

DAYLIGHT DRIVEN DESIGN IN ENHANCING ENERGY EFFICIENCY OF
OFFICE BUILDING IN TROPICAL CLIMATE

GOH ZHENG LIN

A dissertation submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Architecture

Faculty of Built Environment
Universiti Teknologi Malaysia

JUNE 2017

To my beloved parents and siblings

ACKNOWLEDGEMENT

I would first like to express my sincere gratitude to my main thesis supervisor, Dr Malsiah Binti Hamid for her patient, guidance and motivation. I would also like to thank my dissertation supervisor Associate Professor Dr. Syed Ahmad Iskandar Syed Ariffin for his advices, supervision and encouragement. Without their ongoing support, the dissertation will not be ready as it is.

My sincere appreciation to my fellow friends for their continuous support and colleagues who aided me throughout the preparation of dissertation. Finally, I am very thankful to have my beloved parents and family for their continuous support throughout the graduate studies journey.

ABSTRACT

The aim of this research is to establish a daylight driven office building design that improve the energy efficiency of office building in Malaysia. To achieve this aim, the key principles of daylighting are to be establish. The daylighting key principles are solar heat gain minimization, glare prevention, deep penetration of daylight, uniform daylight distribution, electrical light response to harvested daylight, interior planning and design consideration. The research methodology chosen are computer simulation and comparative analysis of case studies. Computer simulation is carried out to determine the optimum building form with minimal solar radiation and the effectiveness of light shelf to harvest daylight in relation to its width. While comparative analysis of case study is carried out to identify the daylighting strategies that implemented and its effectiveness. The results of the research can be categorise as three part that is comparative analysis of case studies, solar radiation simulation and daylighting simulation. Firstly, the three selected case studies show that consideration of all daylighting key principles is crucial to achieve high energy efficiency office building in Malaysia. Secondly, result of six cases of solar radiation simulations show that building form that has podium and tower with self-shading facades has less solar heat gain compared to other building form that do not have those characteristics. Lastly, the results of six cases for daylighting simulation shows that implementation of light shelf of 1500mm width enable to reduce glare effectively but slightly reduced desirable illuminance of 300-400 lux. Therefore, integrated approach that is introduction of reflective ceiling is required to increase the floor area with desirable illuminance of 300- 400 lux for healthy working environment.

ABSTRAK

Kajian ini bertujuan untuk mewujudkan reka bentuk bangunan pejabat yang didorong oleh prinsip pencahayaan semula jadi untuk meningkatkan kecekapan tenaga bangunan pejabat. Prinsip-prinsip utama pencahayaan semula jadi perlu dikenalpasti untuk mencapai matlamat ini. Prinsip-prinsip utama pencahayaan semula jadi merangkumi pengurangan sinaran suria, pencegahan silau, penembusan cahaya semula jadi yang mendalam, pengedaran cahaya dengan seragam, lampu elektrik yang bertindak balas dengan pencahayaan semula jadi, perancangan ruang dalaman dan pertimbangan reka bentuk. Metodologi kajian yang dipilih adalah simulasi komputer dan analisis perbandingan kajian kes. Simulasi komputer digunakan untuk menentukan bentuk bangunan yang optimum dengan radiasi solar yang minimum dan keberkesanan rak cahaya untuk mendapatkan pencahayaan semula jadi berkaitan dengan lebarnya. Analisis perbandingan kajian kes digunakan untuk mengenal pasti strategi pencahayaan semula jadi yang dilaksanakan dan keberkesanannya. Hasil kajian ini boleh dikategorikan kepada tiga bahagian iaitu analisis perbandingan kajian kes, simulasi sinaran suria dan simulasi pencahayaan semula jadi. Pertama, tiga kajian kes yang dipilih menunjukkan bahawa pertimbangan untuk semua prinsip utama pencahayaan semula jadi adalah penting untuk mencapai pejabat bangunan yang mempunyai kecekapan tenaga yang tinggi. Kedua, keputusan enam kes untuk simulasi radiasi solar menunjukkan bentuk bangunan yang mempunyai podium dan menara dengan fasad yang mampu meneduhkan diri sendiri mempunyai haba solar yang kurang berbanding bentuk bangunan lain seperti bentuk bangunan yang tidak mempunyai ciri-ciri tersebut. Ketiga, keputusan enam kes berkaitan dengan simulasi pencahayaan semula jadi menunjukkan bahawa pelaksanaan cahaya rak 1500mm lebar dapat mengurangkan silau dengan berkesan tetapi mengurangkan keterangan yang diperlukan iaitu 300- 400 lux. Oleh itu, integrasi siling yang reflektif diperlukan untuk meningkatkan kawasan lantai dengan keterangan 300- 400 lux dan menghasilkan persekitaran kerja yang sihat.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	i
	DEDUCATION	ii
	ACKNOWLEDGEMENTS	vi
	ABSTRACT	vii
	ABSTRAK	viii
	TABLE OF CONTENTS	ix
	LIST OF TABLES	xiii
	LIST OF FIGURES	xv
	LIST OF APPENDIXES	xxi
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Background Studies	2
	1.3 Problem Statement	4
	1.4 Research Aim	5
	1.5 Objectives of the Study	5
	1.6 Research Questions	5
	1.7 Significance of the Study	6
	1.8 Research Methodology	6
	1.9 Structure of Thesis	7
2	LITERATURE REVIEW	8
	2.1 Introduction	8

