air conditioner are seen as a solution to overcome heat gain from daylighting (Jamaludin et al., 2013). Although indoor daylight quantity is higher than the required level in tropical regions, daylighting design is not effective in buildings because of poor indoor daylight quality. This condition is more critical for home office workspaces where visual comfort needs to be provided for home office workers.

Benefits of daylighting increased attention of architects and designers to consider daylighting for designing new buildings (Labib, 2013). In this case, review of previous studies revealed that researchers mostly investigated daylighting strategies that were only applicable for new building design such as building orientation, building shape, window size, external solar controls, etc. However, these strategies may not be economical or feasible to be retrofitted by users after occupancy in their residences (Cheng et al., 2007; Mayhoub and Carter, 2011). Therefore, they are not appropriate to be used in existing buildings. As many existing buildings were not designed for daylighting, it is essential to explore the possibility of improving daylighting design in existing buildings by developing guidelines to transform them into energy-efficient and productive environments. While living is the only function in the existing residential buildings, the issue is that how to change the typical indoor environment in order to support the home office needs. When the building already exists, a retrofit is the only approach to increase daylight efficiency through building design. It is because the existing buildings are more constrained in comparison with new buildings in applying the energy-efficient design strategies (Lim et al., 2012). Maier (2016) indicates that the successful deployment of daylighting retrofitting strategies in residential buildings will reduce energy use, provide attractive dwellings and financial gains and significantly impact climate change.

Huff and Huff (2011) claimed that internal light shelf as a daylighting strategy can be used for both new constructions and retrofit applications. While external light shelf is more efficient to reflect daylight deeper into room, the application of internal light shelf is simpler and more flexible to be installed (Jamaludin, 2014). Venetian blind as an adjustable internal shading device has potential to prevent direct sunlight, control daylight and avoid glare problems so it plays a major role to prevent visual discomfort inside buildings (Koo et al., 2010; Sanati and Utzinger, 2013). Jamaludin et al. (2015) claimed that tinted window glass and glare protection should widely be implemented either for retrofit or as new designs of any residential building in tropical climate. A study by Konis (2013) defined the solar control film as an interior retrofit to evaluate daylighting effectiveness and occupant visual comfort in buildings. One of the considerations for daylighting systems in retrofit project is room surfaces (Brain, 2015). Jughans (2008) stated that the surface of room contributes to the level of reflectance in controlling glare and light distribution in the room. Interior layout is one of the other considerations for daylighting systems in retrofit project. Furniture and partitions impact the flow of light in a space. During a retrofit, rearranging the interior layout can create a more efficient daylighting design (Brain, 2015).

As it was mentioned in the above paragraph, retrofitting interior spaces for daylighting can be done through internal shading devices, including venation blind and light shelf, window glazing films, surface reflectance, and furniture layout. These daylighting strategies have potentials to be modified by end users and the feasible retrofits can be done with less cost effects. Thus, these parameters were investigated in this thesis to retrofit interior spaces of existing residential buildings for tropical daylighting.

1.3 Research Gap

There are many daylighting studies for Malaysia's tropical climate that were mostly investigated in office buildings. Jamaludin et al. (2015) indicated that there is lack of studies performed at the residential buildings especially in the tropical climate region, as compared to the office or commercial buildings in the temperate climate region. However, due to increase of home office concept, efficient daylighting strategies need to be also investigated in residential buildings in order to provide visual comfort for home office workers. In addition, most of previous tropical daylighting research focused on daylight quantity so they measured the quantitative performance indicators of daylight in buildings (Athienitis and

Tzempelikos, 2002; Cheng et al., 2007; Chou, 2004; Ghasemi, 2015; Roshan, 2014; Sharifah and Sia, 2004; Zain-Ahmed et al., 2002b).

Table 1.1 Summary of previous daylighting research in tropical climate

Tropical Daylighting Research	Design Variable																			Methodology					
	Building Orientation	Building Form	Atrium Design	Horizontal Shading Device	Self-Shading Strategy	External Light Shelf	Internal Light Shelf	Venetian Blind	Window Glazing	Window Glazing Film	Electric Light	Light Pipe	Furniture	Window Design	Shading Depth	Shading Angle	Reflectance	Room Depth	Ceiling	Questionnaire	Calculation Method	Field Measurement	Test Room	Physical Scaled Model	Computer Simulation
Zain-Ahmed et al. (2002b)														■											■
Sharifah and Sia (2004)	■	■		■																		■			■
Fuziah et al. (2004)			■			■			■					■			■							■	■
Ossen (2005)	■			■											■										■
Mansour et al. (2006)						■		■											■				■		
Ibrahim et al. (2006)								■	■					■											■
Shahriar and Mohit (2007)											■										■				
Chia (2008)	■	■			■																				■
Lim et al. (2009)				■										■				■							■
Linhart et al. (2010)												■				■	■								■
Wang et al. (2010)												■										■			
Lim (2011)							■	■							■	■	■			■		■		■	■
Husin and Harith (2012)	■								■					■								■			
Mahdavi et al. (2013b)														■											■
Nikpour et al. (2013)					■												■					■			■
Mahdavi et al. (2013a)	■								■																■
Roshan (2014)												■												■	■
Ghasemi (2015)			■																					■	■
Lim and Heng (2016)							■																	■	■
Present Study (2017)							■	■		■			■				■			■		■			■

However, study on qualitative performance indicators of daylight, such as glare index, is also necessary to provide visual comfort and efficient tropical daylighting in buildings. Review of previous daylighting research in tropical climates (Table 1.1) shows that researchers usually evaluated daylighting strategies which were only applicable for designing new buildings. Lack of research on tropical daylighting strategies for existing buildings compared with new buildings is obvious. Accordingly, this thesis focused on some passive daylighting strategies that can be useful to retrofit interior spaces within the existing residential buildings (ERB).

Due to lack of long-term daylight data and research in Malaysia, most of researchers have used computer simulation tools to assess daylighting performance under tropical skies. Although computer simulation tools are very helpful techniques for daylighting research, most of these simulation tools use CIE sky models (Labayrade et al., 2009; Lim et al., 2013; Reinhart and Breton, 2009). However, CIE skies are very different from tropical skies in which the outdoor illuminance value is extremely high and the cloud's formation is not uniform. Accordingly, the usage of each daylighting simulation tool needs to be validated under the tropical skies. In this thesis, real field measurement of daylight under the Malaysia's tropical sky was conducted to validate the results of simulation tool for tropical climates.

1.4 Research Aim

The aim of this research is to optimise tropical daylighting efficiency through interior retrofit for home office workspaces within the existing residential buildings in Malaysia.

1.5 Research Questions

The following questions are addressed in this research:

1. What is the current scenario of the typical home office rooms (HOR) in the existing residential buildings in Malaysia?

2. How does furniture layout influence daylighting performances in tropical regions?

3. How do internal shading devices, window glazing film, and surface reflectance influence daylighting performances in tropical regions?

