UNIVERSITI PUTRA MALAYSIA

THERMAL PERCEPTION AND WILLINGNESS TO WALK AMONG OFFICE WORKERS IN TROPICAL LOW CARBON CITY OF PUTRAJAYA, MALAYSIA

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FRSB 2020 8

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Master of Science

May 2020

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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May 2020

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Majority of the city dwellers do not normally engage in regular physical activities due to their built environments that are designed to favour mobility by motor vehicles. For the last thirty years, the Malaysian population perpetrated high obesity rates due to decreased physical activity. Data from the Ministry of Health, Malaysia revealed that 73% of the total deaths recorded were due to Non-Communicable Diseases (NCDs), of which, approximately 35% comprised of the working population (< 60 years). Low Carbon City (LCC) is a concept of holistically minimizing carbon emissions in ways that do not compromise economic development and livability of the city. The Malaysian administrative capital—Putrajaya is among one of the designated Tropical Low Carbon City (TLCC) projects initiated by the government to reduce CO^2 emission intensity. This study was conducted to investigate the physical inactivity among office workers through their perceived thermal hindrances on exposure to transient thermal conditions at three different building sites in Putrajaya. The multi-method research framework was applied combining the field measurements and cross-sectional survey approaches. Respondents suffering from NCD were identified and their level of awareness in pursuing active lifestyles was assessed. Perceived thermal hindrances that led to physical inactivity were measured by asking participants to rate their thermal sensation and thermal comfort votes at three different times of the working weekdays, namely morning (7:00-11:59 a.m.), afternoon (12:00-15:59 p.m.) and evening (16:00-18:30 p.m.). Structured observations using a walkability checklist were carried out to explore the features that decrease office workers' willingness to walk in tropical climate. This study is among the first of its kind conducted in a TLCC. The findings may contribute to the National policy on Climate Change, particularly under the premises of societal well-being and environmental protection, as well as complement the LCC Framework. The results suggest that around 85% of the respondents in Putrajaya are vehicle dependent. Most of the respondents were willing to improve their health by walking more but expressed that the midday heat and the natural humidity of the tropical weather coupled with the lack of shaded paths were the main reasons for them to opt for motor vehicles as their mode of transportation in Putrajaya.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PERSEPSI TERMAL DAN KESEDIAAN UNTUK BERJALAN DIKALANGAN PEKERJA PEJABAT DI BANDAR TROPIKA PUTRAJAYA, MALAYSIA

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Sebilangan besar penduduk bandar jarang melakukan aktiviti fizikal kerana persekitarannya yang dibina lebih menggalakkan pergerakan kenderaan bermotor. Selama tiga puluh tahun yang lalu, penduduk Malaysia mengalami kadar kegemukan yang tinggi disebabkan oleh aktiviti fizikal yang menurun. Data dari Kementerian Kesihatan, Malaysia menunjukkan bahawa 73% daripada jumlah kematian disebabkan oleh Penyakit Tidak Berjangkit (NCD), di mana sekitar 35% berasal dari tenaga kerja di bawah umur 60 tahun. Low Carbon City (LCC) adalah konsep ke arah meminimakan pelepasan karbon secara holistik tanpa menghalang pembangunan ekonomi dan kemampuan hidup di bandar. Ibu negeri pentadbiran Malaysia - Putrajaya adalah salah satu projek Tropical Low Carbon City (TLCC) yang ditetapkan oleh kerajaan bagi mengurangkan intensiti pelepasan CO2. Kajian ini dilakukan untuk mengkaji ketidakaktifan fizikal di kalangan pekerja pejabat berdasarkan kekangan terhadap haba yang dialami apabila terdedah kepada keadaan haba sementara di tiga lokasi bangunan yang berbeza di Putrajaya. Rangka kerja penyelidikan pelbagai kaedah telah digunakan dengan menggabungkan kajian lapangan dan kajian soal selidik secara rentas. Responden yang menderita NCD dikenal pasti dan tahap kesedaran mereka mengenai gaya hidup aktif dinilai. Halangan terma yang menyebabkan ketidakaktifan fizikal dikaji dengan meminta peserta menilai sensasi termal dan keselesaan termal mereka pada tiga waktu yang berbeza pada hari kerja, iaitu pagi (7:00-11:59 am), tengah hari (12:00-15:59 pm) dan petang (16:00-18:30 pm). Pemerhatian berstruktur menggunakan senarai semak kemampuan untuk berjalan dilakukan untuk meneroka ciri-ciri yang mengurangkan kesediaan pekerja pejabat untuk berjalan di iklim tropika. Kajian ini adalah antara yang pertama seumpamanya yang dijalankan dalam TLCC. Penemuan ini boleh menyumbang kepada Dasar Perubahan Iklim Negara, terutamanya di bawah premis kesejahteraan masyarakat dan perlindungan alam sekitar, serta melengkapi rangka kerja LCC. Hasil kajian menunjukkan bahawa sekitar 85% responden di Putrajaya bergantung pada kenderaan. Sebilangan besar responden bersedia untuk meningkatkan kesihatan mereka dengan berjalan lebih banyak tetapi menyatakan bahawa panas pada waktu petang dan kelembapan semula jadi cuaca tropika ditambah dengan kekurangan jalan teduh adalah sebab utama mereka memilih kenderaan bermotor sebagai mod pengangkutan mereka di Putrajaya.