2.2	Definition of Daylighting, Illuminance and Glare	8
2.3	Key Principles of Daylight Harvesting	10
2.3.1	Solar Heat Gain Minimization	10
2.3.2	Glare Prevention	11
2.3.3	Deep Penetration of Daylight	12
2.3.4	Uniform Daylight Distribution	13
2.3.5	Electrical Light Response to Daylight Harvested	14
2.3.6	Interior Planning and Design Consideration	14
2.4	Benefits of Daylighting	15
2.5	Uses of Daylighting in Office Building	15
2.6	Daylighting Strategies	16
2.6.1	Site Consideration and Orientation	17
2.6.2	Massing and Form of Building	18
2.6.3	Space Planning	19
2.6.4	Window Design Consideration	20
2.6.5	Ceiling Design Consideration	24
2.6.6	Light Shelf	25
2.6.7	Light Pipe	28
2.6.8	Skylight	29
2.6.9	PSALI (Permanent Supplementary Artificial Lighting of Interior) & Efficient Artificial Light Equipment	31
2.7	Case Studies: Green Office Building in Malaysia	32
2.7.1	The Green Energy Office (GEO) Building	33
2.7.2	The Diamond Building	36
2.7.3	KKR2 Tower	38
2.8	Summary of Chapter	40
3	RESEARCH METHODOLOGY	41
3.1	Introduction	41
3.2	Method of Research	42
3.3	Case Study	43
3.4	Computer Simulation Programme	44
3.4.1	Sketchup 2016	45

3.4.2	Insight 360 Autodesk Revit 2016	46
3.4.3	Velux Daylight Visualizer	46
3.5	Research Framework	47
3.6	Simulation Workflow	48
3.7	Variables of Simulation for Solar Radiation and Daylighting Simulations	49
3.8	Development of Basic Building Forms for Solar Radiation Simulation	50
3.9	Requirements of Daylighting Simulation	52
3.10	Performance Criteria	53
3.11	Summary	54
4	ANALYSIS, FINDINGS AND DISCUSSION	55
4.1	Introduction	55
4.2	Case Study	56
4.2.1	Evaluating the Three Case Studies based on the Six Key Principles of Daylight Harvesting	56
4.3	Simulation result for Solar Radiation	60
4.3.1	Revit Insight 360 Solar Radiation Simulation	60
4.3.2	Comparative of the six Simulation Cases for Solar Radiation	76
4.4	Simulation Result for Illuminance	79
4.5	Simulation Result for Daylight Factor	91
4.6	Building Energy Index	92
4.7	Summary of Chapter	93
5	CONCLUSION AND RECOMMENDATIONS	94
5.1	Introduction	94
5.2	Conclusions	95
5.2.1	Objective 1: To identify the daylight strategies in achieving optimum daylight penetration into the building	95
5.2.2	Objective 2: To determine the building form through daylight principles	96

5.2.3 Objective 3: To find out integrated design that achieve optimum daylighting for working environment and hence enhancing energy efficiency of building	97
5.3 Recommendations	98
REFERENCES	99
APPENDIX	104

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.0	The acceptable ratio of the luminance at two points in the field of view	13
2.1	Different glazing energy performance	22
3.0	Summarized basic data of simulation for the 6 cases	51
4.0	Summary of key principles of daylight harvesting relating to the 3 selected cases	59
4.1	Case 1 range of solar radiation and facades surface area	61
4.2	Case 2 range of solar radiation and facades surface area	65
4.3	Case 3 range of solar radiation and facades surface area	67
4.4	Case 4 range of solar radiation and facades surface area	70
4.5	Case 5 range of solar radiation and facades surface area	73
4.6	Case 6 range of solar radiation and facades surface area	76
4.7	Comparative of simulation results for 6 cases	77
4.8	The number of node for case 1 simulation on 6 th floor	81
4.9	The number of node for case 2 simulation on 6 th , 16 th and 23 rd floors	83

4.10	The number of node for case 3 simulation on 6 th , 16 th and 23 rd floors	85
4.11	The number of node for case 4 simulation on 6 th , 16 th and 23 rd floors	87
4.12	The number of node for case 5 simulation on 6 th , 16 th and 23 rd floors	89
4.13	Comparison of illuminance of 5 cases on 6 th floor	90
4.14	Case 1 Daylight Factor Simulation on 6 th floor	91
4.15	Simplified calculation on energy saving from artificial lighting	92

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.0	Average of building energy efficiency in Malaysia	1
1.1	Energy Index from Electrical Consumption and Carbon Emission Intensity of Building Typologies in Malaysia	3
1.2	CO ² emission per capita of Malaysia, Singapore and Indonesia from year of 1952 to 2010	4
1.3	Typical electricity usage in office buildings in Malaysia	4
1.4	Structure of Thesis	7
2.0	Difference between illuminance and luminance	9
2.1	Daylight factors and its impacts	12
2.2	Section of a side lit space with standard window and rule of thumb for daylight penetration through the window.	13
2.3	The three-tier approach to Sustainable Heating, Cooling and Lighting	16
2.4	The diagram illustrates north and south façade have most daylight while at east and west façade has least daylight and unwanted glare issue	18
2.5	Different cut outs in building plan able to provide good daylight to the space inside	18