4. How to optimise quantitative and qualitative performances of daylight in a typical HOR under the tropical sky?

1.6 Research Objectives

The following objectives support the main aim of this thesis:

1. To investigate the current scenario of (HOR) in the ERBs in terms of interior design profile.

2. To evaluate the impact of furniture layout in HORs on the quantitative and qualitative performances of tropical daylight.

3. To assess the impact of internal shading devices, window glazing film, and surface reflectance in HORs on the quantitative and qualitative performances of tropical daylight.

4. To propose an effective daylighting design model to be used in HORs in tropical regions.

1.7 Research Methodology

Figure 1.1 depicts the methodology flowchart that was used in this thesis. A general observation and the questionnaire survey were conducted in 11 conventional residential buildings in Johor Bahru to record the required data for daylighting analyses. Then, the real field measurement of daylight was done to validate the computer simulation (Radiance-IES) under the Malaysia's tropical sky. Subsequently, a huge number of simulation experiments were run to analyse the impact of various design parameters on the quantitative and qualitative performances of daylight in a typical HOR. Finally, based on the daylighting results for all orientations, an interior retrofitted model was proposed for efficient tropical daylighting in the existing residential buildings.

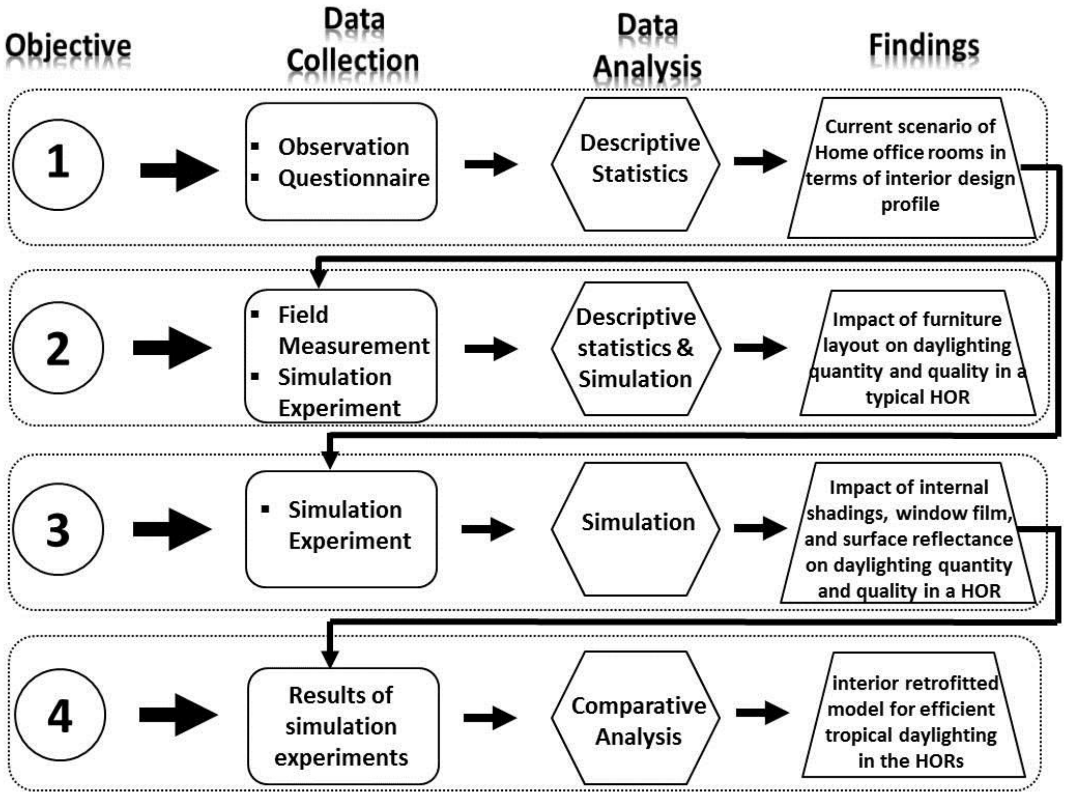

Figure 1.1 Flowchart of the research methodology

1.8 Research Hypothesis

The hypothesis of this research is that interior retrofit can increase tropical daylighting efficiency for home office workspaces through improving the qualitative and quantitative performances of daylight by:

1) Reducing the extremely high daylight level in the interior spaces under the Malaysia's tropical sky.
2) Increasing the effective daylight zone within the recommended range of work plane illuminance (100 – 500 lx).
3) Distributing daylight uniformly throughout the interior spaces.
4) Reducing glare problems to improve visual comfort.

Thus, efficient interior retrofit for tropical daylighting can provide visual comfort for home office workers and also save electric lighting in the existing residential buildings.

1.9 Scope and Limitations

This thesis targets the daylighting efficiency for visual comfort. While daylight is usually related with direct sunlight that causes undesirable solar heat gain, so energy consumption and thermal comfort are not significant issues in this research. However, the justification is that providing sufficient indoor daylight can decrease the dependency on electric light which helps to save electricity.

Due to rapid development of residential buildings in major urban areas in Malaysia, this type of housing, which consumes high electricity for the buildings' lighting and cooling, was chosen in the thesis. Daylight penetration in the ERBs is only dependent on the perimeter windows because of their multilevel design. Therefore, the use of daylight in the ERBs is only limited to their perimeter façades. The facades of ERBs in Malaysia are directly faced to the sun and sky which resulted in big glare problems. Thus, the term ‘ERB’ in this thesis referred to an unobstructed building, irrespective of its height, which is not blocked by adjacent buildings and vegetation and has direct access to sunlight. While there are different rooms and spaces in the ERBs, a typical HOR was considered in this study that included desk-related tasks. However, this room may be used for other household activities.

This thesis focused on interior retrofit through various design parameters to improve tropical daylight efficiency and visual comfort in the typical HORs within the ERBs. Usage of daylight is very limited and needs to be improved in such buildings. There can be many daylight-efficient solutions for new building design that may not be applicable for the existing buildings. However, there are a great number of existing buildings that were built without any daylighting considerations. Hence, the existing buildings need further investigations to improve indoor daylighting efficiency. The computer simulation tool (IES-VE) was used to assess quantitative and qualitative performances of daylight in a typical HOR with different design parameters. The limitations and assumptions of the simulation experiments are discussed in chapter 3.3.6 and chapter 3.4.1.6.

The scope of this study is limited to tropical daylighting. Accordingly, the sky condition which used in the thesis is for hot-humid tropical climates. Since the intermediate sky is the predominant type of Malaysia’s topical sky, this sky type was used in the simulation experiments. However, the overcast sky was only used for the DF method. In addition, clear sky was not employed in this research because there is no possibility of this sky type for tropical climates (Lim, 2011).

1.10 Research Significance

This study claimed that besides accommodation, the existing residential buildings may be used for other tasks such as home office. Thus, these buildings need to have potentials to support flexible functions and provide visual comfort for home office workers. However, there is a lack of available design guideline for daylighting efficiency in the ERBs in tropical climates. This study is significant to specify the critical design parameters of interior retrofit for improving the quantitative and qualitative performances of daylight in a typical HOR. This research proposes an interior retrofitted model for daylighting efficiency that can be implemented in typical HORs within the tropical regions, especially Malaysia. Finally, the proposed design model has potential to improve visual environments for home office workers. It can also help to save electric lighting that resulted in the reduction of buildings' carbon emission and global warming.