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere gratitude to my research supervisor Dr. Nur Dalilah Binti Dahlan, for her continuous support and help at all stages of implementation of the thesis. Her professional assistance and valuable guidance enabled me to learn a lot; creating opportunities for improvement and successful completion of this research work.

Secondly, I wish to thank my co-supervisor Associate Professor, Dr. Zalina Shari, for her valuable remarks and suggestions to improve our work. Special mention should also be made to the leading organizations – the Faculty of Design and Architecture and School of Graduate Studies, at Universiti Putra Malaysia for their assistance during the research process by providing facilities that help students to thrive. Also, I would like to express my appreciation to Mr. Mohd Khairun Nizam Mohamad Noh and the enumerators, namely, Loke Hau Yee, Nur Azzianna Azween Binti Hamzah and Aina Syazana Bt Ahmad Zubir for their kind involvement in this study.

Finally, I would like to thank my loving family for sharing the dream and just being there for me.

I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of Mainur Kurmanbekova on her thesis entitled "Thermal Perception and Willingness to Walk among Office Workers in Tropical Low Carbon City of Putrajaya, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

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TABLE OF CONTENTS

		Page
ABSTRACT		i
ABSTRAK		ii
ACKNOWLEDGEMENTS		iii
APPROVAL		iv
DECLARATION		vi
LIST OF TABLES		xi
LIST OF FIGURES		xii
LIST OF ABBREVIATIONS		xv
CHAPTER		
1	**INTRODUCTION**	1
1.1	Research Background	1
1.1.1	Weather as the Hindrance Factor to Physical Activeness in Hot Climate Countries	1
1.1.2	Low Carbon City Concept Worldwide	3
1.1.3	Low Carbon City Concept in Malaysia	4
1.2	Problem Statement	5
1.3	Research Gap	7
1.4	Research Questions and Objectives	7
1.5	Scope and Limitations of the Study	8
1.6	Significance of the Study	8
1.7	Definition of Terms	9
1.8	Research Flowchart	10
1.9	Thesis Structure	11
2	**LITERATURE REVIEW**	12
2.1	Overview of Outdoor Thermal Comfort and Physical Activities	13
2.1.1	Introduction to Outdoor Thermal Comfort in Urban Environment	14
2.1.2	Overview of Outdoor Thermal Comfort Indices	15
2.1.3	Outdoor Thermal Comfort Assessments	15
2.2	Mixed-use Development Standards and Willingness to Walk	18
2.2.1	Overview of the Existing Low Carbon Cities	19
2.2.2	Overview of Sustainable Urban Design Parameters for Tropical Climate	22
2.2.3	Urban Landscape Design	23
2.3	Built Environment of TLCC and NCDs	24
2.3.1	Awareness to NCDs	25
2.3.2	Walking in TLCC	25

2.3.3 Low Carbon Transportation 26
2.3.4 Walking to Work 27
2.3.5 Pedestrian Environment and Benefits of Walking 28

3 RESEARCH METHODOLOGY 38
3.1 Selected Locations 38
3.1.1 Geography and Climate 38
3.1.2 Selected Buildings 39
3.2 Methodology 42
3.2.1 Objective Measurements 42
3.2.2 Subjective Measurements 46
3.3 Sampling method 48
3.4 Data Analysis 49