2.6	Example of a daylighting opportunity analysis	19
2.7	General rule of penetration of daylighting through sidelit window	20
2.8	Maximum distance allowed between window for uniform daylight distribution	21
2.9	Show the Comparison of daylight factor with opening ratio	23
2.10	Comparison of shading device type and daylight factor across the space	23
2.11	Effect of glazed area on annual energy consumption	24
2.12	90 degree drop ceiling below the top of the facade window height (left) compared to slanting a drop of false ceiling with some angle (right)	25
2.13	Selection criteria for daylighting strategies	26
2.14	Side-lighting enhancement techniques and their limits	27
2.15	Different shape of light shelf reflects daylight with different distance penetration of daylight into building	28
2.16	Component of Light Pipe (left) and the light pipe reflects daylight into the space (right)	29
2.17	Saw-tooth roof (left) and Roof-monitor (right)	30
2.18	Interaction between natural light and artificial light at various distance from window	31
2.19	The flow chart of PSALI	32
2.20	Perspective view of GEO Building	33

2.21	East facade of GEO Building	33
2.22	West facade of GEO Building	34
2.23	Skylight design of GEO Building that uses side lighting	35
2.24	The section of Diamond building relation to the Sun Path and Shadow Casting	36
2.25	The integration of window sill and light shelf	37
2.26	The self-shading glazing incorporate with external fin to reduce solar heat gain	38
2.27	Orientation of building relating to its building form on left and the building's core positioning colored in red on right	39
2.28	Daylight Contour of Level 11 from 9am to 10 am (left) and 1pm to 2pm (right) 1 meter above the floor level	39
3.0	The case study process overview for facility documentation phase	43
3.1	The workflow of the research methodology	47
3.2	Workflow of Modelling and Simulation	48
3.3	The setting of weather data for Revit 2016 Insight 360 software for solar radiation simulation	49
3.4	Sun path of the solar radiation simulation	49
3.5	Axonometric view of building form 1 (left) and 2 (right)	50
3.6	Axonometric view of building form 3 (left) and 4 (right)	50
3.7	Axonometric view of building form 5 (left) and 6 (right)	51

3.8	Axonometric view of the base model for daylighting simulation in Velux (left) and its section (right)	52
3.9	3D model of simulation for daylighting	53
4.0	Six cases of solar radiation simulation	60
4.1	Simulation result of case 1	60
4.2	Case 1 3D simulation result view from east (left) and view from west (right)	61
4.3	Top view of case 1 simulation result	62
4.4	The facades of case 1 simulation result	62
4.5	Simulation result of case 2	63
4.6	The 3D view of case 2 simulation result view from north-east (left) and south-west (right)	63
4.7	Top view of case 2 simulation result	64
4.8	The facades of case 2 simulation result	64
4.9	Simulation result of case 3	65
4.10	The 3D view of case 3 simulation result view from north-east (left) and south-west (right)	66
4.11	The top view of case 3 simulation result	66
4.12	The facades of case 3 simulation result	67
4.13	Simulation result of case 4	68
4.14	The 3D view of case 3 simulation result view from north-east (left) and south-west (right)	68

4.15	Top view of case 4 simulation result	69
4.16	Facade of case 4 simulation result	69
4.17	Simulation result of case 5	71
4.18	The 3D view of case 5 simulation result view from north-east (left) and south-west (right)	71
4.19	Top view of case 5 simulation result	72
4.20	Facade of case 5 simulation result	72
4.21	Simulation result of case 6	74
4.22	The 3D view of case 6 simulation result view from north-east (left) and south-west (right)	74
4.23	Top view of case 5 simulation result	75
4.24	Facade of case 5 simulation result	75
4.25	Case 1 simulation of 3 floors without light shelf	79
4.26	Case 1 (no light shelves) simulation result on 6 th floor (left) and 13 th floor (right)	80
4.27	Case 1 (no light shelves) simulation result on 23 th floor	80
4.28	Case 2 simulation result on 6 th (left) and 16 th (right)	82
4.29	Case 2 simulaiton result on 23th	82
4.30	Case 3 simulation result on 6 th floor (left) and 16 th floor (right)	84
4.31	Case 3 simulaiton result on 23 rd floor	84
4.32	Case 4 simulation result for 6 th floor (left) and 16 th floor (right)	86

4.33	Case 4 simulation result for 23 rd floor	86
4.34	Case 5 simulation result (1500mm light shelf) of 6 th floor (left) and 16 th floor (right)	88
4.35	Case 5 simulation result (1500mm light shelf) of 23 th floor	88
4.36	Daylight Factor simulation result for Case 1 (without light shelves) on left and Case 5 (with 1500mm light shelves and reflective ceiling) on right	91

LIST OF APPENDIXES

NO.	TITLE	PAGE
A	List of compilations of final design thesis presentation boards and drawings	104

CHAPTER 1

INTRODUCTION

1.1 Introduction

Daylight availability in Malaysia can be considered numerous in amount throughout the year, but energy usage for typical office building remain high with average Building Energy Index (BEI) of 200 to 250 kWh/m²/year (Chan, 2009) as shown in Figure 1.0. Without taking daylighting as part of the design consideration, the building design will lead to a typical deep building plan design that rely heavily on artificial light despite of having large window opening.