1.11 Thesis Organisation

This research comprised of 5 chapters. **Chapter One** represents the major issues and focus of this thesis. This chapter explains the research hypotheses, research questions, gap and objectives of the research. In addition, the limitations and scope of the research are also discussed. Finally, the significance of the research and the overall thesis organisation are determined.

Chapter Two is divided into 7 parts. The first part discussed about the development of home office workspaces and the benefits of working from home. The second part was focused on daylighting and its significance for home office workspaces in the existing residential buildings (ERB). In the third part, daylighting through architectural design strategies for new building design and retrofitting existing buildings were pinpointed. Apart from that, review of previous research on daylighting and architecture was discussed. The fourth part described the characteristics of tropical sky and issues in tropical daylighting. Techniques for daylighting analysis, review of daylight simulation tools and daylighting performance indicators were explained in the next sections.

Chapter Three illustrates the methodologies employed in the thesis. This chapter describes the methodologies that were used in the thesis. It comprised of 4 sections. The first section explained the overall methodological flowchart of the thesis. The second section described the filed survey to achieve data about the current scenario of the typical HORs in the ERBs in Johor Bahru. The third section described the procedure of validation test for Radiance-IES under a real tropical sky through the field measurement of daylight in real context. The last section illustrated all the three phases of daylight simulation experiments.

Chapter Four firstly evaluates interior layout of the typical HORs within the ERBs in Johor Bahru by focusing on the users' response. In addition, the typologies of MUFL were configured based on the desk location in the HOR. The results of validation test through field measurement and simulation test of daylight were described. Then, simulation experiments were performed in the three phases to analyse quantitative and qualitative performances of daylight in a typical HOR with various design parameters. Accordingly, the illuminance-related indicators (DR, EWPI, IUR, and SDZ) and the glare-related metrics (GVCP and CGI) were calculated in the room with various conditions. Afterwards, an interior retrofitted model for tropical daylighting for home office workspaces was proposed.

Chapter Five indicates the overall thesis findings achieved through the previous chapters. The implications and contributions of the thesis results are also discussed for tropical daylighting efficiency in the existing residential buildings. Lastly, some future studies are suggested related to this research. Figure 1.2 depicts the flow of research process and the thesis organisation.

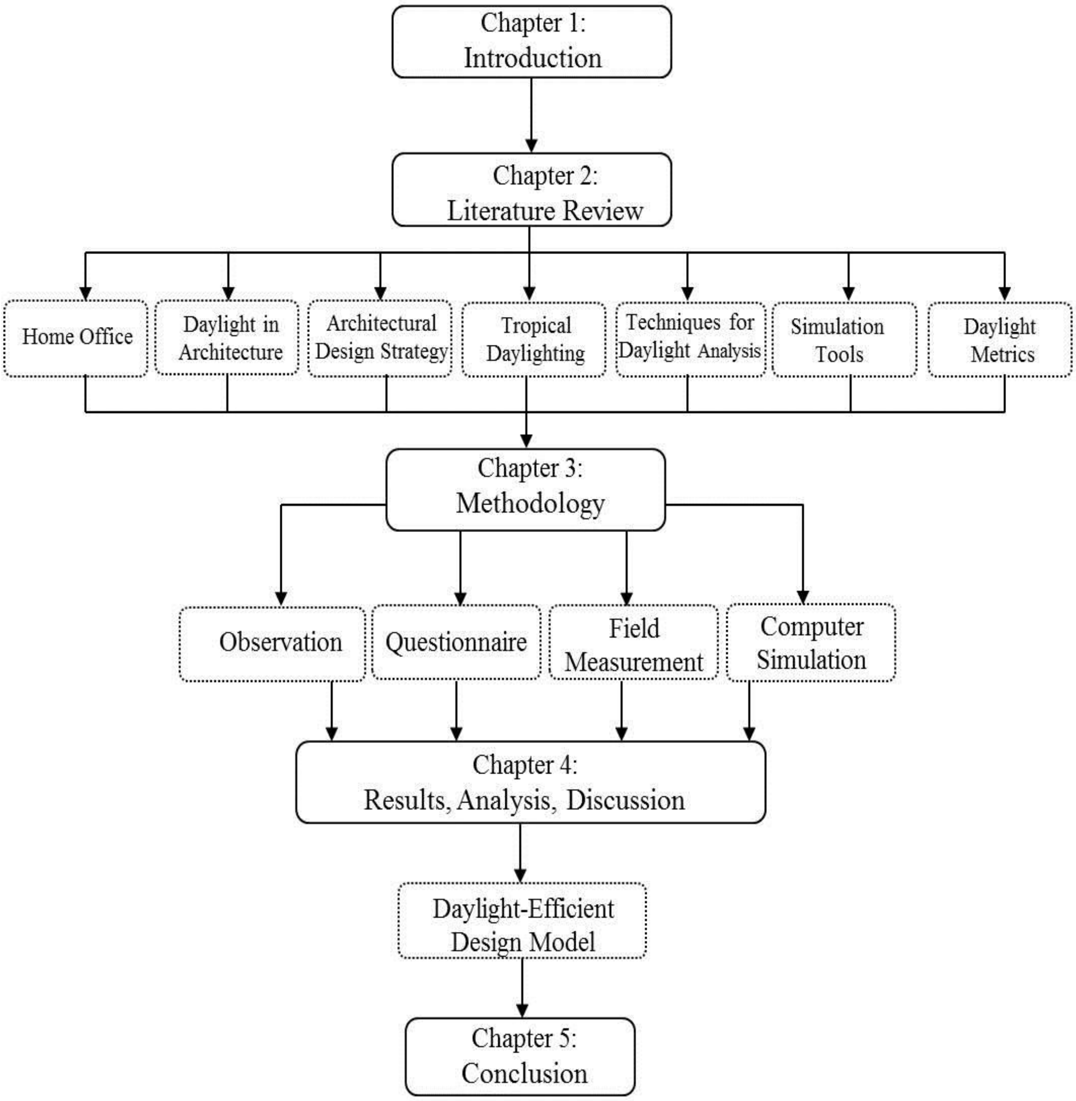

Figure 1.2 Research flowchart

REFERENCES

Abdullah, A., Fadzil, S.F.S., & Al-Tamimi, N.A.M. (2009). *Daylight illumination levels in varied room configurations at the view condominium, penang, malaysia*.

Ahmad, M.H., Ossen, D.R., Khaidzir, M., & Anwar, K. (2008). *Methodology in architectural research*. Universiti Teknologi Malaysia, Malaysia: Penerbit UTM Press.

Al-Tamimi, N.A., & Fadzil, S.F.S. (2011). The potential of shading devices for temperature reduction in high-rise residential buildings in the tropics. *Procedia Engineering, 21*, 273-282.