4 RESULTS AND DISCUSSIONS 50
4.1 Descriptive Analysis 50
4.1.1 Socio-demographic Variables 50
4.1.2 Clothing Insulation Values 56
4.1.3 Physical Activity 57
4.2 Research Objective 1: Weather as a Factor Affecting Willingness to Walk 60
4.2.1 Results 60
4.2.2 Discussion 85
4.3 Research Objective 2: Built Environment Conditions as Factors Affecting Willingness to Walk 87
4.3.1 B1 88
4.3.2 B2 92
4.3.3 B3 97
4.3.4 Discussion 101
4.4 Environmental and Commuting Factors Analysis 105
4.4.1 Commuting to Work 105
4.4.2 Relationship between BMI and Tolerance to Sun Exposure 107
4.4.3 Relationship between BMI and Perception to Air Movement 107
4.4.4 Relationship between Age and Tolerance to Sun Exposure 109
4.4.5 Relationship between Age and Perception to Air Movement 110
4.4.6 Relationship between NCDs and Tolerance to Sun Exposure 112
4.4.7 Relationship between NCDs and Perception to Air Movement 112
4.4.8 Discussion 113
4.5 Research Objective 3: An Assessment of Awareness of Physical Activity Levels as a Factor Affecting Non-Communicable Diseases 114
4.5.1 NCDs Awareness in Relation to Willingness to Walk 114

4.5.2 Relationship between Gender and Awareness Level to Physical Inactivity/Willingness to Walk 116
4.5.3 Relationship between Age and Awareness Level to Physical Inactivity/Willingness to Walk 118
4.5.4 Relationship between BMI and Awareness Level to Physical Inactivity/Willingness to Walk 119
4.5.5 Discussion 121

5 CONCLUSION AND RECOMMENDATIONS 122
5.1 Introduction 122
5.2 Overview 122
5.3 Conclusion 122
5.4 Knowledge Contribution 123
5.5 Recommendations 124

REFERENCES 125
APPENDICES 155
BIODATA OF STUDENT 165
PUBLICATION 166

LIST OF TABLES

Table		Page
2.1	Case studies of 10 cities with known or recent low carbon strategies	21
2.2	Summary of studies investigating outdoor thermal comfort, perception, and sensation assessments and their influence on physical activities	29
2.3	Summary of studies investigating outdoor built environment and their influence on physical activities	34
3.1	ASHRAE 7-point Thermal Comfort and Sensation scale	47
4.1	Mean Level of Frequency of Weekly Walking by Site and Gender of Respondents	74
4.2	The Pearson Correlation between Walking and NCDs in the Three Sites	78
4.3	Outdoor Thermal Sensation Vote against Age	82
4.4	Outdoor Thermal Sensation Vote against NCDs	85
4.5	Walkability Checklist at three sites	101
4.6	The Pearson Correlation between Age and TSE in Three Sites	109
4.7	The Pearson Correlation between NCDs and TSE in the Three Sites	112
4.8	The Pearson Correlation between NCDs and PAM in the Three Sites	113

LIST OF FIGURES

Figure		Page
1.1	The Research Flowchart	10
2.1	Conceptual Framework	13
3.1	Weather Statistics for Putrajaya	39
3.2	The Site Plan of Putrajaya	40
3.3	The Ministry of Higher Education building (B1)	41
3.4	The Galeria PjH building (B2)	41
3.5	The Energy Commission of Malaysia building (B3)	42
3.6	Instrument position at B1	43
3.7	Instrument position at B2	44
3.8	Instrument position at B3	44
3.9	OHM Delta HD 32.2 instrument	45
4.1	Total Percentage of Respondents by Gender per Site	51
4.2	Breakdown of age group of the respondents in B1	52
4.3	Breakdown of age group of the respondents in B2	52
4.4	Breakdown of age group of the respondents in B3	53
4.5	Percentage of Residency Status of respondents	54
4.6	Percentage of Office Workers suffering from NCDs in the three Study Areas	55
4.7	BMI Percentage per Site	56
4.8	Mean Full Clothing Values	57
4.9	Frequency of Weekly Moderate Walking (≥10min)	58
4.10	Time Spent Walking per Day	59
4.11	Frequency of Weekly Cycling (≥10min)	59
4.12	Façade Materials of B2 Building	61
4.13	Water Feature at the Entrance to B3	62
4.14	Mean Ta (C^o) During Field Measurements	62
4.15	Mean RH (%) During Field Measurements	63
4.16	Mean Va (m/s) During Field Measurements	64
4.17	300 m Radius Map of B1	65
4.18	Mean TCV and TSV between Three Sites	66
4.19	General Weekly Walking by Age	67
4.20	Frequency of Weekly Walking by Age	67
4.21	Time Spent Walking per Day by Age Group at B1	68
4.22	Time Spent Walking per Day by Age Group at B2	69
4.23	Time Spent Walking per Day by Age Group at B3	69
4.24	General Weekly Walking vs. BMI	70
4.25	Moderate Weekly Walking vs. BMI	71
4.26	Time Spent Walking per Day vs. BMI at B1 (n = 165)	72
4.27	Time Spent Walking per Day vs. BMI at B2 (n = 148)	72
4.28	Time Spent Walking per Day vs. BMI at B3 (n = 75)	73
4.29	Frequency of Weekly Walking by Gender at B1, B2, and B3	74
4.30	Time Spent Walking per day with reference to Gender at B1 site	75