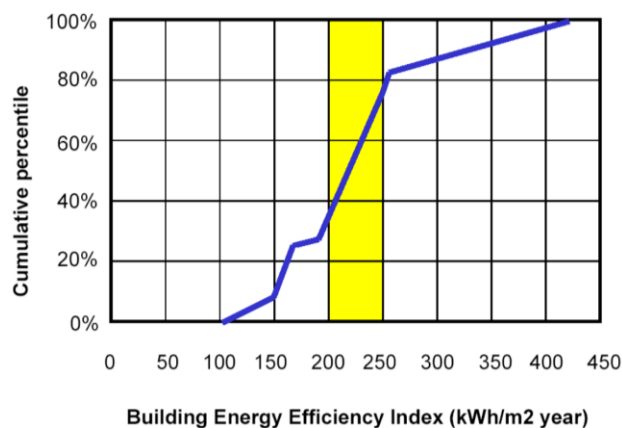


Figure 1.0: Average of building energy efficiency in Malaysia (Source: Chan, 2009)

Furthermore, despite of high direct solar heat gain of high rise facades, intends usage of expensive glazing caused emerging forest of “glass boxes” office building design which further worsen urban heat island effect and lead to high energy consumption for cooling. As energy efficiency is one of the key to sustainable future therefore through passive daylighting principles, building performance and working environment in office building can be enhanced and hence achieving energy efficient in office building.

By prioritizing the key principles of daylighting harvesting which are solar heat gain minimisation, glare prevention, deep penetration of daylight, uniform daylight distribution, electrical light response to daylight harvested and lastly interior designing will aid designer to design building that are more sustainable and efficient in the future.

The average minimum daylight available in Malaysia is above 10,000 lux during daytime and with office spaces only required daylighting of 300 lux to 400 lux during working hour. Thus, this shows that there is potential in harvesting daylight in Malaysia. Therefore, buildings should be designed to maximise the amount of natural light that enters the building, particularly workplaces. This can lead to significant energy savings by reducing the need for artificial lighting and furthermore has been shown to improve productivity (Edwards & Torcellini, 2002).

1.2 Background Studies

According to Green Tech Malaysia (2010), office building is the third highest energy consumption building typology after the hospital and hotel building in second and first respectively as shown in Figure 1.1. When building consumed high energy, it also represents the high carbon emission to the environment. Green Technology Corporation (2011) stated in the Clean Development Mechanism (CDM) Report, every

0.747kg of CO² equals to 1kWh of electricity generated by power plant in Peninsula Malaysia.

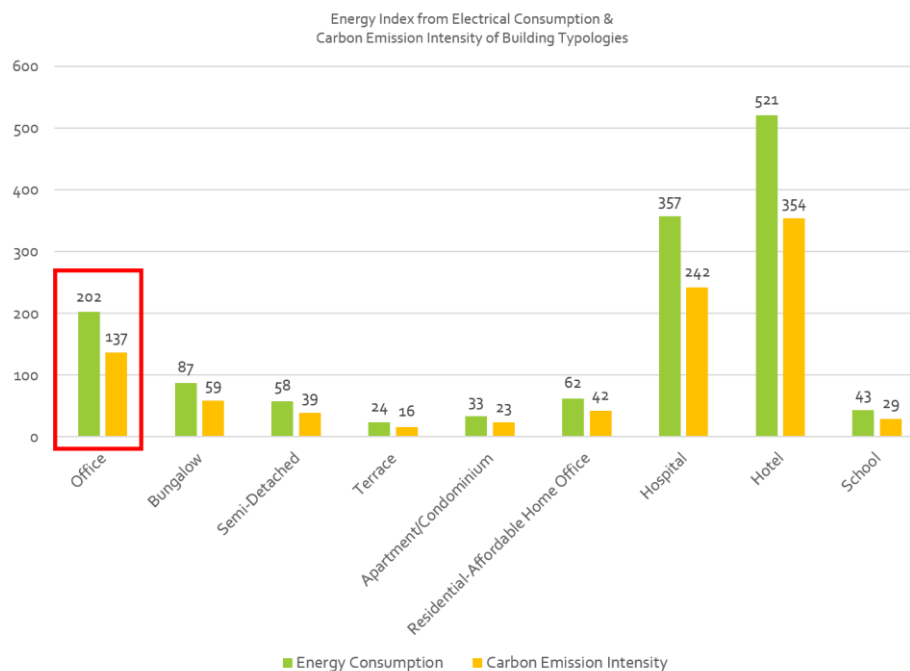


Figure 1.1: Energy index from electrical consumption and carbon emission intensity of building typologies in Malaysia (Source: Green Tech Malaysia ,2010)

Figure 1.2 shows that Malaysia is the highest CO² emission per capita compared to neighbouring countries such as Singapore and Indonesia (World Bank, 2016). World Resources Institute (WRI) suggested that 2 tons of CO² per capita per year must be targeted for a sustainable living on earth while currently Malaysia is on 7.9 tonnes per capita which exceeded the suggested CO² emission per capita.