Alison G. Kwok, & Grondzik, W.T. (2007). *The green studio handbook: Environmental strategies for schematic design*. London, UK: Elsevier Inc.

Alzoubi, H., & Bataineh, R.F. (2010). Pre-versus post-occupancy evaluation of daylight quality in hospitals. *Building and Environment, 45*(12), 2652-2665.

Alzoubi, H.H., & Al-Zoubi, A.H. (2010). Assessment of building façade performance in terms of daylighting and the associated energy consumption in architectural spaces: Vertical and horizontal shading devices for southern exposure facades. *Energy Conversion and Management, 51*(8), 1592-1599.

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

Aries, M.B.C. (2005). *Human lighting demands: Healthy lighting in an office environment*: Technische Universiteit Eindhoven, Faculteit Bouwkunde.

Athienitis, A., & Tzempelikos, A. (2002). A methodology for simulation of daylight room illuminance distribution and light dimming for a room with a controlled shading device. *Solar Energy, 72*(4), 271-281.

Attia, S.G.M., & De Herde, A. (2011). Early design simulation tools for net zero energy buildings: A comparison of ten tools. *IBPSA, 1*.

Australian Bureau of Statistics. (2005). Characteristics of small business operators *No. 8127.0, AGP,* . Canberra.

Bateman, L. (2000). Home-work. *Work Study, 49*(5), 198-200.

Bhattacherjee, A. (2012). Social science research: Principles, methods, and practices.

BHWT. (2011). *Window tinting: 12 things you should know before buying* B. H. W. Tinting (Ed.) Retrieved 26 September, 2017, from http://www.bhwtinc.com/uploads/2/0/3/4/20341415/window_tinting_-_12_things_you_should_know_before_buying.pdf

Bluyssen, P.M. (2010). Towards new methods and ways to create healthy and comfortable buildings. *Building and Environment, 45*(4), 808-818.

Booth, A. (2009). Modelling and simulation of building physics. University of Cambridge: Department of Engineering.

Brain, J. (2015). 5 considerations for daylighting systems in retrofit projects. *CIRALIGHT.* Retrieved 26 September, 2017, from http://www.ciralight.com/blog/5-considerations-for-daylighting-systems-in-retrofit-projects

Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done? *Qualitative research, 6*(1), 97-113.

Buildings. (2016). 3 daylighting strategies for existing buildings: Don't let costs and complexity deter a retrofit. Retrieved 26 September, 2017, from https://www.buildings.com/article-details/articleid/19755/title/3-daylighting-strategies-for-existing-buildings

Bülow-Hübe, H. (2001). *Energy-efficient window systems.* Doctor of Philosophy, Lund University.

Carmody, J. (2007). *Residential windows: A guide to new technologies and energy performance*: WW Norton & Company.

Carmody, J., Selkowitz, S., Lee, E., Arasteh, D., & Willmert, T. (2004). Window system for high-performance buildings: W. W. Norton & Company.

Carr, M., Chen, M.A., & Tate, J. (2000). Globalization and home-based workers. *Feminist Economics, 6*(3), 123-142.

Chaiwiwatworakul, P., Chirarattananon, S., & Rakkwamsuk, P. (2009). Application of automated blind for daylighting in tropical region. *Energy Conversion and Management, 50*(12), 2927-2943.

Chan, S.A. (2009, 14 February). *Applying ms1525:2007 code of practice on energy efficiency and use of renewable energy for non-residential buildings.* Paper presented at the Green Building Index - MS1525. PAM CPD Seminar, Kuala Lumpur, Malaysia

Chauvel, P., Collins, J., Dogniaux, R., & Longmore, J. (1982). Glare from windows: Current views of the problem. *Lighting research and Technology, 14*(1), 31-46.

Chavez, J.G. (1989). *The potential of beam core daylighting for reducing the energy consumption of artificial lighting and air-conditioning in hot/arid regions of mexico.* Council for National Academic Awards (CNAA).

Cheng, C., Chen, C., Chou, C., & Chan, C. (2007). A mini-scale modeling approach to natural daylight utilization in building design. *Building and Environment, 42*(1), 372-384.

Cheong, K., Djunaedy, E., Tham, K., Sekhar, S., Wong, N., & Ullah, M. (2002). Influence of furniture layout and ventilation design on air quality and thermal comfort.

Cheung, H.-d. (2006). *Daylighting performance assessment methods for high-rise residential buildings in a dense urban environment.* The Hong Kong Polytechnic University.

Chia, S. (2008). Minimizing solar insulation in high-rise buildings through self-shaded form. *Journal of Applied Sciences*, *12,* 897-901.

Chia, S.L. (2007). *Minimizing solar insolation in high-rise buildings through selfshaded form.* (Master of Architecture,), Universiti Teknologi Malaysia.

Chinnayeluka, S.R. (2011). *Performance assessment of innovative framing systems through building information modeling based energy simulation.* Faculty of the Louisiana State University

Chou, C.-P. (2004). The performance of daylighting with shading device in architecture design. *Tamkang Journal of Science and Engineering. 7*(4), 205-212.

Chung, L.P., & Ossen, D.R. (2012). Comparison of integrated environmental solutions< virtual environment> and autodesk ecotect simulation software accuracy with field measurement for temperature. *Sustainability In Built Environment I*, 85.

CIBSE. (1994). Code for interior lighting *The Chartered Institute of Building Services Engineer (CIBSE)*. London (UK).

CIE. (1986). Guide on interior lighting *Second Edition*. Vienna, Austria: Commission Internationale de l'Éclairage (CIE).

Crawley, D.B., Hand, J.W., Kummert, M., & Griffith, B.T. (2008). Contrasting the capabilities of building energy performance simulation programs. *Building and environment, 43*(4), 661-673.

Creswell, J.W., & Clark, V.L.P. (2007). Designing and conducting mixed methods research. Los Angeles, USA.

Dahlan, N.D., Jones, P.J., Alexander, D.K., Salleh, E., & Alias, J. (2009). Daylight ratio, luminance and visual comfort assessments in typical malaysian hostels. *Indoor and Built Environment*.

DeKay, M., & Brown, G. (2013). *Sun, wind, and light: Architectural design strategies*: John Wiley & Sons.

Denzin, N.K., & Lincoln, Y.S. (2008). *Strategies of qualitative inquiry* (Vol. 2): Sage.

Djamila, H., Ming, C.C., & Kumaresan, S. (2011). Estimation of exterior vertical daylight for the humid tropic of kota kinabalu city in east malaysia. *Renewable Energy, 36*(1), 9-15.

Dodo, Y.A. (2015). *Office window opening influence on occupants' task performance*. Ph.D Thesis, Universiti Teknologi Malayzia, Johor Bahru.

Dubois, M.-C. (2001a). Impact of solar shading devices on daylight quality: Simulations with radiance. *Division of Energy and Building Design: Lund University, Sweden*.

Dubois, M.-C. (2001b). Impact of solar shading devices on daylight quality:Measurements in experimental office rooms. *Lund, Lund University*.