4.31	Time Spent Walking per day with reference to Gender at B2 site	75
4.32	Time spent walking per day with reference to Gender at B3 site	76
4.33	General Weekly Walking among Residents and Non-Residents of Putrajaya	77
4.34	Frequency of Weekly Walking among Residents and Non-Residents of Putrajaya	77
4.35	Time Spent Walking per Day among Residents and Non-Residents of Putrajaya	78
4.36	General Weekly Walking vs. NCDs	79
4.37	Frequency of Weekly Walking vs. NCDs	79
4.38	Time Spent Walking Per Day vs. Number of Respondents with NCDs at B1	80
4.39	Time Spent Walking Per Day vs. Number of Respondents with NCDs at B2	81
4.40	Time Spent Walking Per Day vs. Number of Respondents with NCDs at B3	81
4.41	Mean TSV of Respondents by their BMI across Three Sites	83
4.42	Outdoor Thermal Sensation Vote by Gender	84
4.43	Outdoor Thermal Sensation Votes of Residents and Non-residents of Putrajaya Office Workers	85
4.44	The Bus stops and Parking Map of the B1 site	89
4.45	Walking and Cycling Amenities at B1 site	90
4.46	Facilities in Close Proximity to B1 site	91
4.47	Public Transport Diagram of the B2 site	94
4.48	Walking and Cycling Amenities at B2 site	95
4.49	Facilities in Close Proximity to B2 site	96
4.50	Public Transport Diagram of the B3 site	98
4.51	Walking and Cycling Amenities at B3 site	99
4.52	Facilities in Close Proximity to B3 site	100
4.53	Frequency of Daily Commuting by Motor Vehicle by Site	106
4.54	Frequency of Daily Commuting to Work by Walking per Site	106
4.55	Mean TSE vs. BMI	107
4.56	Overall Relation between PAM Indoor against BMI	108
4.57	Overall Relation between PAM Outdoor against BMI	108
4.58	Frequency of TSE Indoor by Age	109
4.59	Frequency of TSE Outdoor by Age	110
4.60	Frequency of PAM Outdoor by Age at B1	111
4.61	Frequency of PAM Outdoor by Age at B2	111
4.62	Frequency of PAM Outdoor by Age at B3	112
4.63	Percentage of Awareness to Physical Inactivity between the Respondents with NCDs vs. without NCDs	115
4.64	Percentage of Willingness to Walk More between the Respondents with NCDs vs. without NCDs	115
4.65	Male Respondents' Awareness Level	116
4.66	Female Respondents' Awareness Level	117
4.67	Willingness to Walk by Gender	118
4.68	Awareness Level vs. Age	119

4.69	Willingness to Walk vs. Age	120
4.70	Willingness to Walk vs. BMI	120
4.71	Awareness Level vs. BMI	122

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
C40	C40 Cities Climate Leadership Group
CDP	Carbon Disclosure Project
CDV	Cardiovascular Diseases
COP	Conference of Parties
CRD	Chronic Respiratory Diseases
GHG	Greenhouse Gas
GHO	Global Health Observatory
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KeTTHA	Ministry of Energy, Green Technology and Water, Malaysia
LCC	Low-Carbon City
LCCF	Low Carbon City Framework and Assessment System
NCDs	Non-Communicable Diseases
NGTP	National Green Technology Policy
NHMS	National Health and Morbidity Survey, Malaysia
OECD	Organization for Economic Cooperation and Development
PET	Physiologically Equivalent Temperature
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
PT	Perceived Temperature
SET	Standard Effective Temperature
SOV	Single Occupancy Vehicle
THI	Temperature Humidity Index
TLCC	Tropical Low-Carbon City
UCMap	Urban Climate Map and Standards for Wind Environment
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UTCI	Universal Thermal Climate Index
WBGT	Wet Bulb Globe Temperature
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Research Background