As Malaysia's voluntarily committed to reduce 40% of its greenhouse gas (GHG) emissions from 1990 levels by 2020, announced at the 2009 United Nations Climate Change Conference in Copenhagen (COP-15). Therefore, it is crucial for office building in Malaysia to be energy efficiency to significantly reduce energy consumption and carbon emission.

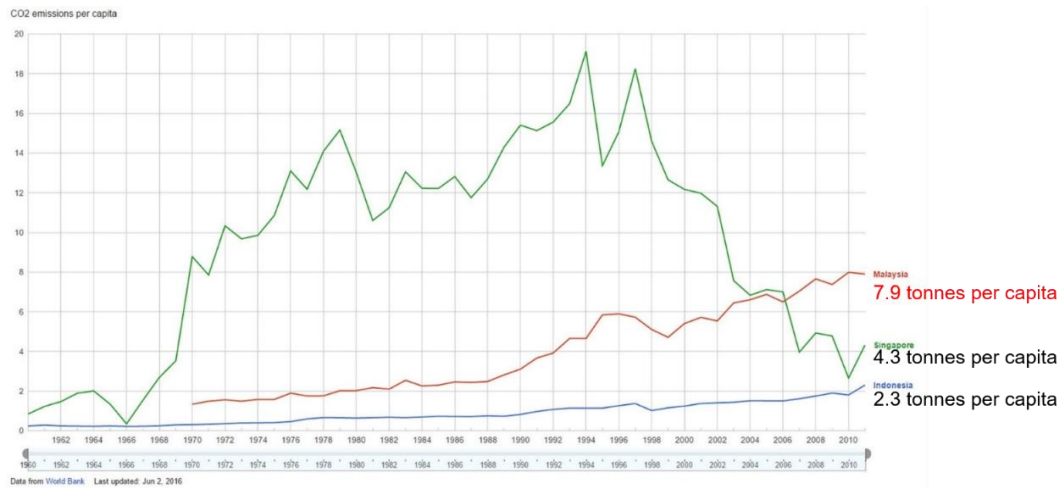


Figure 1.2: CO² emission per capita of Malaysia, Singapore and Indonesia from year of 1952 to 2010 (Source: World Bank, 2016)

1.3 Problem Statement

Typical office building in Malaysia is ranked as the top three building typology of high energy consumption and carbon emission (Green Tech Malaysia, 2010). As shown in Figure 1.3, the energy consumption during the operational stage by artificial light is second highest (20%) after the HVAC (58%). Therefore, by implementing the key principles of daylighting during the initial design stage will enhance the building's performances as it reduces the usage of artificial lighting and hence reduce the energy consumption of the building.

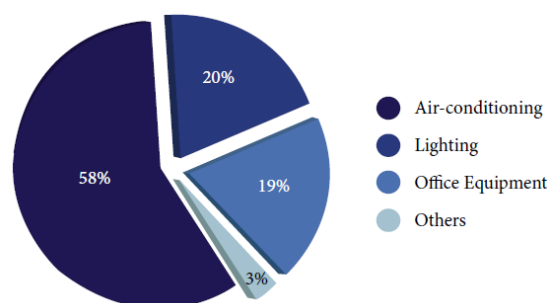


Figure 1.3: Typical electricity usage in office buildings in Malaysia (Source: Energy Commission, 2016)

1.4 Research Aim

The aim of the research is to establish a daylight driven office building design that improve the energy efficiency of office building in tropical climate.

1.5 Objectives of the Study

There are three main objectives that are targeted to be achieved in this research which stated as below: -

- i. To identify the daylight strategies in achieving optimum daylight penetration into the building.
- ii. To determine the building form through daylight principles.
- iii. To develop integrated daylighting strategies for optimum working environment and hence enhancing energy efficiency of building.

1.6 Research Questions

The research questions are established and is interrelated to the objective of the study are stated as below: -

- a) What are the possible daylight strategies that can be implemented to enhance daylight penetration into the building in tropical climate?
- b) How daylighting enhances the working environment and enhancing the energy efficiency of building?
- c) How daylight principles affect the building forms?

1.7 Significance of the Study

This research is crucial in understanding the important role of daylighting and integrated the strategies into design consideration especially during the initial stage of building design. This can significantly improve the energy performance of the building. By taking solar as the design driving force, it will establish a solar and environmentally responsive architecture design which will enhance the energy efficiency as well as the working environment of the building. Finally, the findings of this research will be implemented and integrated into the design thesis as part of the design strategies.

1.8 Research Methodology

The research methodology employed primary is through computer simulation. Software such as Insight 360 Revit solar simulation will be used to analyse the solar heat gain of six building forms and Velux simulation software is used to analyse the daylight's quantity and quality the six cases regarding light shelf and reflective ceiling.

Apart from computer simulation, three case studies of energy efficient office buildings in Malaysia are selected to compare and analyse the daylighting strategies that implemented and their performances. Further information regarding research methodology and the framework of research will be elaborated in Chapter 3.