Dwelly, T., Maguire, K., Truscott, F., & Thompson, L. (2006). Under the radar: Tracking and supporting rural home-based business. *Report for the Commission for Rural Communities, Cheltenham, and Live Work Network, Penzance*.

Egan, M.D., & Olgyay, V. (2002). *Architectural lighting*: McGraw-Hill New York.

Emmanuel, R. (1993). A hypothetical 'shadow umbrella'for thermal comfort enhancement in the equatorial urban outdoors. *Architectural Science Review, 36*(4), 173-184.

Emmitt, S., & Gorse, C.A. (2013). *Barry's introduction to construction of buildings*: John Wiley & Sons.

Evans, B.H. (1981). Daylight in architecture.

Ezeadichie, N. (2012). Home-based enterprises in urban spaces: An obligation for strategic planning? *Berkeley Planning Journal, 25*(1).

Fogg, B.J. (2009). *A behavior model for persuasive design.* Paper presented at the Proceedings of the 4th international Conference on Persuasive Technology.

Fong, A., Ching, C., Yip, K., & Chan, J. (2000). *Working@ home: A guidebook for working women and homemakers*. Singapore: Corpcom Services Sdn.Bhd Publication.

Freewan, A., Shao, L., & Riffat, S. (2008). Optimizing performance of the lightshelf by modifying ceiling geometry in highly luminous climates. *Solar Energy, 82*(4), 343-353.

Freewan, A.A., Shao, L., & Riffat, S. (2009). Interactions between louvers and ceiling geometry for maximum daylighting performance. *Renewable energy, 34*(1), 223-232.

Fuziah, S., Azni, Z.A., Shuzlina, A.R., & Adizul, A. (2004). Daylight modelling and thermal performance of atrium of new mecm building at putrajaya.

Galasiu, A.D., Atif, M.R., & MacDonald, R.A. (2004). Impact of window blinds on daylight-linked dimming and automatic on/off lighting controls. *Solar Energy, 76*(5), 523-544.

Galasiu, A.D., & 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.

Garnett, N.S. (2001). On castles and commerce: Zoning law and the home-business dilemma. *William & Mary Law Review, 42*, 1191.

GBI. (2009). Green building index: *Design Reference Guide (1st ed.)*. Kuala Lumpur, Malaysia: Green Building Index Sdn. Bhd.

GBI. (2013). Green building index: For residential new construction (rnc), version 3.0. Kuala Lumpur, Malaysia: Green Building Index Sdn. Bhd.

Ghasemi, M. (2015). *Daylight performance in the adjoining spaces of vertical top-lit atrium in the tropics.* Ph.D Thesis, Universiti Teknologi Malayzia, Johor.

Ghasemi, M., Kandar, M.Z., & Noroozi, M. (2015). Investigating the effect of well geometry on the daylight performance in the adjoining spaces of vertical top-lit atrium buildings. *Indoor and Built Environment*, 1420326X15589121.

Givoni, B. (1998). *Climate considerations in building and urban design*: John Wiley & Sons.

Goody, J., Chandler, R., Clancy, J., Dixon, D., & Wooding, G. (2010). *Building type basics for housing* (Vol. 17): John Wiley & Sons.

Groat, L.N., & Wang, D. (2002). *Architectural research methods*: John Wiley & Sons.

Gugliermetti, F., & Bisegna, F. (2006). Daylighting with external shading devices: Design and simulation algorithms. *Building and Environment, 41*(2), 136-149.

Guzowski, M. (2000). *Daylighting for sustainable design*: McGraw-Hill Professional Publishing.

Hall, R. (2013). Mixed methods: In search of a paradigm. *L. Lê (Éd.), Conducting research in a changing and challenging World*, 71-78.

Harrison, A., Wheeler, P., & Whitehead, C. (2003). *The distributed workplace: Sustainable work environments*: Routledge.

Hegger, M., Fuchs, M., Stark, T., & Zeumer, M. (2008). *Energy manual-sustainable architecture*: Institut für Internationale Architekturdokumentation/Birkhäuser.

Ho, M.-C., Chiang, C.-M., Chou, P.-C., Chang, K.-F., & Lee, C.-Y. (2008). Optimal sun-shading design for enhanced daylight illumination of subtropical classrooms. *Energy and buildings, 40*(10), 1844-1855.

Hong, T., Chou, S., & Bong, T. (2000). Building simulation: An overview of developments and information sources. *Building and environment, 35*(4), 347-361.

Horn, Z.E. (2009). No cushion to fall back on: The global economic crisis and informal workers. *Inclusive Cities project, Cambridge, MA: Women in Informal Employment: Globalizing and Organizing (WIEGO), 20*.

Huff, C.J., & Huff, J.C. (2011). Curved light shelf system for daylighting an interior space: Google Patents.

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.

Hussein, H., & Jamaludin, A.A. (2015). Poe of bioclimatic design building towards promoting sustainable living. *Procedia-Social and Behavioral Sciences, 168*, 280-288.

Ibarra, D., & Reinhart, C.F. (2009). *Daylight factor simulations–how close do simulation beginners 'really'get?* Paper presented at the Building Simulation.

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

Ibrahim, N., Zain-Ahmed, A., & Commercialisation, U. (2006). A simple prediction tool for energy savings due to daylighting in malaysia. *Journal Science & Technology Vision, 2*(1), 25-29.

IES-VE. (2016a). Iesve for architects, trial support material. Retrieved 26 September, 2017, from https://www.iesve.com/content/downloadasset_8516.

IES-VE. (2016b). Virtual environment <ve> module tutorial. Retrieved 26 September, 2017, from http://www.iesve.com/software/ve-pro/tutorial-files/ies_ve_tutorial.pdf

IESNA. (1993). Lighting handbook: Reference and application. *(8th ed.) Illuminating Engineering Society of North America (IESNA).*

Ihm, P., Nemri, A., & Krarti, M. (2009). Estimation of lighting energy savings from daylighting. *Building and Environment, 44*(3), 509-514.

Iwata, T., Kimura, K.-I., Shukuya, M., & Takano, K. (1990). Discomfort caused by wide-source glare. *Energy and Buildings, 15*(3-4), 391-398.

Jamaludin, A.A. (2014). *Performance of bioclimatic design strategies at residential college buildings in university of malaya.* Doctor of Philosophy, University of Malaya, Kuala lumpur.

Jamaludin, A.A., Daud, N.K., Mohd Ariffin, A.R., & Hussein, H. (2011). Energy performance of three residential college buildings in university of malaya campus, kuala lumpur. *Journal of Design and Built Environment, 9*, 59-73.

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.

Jamaludin, A.A., Inangda, N., Ariffin, A.R.M., & Hussein, H. (2011). *Energy performance: A comparison of four different multi-residential building designs and forms in the equatorial region.* Paper presented at the Clean Energy and Technology (CET), 2011 IEEE First Conference on.

Jamaludin, A.A., Keumala, N., Ariffin, A.R.M., & Hussein, H. (2014). Satisfaction and perception of residents towards bioclimatic design strategies: Residential college buildings. *Indoor and Built Environment, 23*(7), 933-945.

Jamaludin, A.A., Mahmood, N.Z., & Ilham, Z. (2017). Performance of electricity usage at residential college buildings in the university of malaya campus. *Energy for Sustainable Development, 40*, 85-102.

Jamaludin, A.A., Zalina Mahmood, N., Keumala, N., Rosemary Mohd Ariffin, A., & Hussein, H. (2013). Energy audit and prospective energy conservation: Studies at residential college buildings in a tropical region. *Facilities, 31*(3/4), 158-173.

Jamaludina, A.A., Husseinb, H., Keumalab, N., & Ariffinb, A.R.M. (2017). Post occupancy evaluation of residential college building with bioclimatic design strategies in tropical climate condition of malaysia. *Jurnal Teknologi*, 113–122.

Jughans, L. (2008). Design, elements and strategies: Daylighting. *Bioclimatic housing: Innovative designs for warm climates*, 345-365.

Kanarek, L. (2001). *Home office life: Making a space to work at home*: Rockport Publishers.

Kandar, M.Z., Sulaiman, M.S., Rashid, Y.R., Ossen, D.R., MAbdullah, A., Wah, L.Y., & Nikpour, M. (2011). Investigating daylight quality in malaysian government office buildings through daylight factor and surface luminance. *World Academy of Science, Engineering and Technology, International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 5*(11), 589-594.

Kaufman, J.E., & Haynes, H. (1981). *Ies lighting handbook; reference volume and application volume.*

Kelly, A.P. (2007). Social research methods. *Undergraduate study in Economics, Management, Finance and the Social Sciences*.

Khan, T.H. (2008). Living with transformation: A study of self-built houses in dhaka. *HKU Theses Online (HKUTO).*

Kim, G., & Kim, J.T. (2010). Healthy-daylighting design for the living environment in apartments in korea. *Building and Environment, 45*(2), 287-294.

Kischkoweit-Lopin, M. (2002). An overview of daylighting systems. *Solar Energy, 73*(2), 77-82.

Ko, D.-H. (2009). *Fenestration guideline for energy and daylight efficiency: Evaluation and prediction of performance in office buildings*.

Konis, K. (2013). Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open-plan office building in san francisco, california. *Building and Environment, 59*, 662-677.

Koo, S.Y., Yeo, M.S., & Kim, K.W. (2010). Automated blind control to maximize the benefits of daylight in buildings. *Building and Environment, 45*(6), 1508-1520.

Labayrade, R., Jensen, H.W., & Jensen, C. (2009). *Validation of velux daylight visualizer 2 against cie 171: 2006 test cases.* Paper presented at the Proceedings 11th International IBPSA Conference, International Building Performance Simulation Association.

Labib, R. (2013). Improving daylighting in existing classrooms using laser cut panels. *Lighting Research & Technology, 45*(5), 585-598.

Lam, J.C. (2000). Energy analysis of commercial buildings in subtropical climates. *Building and Environment, 35*(1), 19-26.

Lam, J.C., & Li, D.H. (1998). Daylighting and energy analysis for air-conditioned office buildings. *Energy, 23*(2), 79-89.

Lam, J.C., Tsang, C., Li, D.H., & Cheung, S. (2005). Residential building envelope heat gain and cooling energy requirements. *Energy, 30*(7), 933-951.

Larson, G.W., & Shakespeare, R. (2004). *Rendering with radiance: The art and science of lighting visualization*: Booksurge Llc.

Lawrence Berkeley National Laboratory. (2001). Radiance, desktop 2.0 beta user manual. *California, US: Lawrence Berkeley National Laboratory,*.

Lechner, N. (2014). *Heating, cooling, lighting: Sustainable design methods for architects*: John wiley & sons.

Leng, P., bin Ahmad, M.H., Ossen, D.R., & Hamid, M. (2012). *Investigation of integrated environmental solutions-virtual environment software accuracy for air temperature and relative humidity of the test room simulations.* Paper presented at the UMT 11th The International Annual Symposium on Sustainability Science and Management, Terengganu, Malaysia.

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

Li, D.H., & Lam, J.C. (2000). Solar heat gain factors and the implications to building designs in subtropical regions. *Energy and Buildings, 32*(1), 47-55.

Li, D.H., Lam, T.N., Wong, S.L., & Tsang, E.K. (2008). Lighting and cooling energy consumption in an open-plan office using solar film coating. *Energy, 33*(8), 1288-1297.

Li, D.H., Tsang, E.K., Cheung, K.L., & Tam, C.O. (2010). An analysis of light-pipe system via full-scale measurements. *Applied Energy*, *87*(3), 799-805.

Li, D.H., Wong, S., Tsang, C., & Cheung, G.H. (2006). A study of the daylighting performance and energy use in heavily obstructed residential buildings via computer simulation techniques. *Energy and Buildings, 38*(11), 1343-1348.

Lim, Y.W. (2012). *Building modelling and simulation for green building design Sustainability In Built Environment I* (pp. 70).

Lim, Y.W. (2014). Dynamic daylight and solar control in tropical climate. *American Journal of Applied Sciences*, *11*(10), 1766.

Lim, Y.W., & Ahmad, M.H. (2014). The effects of direct sunlight on light shelf performance under tropical sky. *Indoor and Built Environment,* 1420326X14536066.

Lim, Y.W., Ahmad, M.H., & Ossen, D.R. (2013). Internal shading for efficient tropical daylighting in malaysian contemporary high-rise open plan office. *Indoor and Built Environment, 22*(6), 932-951.

Lim, Y.W., & Heng, C. (2016). Dynamic internal light shelf for tropical daylighting in high-rise office buildings. *Building and Environment, 106*, 155-166.

Lim, Y.W., Kandar, M.Z., Ahmad, M.H., Ossen, D.R., & Abdullah, A.M. (2012). Building façade design for daylighting quality in typical government office building. *Building and Environment, 57,* 194-204. doi:10.1016/j.buildenv.2012.04.015

Lim, Y.W. (2011). Internal shading for efficient tropical daylighting in high-rise open plan office. *Doctor of Philosophy, Faculty of Built Environment, Universiti Teknologi Malaysia*.

Lim, Y.W., Ahmad, M.H., & Ossen, D.R. (2008). Review on solar shading strategies and measuring tools for building energy efficiency in tropical climate. *10th SENVAR+ 2nd ISESEE 2008 Humanity & Technology*.

Lim, Y.W., & Ahmad, M.H. (2010). *Daylight and users' response in high rise open plan office: A case study of malaysia.* Paper presented at the 3rd International Graduate Conference on Engineering, Science, and Humanities, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia.

Lim, Y.W., Ahmad, M.H., & Ossen, D.R. (2009). *Effect of solar shading, fenestration and room geometry on office building energy efficiency in hot humid tropic.* Paper presented at the 3rd International Conference on Built Environment in Developing Countries.

Lim, Y.W., Ossen, D.R., & Lim, Y. (2008). Review on measuring tools for energy efficient solar shading strategies in tropical climate. *J. Alam. Bina, 14*, 33-42.