1.9 Structure of Thesis

Referring to Figure 1.4, it shows the structure of the thesis which developed from objectives to data collection then followed by data analysis and lastly conclude with expected findings.

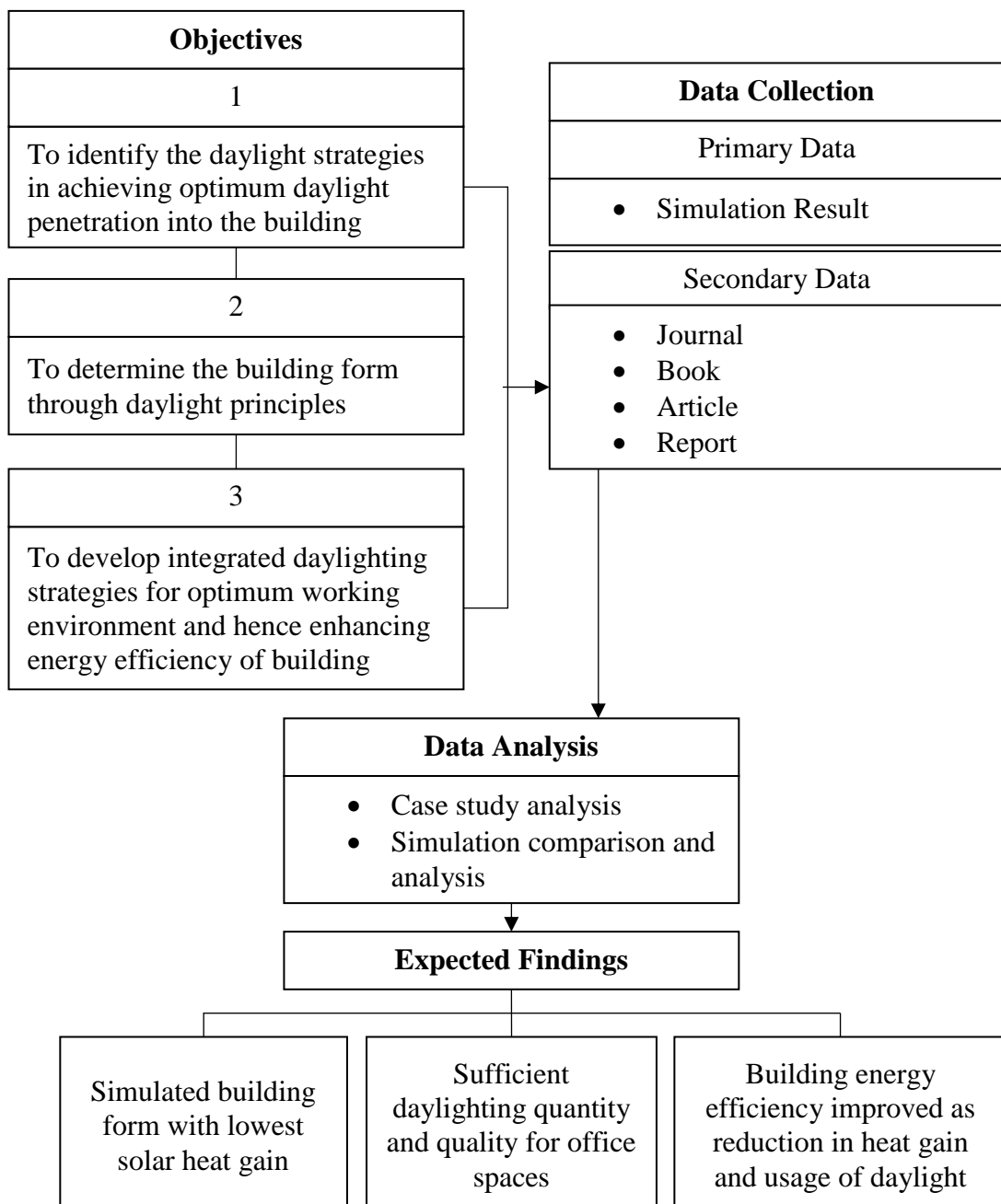


Figure 1.4 Structure of Thesis

REFERENCES

- Ander, G. D. (2003). *Daylighting Performance and Design* (2nd ed.). Hoboken, New Jersey: John Wiley & Sons, Inc.
- Autodesk . (2017). *Sustainability Workshop Glazing Properties*. Retrieved 22 March, 2017, from <https://sustainabilityworkshop.autodesk.com/buildings/glazing-properties#SHGC>
- Autodesk. (2011). *Sustainability workshop*. Retrieved 15 March, 2017, from <http://sustainabilityworkshop.autodesk.com/buildings/massing-orientation-daylighting>
- Autodesk. (2017). *Autodesk INSIGHT 360*. Retrieved 11 March, 2017, from <http://www.autodesk.com/products/insight-360/overview>
- Autodesk Education Community. (2011). *Autodesk Sustainability Workshop*. Retrieved 11 June, 2015, from Passive Design Strategies | Sustainability Workshop: <http://sustainabilityworkshop.autodesk.com/buildings/massing-orientation-cooling>
- Bainbridge, D., & Haggard, K. (2011). *Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting and More Using Natural Flows* (1st ed.). United State: Chelsea Green.
- Battisto, D., & Franqui, D. (2013). A Standardized Case Study Framework and Methodology to Identify "Best Practices". Clemson, South Carolina: Clemson University.
- Beltran, L. O., Lee, E. S., Papamichael, K., & Selkowitz, S. (1994). The design and evaluation of three advanced daylighting systems: light shelves, light pipes and skylights. Berkeley, CA: Lawrence Berkeley National Laboratory.
- Bleicher, P. D.-I. (29 May, 2014). *Climate Responsive Building Design- ZEO Building in Kuala Lumpur, Malaysia*. Retrieved 14 December, 2016, from en.e4g.org: <http://en.e4g.org/wp-content/uploads/2015/07/E4G-Climate-responsive-building-design-----Malaysia-project-Volkmar-Bleicher-ENG.pdf>
- Boyce, P., Hunter, C., & Howlett, O. (2003). *The benefits of daylight through windows*. Troy (NY): Rensselaer Polytechnic Institute.
- Bright Shelf. (2015). *BrightShelf® vs. Traditional Flat Shelf*. Retrieved 3 May, 2017, from http://www.brightshelf.com/light_shelf_comparison.html
- Carmody, J., Selkowitz, S., Lee, E. S., Arasteh, D., & T., W. (2004). *Window system for high performance building*. New York: Norton & Company.