Lim, Y.W., Ahmad, M.H, & Ossen, D.R. (2010). Empirical validation of daylight simulation tool with physical model measurement. *American Journal of Applied Sciences, 7*(10), 1426-1431. doi:10.3844/ajassp.2010.1426.1431

Linhart, F., & Scartezzini, J.-L. (2010). Minimizing lighting power density in office rooms equipped with anidolic daylighting systems. *Solar Energy, 84*(4), 587-595.

Linhart, F., Wittkopf, S.K., & Scartezzini, J.-L. (2010). Performance of anidolic daylighting systems in tropical climates–parametric studies for identification of main influencing factors. *Solar Energy, 84*(7), 1085-1094.

Louis I. Kahn. (1966). *Kimbell art museum, fort worth, chapter 16, p 237*. Texas.

Loutzenhiser, P.G., Maxwell, G.M., & Manz, H. (2007). An empirical validation of the daylighting algorithms and associated interactions in building energy simulation programs using various shading devices and windows. *Energy, 32*(10), 1855-1870.

Mahdavi, A., Rao, S., & Inangda, N. (2013a). *Orientation effects on daylighting in high-rise office buildings in malaysia: A simulation study.* Paper presented at the International Conference on Alternative Energy in Developing Countries and Emerging Economies, Bangkok, Thailand.

Mahdavi, A., Rao, S.P., & Inangda, N. (2013b). Parametric studies on window-to-wall ratio for day lighting optimisation in high-rise office buildings in kuala lumpur, malaysia. *Journal of Design and Bulit Environ. t, 12*.

Maier, A.E. (2016). Daylight as starting point for retrofitting residential buildings and cities. *Acta Technica Napocensis: Civil Engineering & Architecture, 58, No. 4*

Mansour, A., Sopian, K., Zain-Ahmed, A., & Reimann, G. (2006). Daylight distribution of a new design for future commercial office building in malaysia. *ISESCO Sci Technol Vis, 2*(1), 53e56.

Mardaljevic, J. (1995). Validation of a lighting simulation program under real sky conditions. *Lighting research and Technology, 27*(4), 181-188.

Mason, C.M., Carter, S., & Tagg, S. (2011). Invisible businesses: The characteristics of home-based businesses in the united kingdom. *Regional Studies, 45*(5), 625-639.

Mattis, M.C. (2004). Women entrepreneurs: Out from under the glass ceiling. *Women in Management Review, 19*(3), 154-163.

Mayhoub, M., & Carter, D. (2011). The costs and benefits of using daylight guidance to light office buildings. *Building and Environment, 46*(3), 698-710.

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.

Mekhilef, S., Saidur, R., Said, S., Hong, P., & Islam, M. (2014). Techno-economic evaluation of energy efficiency measures in high rise residential buildings in malaysia. *Clean Technologies and Environmental Policy, 16*(1), 23-35.

Mirrahimi, S., Surat, M., Ibrahim, N.L.N., Che-Ani, A.I., & Johar, S. (2013). Optimal of daylighting performance with shading device via computer simulation for office building in malaysia. *Advances in Natural and Applied Sciences, 7*(1), 51-60.

Mistrick, R.G. (2000). Desktop radiance overview. *Retrieved September, 16*, 2003.

Miyazaki, T., Akisawa, A., & Kashiwagi, T. (2005). Energy savings of office buildings by the use of semi-transparent solar cells for windows. *Renewable energy, 30*(3), 281-304.

Mohammadi, M.P., Ahmad, A.S., Mursib, G., Roshan, M., & Torabi, M. (2014). Interior layout design parameters affecting user comfort in ee buildings.

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.

Moore, F. (1985). *Concepts and practice of architectural daylighting*: Van Nostrand Reinhold Company.

MS 1525. (2014). Malaysian standard: Code of practice on energy efficiency and use of renewable energy for non-residential buildings, department of standards malaysia, 1st revision. Malaysia: MS 1525.

Muneer, T., & Gul, M. (2000). Evaluation of sunshine and cloud cover based models for generating solar radiation data. *Energy Conversion and Management, 41*(5), 461-482.

Murray, V., O'Flynn, C., & Beattie, K. (2001). *Advanced building services simulation software providing design solutions in dublin and boston.* Paper presented at the 7th Internation IBPSA Conference. Brazil: Rio de Janeiro.

Nawab, M. (1990). Outdoors indoors. *Lighting Design & Application*, *6*, 24-31.

Nazzal, A.A. (2005). A new evaluation method for daylight discomfort glare. *International Journal of Industrial Ergonomics, 35*(4), 295-306.

Nedhal, A.-T., Syed, F.S.F., & Adel, A. (2016). Relationship between window-to-floor area ratio and single-point daylight factor in varied residential rooms in malaysia. *Indian Journal of Science and Technology*, *9*(33).

Nielsen, J., Nielsen, P.V., & Svidt, K. (1998). The influence of furniture on air velocity in a room: An isothermal case: Dept. of Building Technology and Structural Engineering.

Nikpour, M. (2014). *Heat gain and daylight assessment in self shading office buildings in tropical.* Ph.D Thesis, Universiti Teknologi Malayzia, Johor.

Nikpour, M., Kandar, M.Z., & Mosavi, E. (2013). Investigating daylight quality using self-shading strategy in energy commission building in malaysia. *Indoor and Built Environment, 22*(5), 822-835.

NSW. (2008). *Exempt development: Home-based enterprises*. New South Wales Government: Retrieved from https://dpe-files-prod1.s3-ap-southeast-2.amazonaws.com/s3fspublic/documents/2016/May/Home_based_enterprises.pdf.

Olgyay, V. (2015). *Design with climate: Bioclimatic approach to architectural regionalism*: Princeton University Press.

Ossen, D.R. (2005). *Optimum overhang geometry for high rise office building energy saving in tropical climates*. Doctor of Philosophy, Faculty of Built Environment, Universiti Teknologi Malaysia, Johor.

Ossen, D.R. (2008). Building simulation for energy efficient solar shading.

Osterhaus, W. (1996). *Discomfort glare from large area glare sources at computer workstations.* Paper presented at the Proc. of the 1996 International Daylight Workshop: Building with Daylight: Energy Efficient Design.

Osterhaus, W. (1998). *Brightness as a simple indicator for discomfort glare from large area glare sources.* Paper presented at the Proceedings of Tagungsband First International CIE Symposium on Lighting Quality.

Phelan, J. (2002). *Commissioning lighting control systems for daylighting applications*. Paper presented at the National Conference on Building Commissioning.

Phillips, L. (2013). How to run a business from home. Retrieved 26 September, 2017, from https://www.theguardian.com/money/2013/oct/10/jobs-home-working-tips

Pratt, J.H. (2000). Homebased business: The hidden economy. *University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship*.

Radiance. (2014). Ies virtual environment : Introduction to lighting *Integrated Environmental Solutions Limited*.

Rahim. (2010). Soho. Retrieved 26 September, 2017, from http://rahim-co.com/art6.htm

Rahim, R. (2004). Analisa luminansi langit dengan metode rasio awan. *DIMENSI Journal of Architecture and Built Environmen), 28*(2).

Rahim, R., & Mulyadi, R. (2004). Preliminary study of horizontal illuminance in indonesia.

Reinhart, C., & Fitz, A. (2006). Findings from a survey on the current use of daylight simulations in building design. *Energy and Buildings, 38*(7), 824-835.

Reinhart, C.F. (2002). *Effects of interior design on the daylight availability in open plan offices.* Paper presented at the 2002 ACEEE Summer Study on Energy Efficiency in Buildings.

Reinhart, C.F., & Breton, P.-F. (2009). Experimental validation of 3ds max® design 2009 and daysim 3.0. *Draft manuscript submitted to Building Simulation*.

Robbins, C. (1986). Daylighting: Design and analysis: New York: Van Nostrand Reinhold Company.

Roshan, M. (2014). *Anadolic daylighting system for efficient daylighting in deep plan office building in the tropics.* Ph.D Thesis, , Universiti Teknologi Malaysia, Johor.

Roshan, M., Kandar, M.Z., Najafpour, H., Ossen, D.R., Ghasemi, M., Gharakhani, A., & Torabi, M. (2014). Analysis of anidolic daylighting system parameters in tropical climate. *Life Science Journal, 11*(8).

Roshan, M., Kandar, M.Z.B., Nikpur, M., Mohammadi, M.P., & Ghasemi, M. (2013). Investigating the performance of anidolic daylighting system with respect to building orientation in tropical area. *system, 3*(1).

Sanati, L., & Utzinger, M. (2013). The effect of window shading design on occupant use of blinds and electric lighting. *Building and environment, 64,* 67-76.

Shahriar, A.N.M., & Mohit, M.A. (2007). Estimating depth of daylight zone and psali for side lit office spaces using the cie standard general sky. *Building and environment, 42*(8), 2850-2859.

Sharifah, F.F.S., & Sia, S.-J. (2004). Sunlight control and daylight distribution analysis: The komtar case study. *Building and Environment, 39*(6), 713-717.

Sharples, S., & Lash, D. (2007). Daylight in atrium buildings: A critical review. *Architectural Science Review, 50*(4), 301-312.

Shen, H., & Tzempelikos, A. (2013). Sensitivity analysis on daylighting and energy performance of perimeter offices with automated shading. *Building and environment, 59,* 303-314.

Steffy, G. (2002). *Architectural lighting design*: John Wiley & Sons.

Strassmann, W.P. (1987). Home-based enterprises in cities of developing countries. *Economic Development and Cultural Change, 36*(1), 121-144.

Sulaiman, R. (2011). *Developing a malaysian electronic home-based businesses pre-implementation framework.*, Ph.D Thesis, Universiti Tenaga Nasional, Malaysia.

Sulaiman, R., & Shariff, S.S.M. (2012). The transformation of home-based businesses into electronic-home-based businesses.

Sulaiman, R., Shariff, S.S.M., & Ahmad, M.S. (2009). The e-business potential for home-based businesses in malaysia: A qualitative study. *International Journal of Cyber Society and Education, 2*(1), 21-36.

Szokolay, S.V. (2014). *Introduction to architectural science: The basis of sustainable design*: Routledge.

Trebilcock, A. (2005). *Decent work and the informal economy*: United Nations University, World Institute for Development Economics Research.

Tzempelikos, A. (2005). *A methodology for integrated daylighting and thermal analysis of buildings.* Concordia University.

Tzempelikos, A., & Athienitis, A.K. (2007). The impact of shading design and control on building cooling and lighting demand. *Solar Energy, 81*(3), 369-382.

Velds, M. (2000). *Assessment of lighting quality in office rooms with daylighting systems.* TU Delft, Delft University of Technology.

Walker, E., Wang, C., & Redmond, J. (2008). Women and work-life balance: Is home-based business ownership the solution? *Equal Opportunities International, 27*(3), 258-275. doi: doi:10.1108/02610150810860084

Walker, E., & Webster, B. (2004). Gender issues in home-based businesses. *Women in Management Review, 19*(8), 404-412.

Wang, C., Abdul-Rahman, H., & Rao, S. (2010). Daylighting can be fluorescent: Development of a fiber solar concentrator and test for its indoor illumination. *Energy and Buildings, 42*(5), 717-727.

Wang, N. (2009). *In broad daylight: An investigation of the multiple environmental factors influencing mood, preference, and performance in a sunlit workplace*: ProQuest.

Ward, G. (1996). Adeline 2.0-radiance reference manual, advanced daylighting and electric lighting integrated new environment. *Lawrence Berkeley Laboratory, 1*.

Waters, C.E., Mistrick, R., & Bernecker, C. (1995). Discomfort glare from sources of nonuniform luminance. *Journal of the Illuminating Engineering Society, 24*(2), 73-85.

Weather. (2015) *Weather History for WSSL nearest airport to Johor Bahru*. meteorological station Weather Underground. Retrieved 26 September, 2017, from http://www.wunderground.com/history/airport/WSSL/2015/3/11/DailyHistory.html?req_city=Johor+Bahru&req_state=&req_statename=Malaysia&reqdb.zip=00000&reqdb.magic=13&reqdb.wmo=48692.

Whitehead, R. (2009). Residential lighting a practical guide to beautiful and sustainable design second edition, John Wiley&Sons: Inc.

Winch, J. (2013). 8m britons run online businesses from home. Retrieved 26 September, 2017, from http://www.telegraph.co.uk/finance/personalfinance/9997044/8m-Britons-run-online-businesses-from-home.htmls website:

Wong, N.H., & Istiadji, A.D. (2004). Effect of external shading devices on daylighting penetration in residential buildings. *Lighting Research & Technology, 36*(4), 317-330.

Worthington, J. (2006). *Reinventing the workplace*: Routledge.

Xia, C., Zhu, Y., & Lin, B. (2008). *Building simulation as assistance in the conceptual design.* Paper presented at the Building simulation.

Yeang, K. (2008). *Ecodesign: A manual for ecological design*. London, UK: John Wiley & Son Ltd.

Yi, Y.K., & Yi, Y.K. (2010). Environmental performance of furniture layouts in si housing. *Journal of Asian Architecture and Building Engineering, 9*(2), 547-553.

Yu, J., Yang, C., & Tian, L. (2008). Low-energy envelope design of residential building in hot summer and cold winter zone in china. *Energy and Buildings, 40*(8), 1536-1546.

Zain-Ahmed, A., Sopian, K., Abidin, Z.Z., & Othman, M. (2002). The availability of daylight from tropical skies—a case study of malaysia. *Renewable Energy, 25*(1), 21-30.

Zain-Ahmed, A., Sopian, K., Othman, M., Sayigh, A., & Surendran, P. (2002). Daylighting as a passive solar design strategy in tropical buildings: A case study of malaysia. *Energy Conversion and Management, 43*(13), 1725-1736.