- Chan, S. A. (14 February, 2009). *GREEN BUILDING INDEX – MS1525 Applying MS1525:2007 Code of Practice on Energy Efficiency and Use of Renewable*. Retrieved 20 May, 2017, from [http://www.greenbuildingindex.org/Resources/20090214%20-%20GBI%20MS1525-2007%20Seminar/20090214%20-%20GBI%20MS1525-2007%20Seminar%20\(CSA\)%20Notes.pdf](http://www.greenbuildingindex.org/Resources/20090214%20-%20GBI%20MS1525-2007%20Seminar/20090214%20-%20GBI%20MS1525-2007%20Seminar%20(CSA)%20Notes.pdf)
- Chen, T., P.E., ENG, C., Ashrae, F., & P.E, A. I. (2013). Malaysia's Green Diamond. *High Performing Building Fall 2013*, 20-32.
- Chia, C. P. (2004). The Performance of Daylighting with Shading Device. *Tamkang Journal of Science and Engineering*, VII(4), 205-212.
- Department of Standard Malaysia. (2007). *MS 1525*. Malaysia: Department of Standard Malaysia.
- Edwards, L., & Torcellini, P. (2002). *A Literature Review of the Effects of Natural Light on Building Occupants*. United States: National Renewable Energy Laboratory.
- Egan, D. M., & Olgyay, V. (2003). *Architectural lighting* (Architectural lighting 2nd ed.). Troy (NY): Lighting Research Center.
- Energy Commission. (2016). *Guidelines on No-Cost and Low-Cost Measures for Efficient Use of Electricity in Buildings*. Putrajaya: Suruhanjaya Tenaga (Energy Commission).
- Evans, B. H. (1961). *Natural Lighting and Skylights*. Texas: A&M University.
- Evans, B. H. (1981). *Daylight in Architecture* (Architectural Record ed.). America: McGraw-Hill Publication Company.
- Garcia Hansen, V., & Edmonds, I. (2003). Natural Illumination of Deep-Plan Office Buildings: Light Pipe Strategies. Sweden: Research Gate.
- Garde, F., Mara, T., Laure, A. P., Boyer, H., & and Cellaire, R. (2001). Bringing Simulation to Implementation: Presentation of Global Approach in the Design of Passive Solar Buildings under Humid Tropical Climates. *Journal of Solar Energy*(71), 109-120.
- GDP Architect. (2015). *KKR2 Tower*. Retrieved 23 May, 2017, from <http://gdparchitects.com/2015/?project=kk2-tower>
- General Services Administration (US). (2016). *Integrated Daylight System*. Retrieved 23 May, 2017, from <https://www.gsa.gov/portal/content/193339>
- Google. (2017). *Google Map*. Retrieved 23 May, 2017, from <https://www.google.com.my/maps/@3.1531586,101.6904303,275m/data=!3m1!1e3?hl=en>

- Green Building Index Sdn Bhd. (2013). *WHAT IS A GREEN BUILDING?* Retrieved 4 March, 2017, from <http://www.greenbuildingindex.org/why-green-buildings.html>
- Green Tech Malaysia. (29 March, 2010). *Common Carbon Metric Report*. Putrajaya: Green Tech. Retrieved 20 May, 2017, from <https://www.slideshare.net/asetip/common-carbon-metric-in-buildings-in-putrajaya>
- Hopkinson, R. G., & Longmore, J. (1959). Lighting Research & Technology. *The Permanent Supplementary Artificial Lighting of Interiors*, 24(3), 121-148.
- IEN Consultants. (27 August, 2015). *Daylight Strategies and Case Studies*. Retrieved 23 March, 2017, from <http://www.ien.com.my/downloads/Daylighting-Strategies-and-Case%20Studies-By%20Gregers%20Reimann-IEN%20Consultants.pdf>
- Lechner, N. (2014). *Heating, Cooling and Lighting: Sustainable Design Methods for Architects* (4th ed.). Canada: John Wiley & Sons, Inc.
- Lee, E. S., & Selkowitz, S. (1995). The Design and Evaluation of Integrated Envelope and Lighting Control Strategies for Commercial Building. *ASHRAE Transaction* 95, 1(101), 326-342.
- Lightway Crysrtal Tubular Skylights. (2010). *What are Light Pipes*. Retrieved 4 May, 2017, from <http://www.lightway.cz/en/sunlight/what-are-light-pipes/>
- Mardaljevic, J., Hescong, L., & Lee, E. (2009). Daylight metrics and energy saving. *Lighting Res. Technol*, 41(3), 261-283.
- NBI, IDL, & Architect, I. I. (2014). *Daylighting Guide For Office Interior*. Retrieved 16 March, 2017, from <http://www.advancedbuildings.net/files/advancebuildings/DaylightingGuideOfficeInteriors.pdf>
- Ng, B. H., & Zainal, A. b. (2011). An Overview of Malaysia Green Technology Corporation Office. *Journal of Sustainable Development*, 212-228.
- Oberlin College . (8 September , 2009). *Chapter 6: Windows, Light, and Heat Gain* . Retrieved 3 May, 2017, from <http://www.oberlin.edu/physics/Scofield/p268/library/Ch-06%20Windows.pdf>
- Philip, L. (2010). Introduction to Daylighting. Sun Cam.
- Ransen, O. F. (2017). *Candelas, Lumens and Lux* (2nd ed.). Owen Ransen.
- Rea, M. S. (2000). *IESNA Lighting Handbook: Reference and Application* (9th ed.). New York: Illuminating Engineering Society of North America.

- Reinhart, C., & Otis, T. (13 March , 2009). *Daylighting "Rule of Thumb"*. Retrieved 3 May, 2017, from <http://isites.harvard.edu/fs/docs/icb.topic539779.files/Diffuse%20Daylighting%20Design%20Sequence.pdf>
- Roche, L., Dewey, E., & Littlefair, P. (2000). Occupant reactions to daylight in office. *Lighting Research and Technology*, 32(3), 119-126.
- Rungta, S., & Singh, V. (2011). *Design Guide: Horizontal Shading devices and Light Shelves*. Retrieved 22 March, 2017, from <http://studylib.net/doc/18142586/table-of-contents>
- Saddam Hussin, 3. D. (10 December, 2014). *KKR2*. Retrieved 23 May, 2017, from <https://www.slideshare.net/MUHAMMADHUSSIN4/kkr-2>
- Singh, M. C., & Garg, S. N. (2011). Suitable Glazing Selection for Glass Curtain Walls in Tropical Climate of India. *ISRN Renewable Energy*, 2011, 11-23.
- Smith, P. (2005). *Architecture in a climate of change* (2nd ed.). London: Oxford: Architectural Press.
- Sonia, A., & Valerian, M. (2005). Development Of An Integrated Building Design Information Interface. Montreal, Canada: Ninth International IBPSA Conference.
- Suruhanjaya Tenaga. (2013). *Energy Commission Diamond Building [The Gem of Putrajaya]*. Putrajaya: ENERGY COMMISSION (SURUHANJAYA TENAGA).
- Tang, C., & Chin, N. (2013). *Building Energy Efficiency Technical Guideline for Passive Design*. Kuala Lumpur: Building Sector Energy Efficiency Project (BSEEP).
- The Society of Light and Lighting. (2002). *Lighting Guide 7: Office Lighting* (7 ed.). England: Chartered Institution of Building Services Engineers.
- Trimble Inc. (2017). *Sketchup*. Retrieved 23 May, 2017, from http://www.sketchup.com/products/sketchup-pro/new-in-2017?gclid=Cj0KEQjwmIrJBRCRmJ_x7KDo-9oBEiQAuUPKMIK5b5ozXne4-FPMLpRT903EGEPbnvL0FZFOy11b22oaAnHj8P8HAQ
- U.S. Department of Energy. (2007). *National Best Practices Manual For Building High Performance Schools*. United State: Office of Energy Efficiency and Renewable Energy.
- VELUX Group. (2005). *VELUX Daylight Visualizer*. Retrieved 11 March, 2017, from <http://www.velux.com/article/2016/daylight-visualizer>

- Von, C. E. (6 December, 2015). *Project 1: Lighting & Acoustics Performance Evaluation & Design* . Retrieved 23 May, 2017, from https://issuu.com/cheaheevon/docs/building_science_menara_kkr2
- WAUSAU . (2010). *Understanding U-Factor*. Retrieved 3 May, 2017, from <http://www.wausauwindow.com/resources/education/ufactors/ufactor.pdf>
- Wilkinson, M. A. (1992). Lighting Research and Technology. *The effect of glazing upon energy consumption withing buildings*, 24(2), 99-101.
- World Bank. (2016). *CO2 emissions (metric tons per capita)*. Retrieved 20 May, 2017, from <http://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=MY>
- Zumtobel Group. (2013). *The Lighting Handbook* (4th ed.). Austria: Zumtobel .