1.1.1 Weather as the Hindrance Factor to Physical Activeness in Hot Climate Countries

The occurrence and intensity of extreme weather events are regarded by scientists as an increasing consequence of the climate change. Climatic changes have impacts on the frequency, severity, and characteristics of many extreme weather occurrences including droughts, floods, heavy rain, snowfalls, cyclones, hurricanes, heat and cold waves since 1950s (Q. Cao et al., 2018; Naveendrakumar et al., 2019; Pachauri et al., 2014). In addition, Asia and the Pacific regions are regarded as the most disaster-prone area of the world. This is supported by the Organization for Economic Cooperation and Development (OECD, 2018) report that increasing numbers of heat-wave related mortality and morbidity is an emerging public health concerns in South East Asia (Phung et al., 2017; M. Singh et al., 2016). Workplace productivity losses and heat-stress disorders are some of the consequences that have been widely reported by Kjellstrom and colleagues (Kjellstrom et al., 2009; Sahu et al., 2013; Zander et al., 2015). According to the International Labour Organization (ILO) report, in the coming two decades Malaysia will lose 1.5 per cent of working hours (or 246 thousands full-time jobs) due to heat-stress and will be most pronounced especially in the agricultural and construction sectors (Kjellstrom et al., 2019).

South-east Asian countries are anticipated to generate notable economic growth of 5.2% from 2018 to 2022 (OECD, 2018).However, the potential negative effects of heat-stress has been mainly disregarded in the financial modelling of the region. According to the Climate Vulnerability Monitor 2012, impactful signs of climate change like rising temperatures and humidity results in a number of dangerous heat-stress days which puts South-east Asian countries at a greater risk of major productivity loss in the next three decades (McKinnon, 2012). At the local level, Malaysia is home to 20 out of the 50 global cities acknowledged as losing the most labour capacity due to heat stress. This substantiates the projection that by year 2045 the number of heat-stress days in Malaysia will rise to 338. This means that it is not only going to reduce the work performance but will impact the health of the people (VM, 2015). Coincidentally, 212 cases of heat-related illnesses were reported by the Malaysian Ministry of Health as of May 4, 2016, comprising of 52 cases of heat-cramps, 136 cases of heat-fatigue, and 24 cases of heat-stroke and including 2 fatal cases (Star, 2016).

Heat-fatigues and heat-strokes are some of the disturbing menaces for occupational health. Generally, a physically active or working person generates internal body heat which adds to the heat stress in hot environments. Even commuting to and from work is an additional daily source of heat exposure. According to some studies, if there is unsatisfactory cooling, the only innate adaptive action is to diminish the work intensity or increase the rate of short breaks (Bridger, 2008; Parsons, 2014). Although most of the research on heat-stress focus on the outdoor work activities like military, construction, agriculture, and transportation sectors, but majority of the working population is noticeably concentrated indoors. Nonetheless for both outdoor and indoor occupations, heat-stress not only impacts physical functions of the body, but also has negative impact on the mental state (N. Ding et al., 2016; R. Thompson et al., 2018). Interestingly, the research done by Zander and Mathew (2019) concludes that people working in mentally demanding occupations experience higher productivity losses due to heat-stress as compared to those who work physically. Another finding is that they estimate that about 10 per cent of the Malaysian population will lose their average earnings per year due to extreme heat that affect their productivity.

Thermal discomfort of people staying outdoors and exposed to hot weather might discourage them from using the urban space like parks or streets, depending on the climatic combination of the air temperature, wind speed, humidity level and surface temperature of the neighboring objects (Aflaki et al., 2017; Ghaffarianhoseini et al., 2019). However, if proper outdoor utilities to shield from heat are provided then the public may utilize the open spaces more. Consequently, increasing the active use of the location during extreme weather conditions (Böcker et al., 2016; Kjellstrom et al., 2017). The choice of the design details like the availability of proper shading elements, wind openness or breaks, materials and colours of the surrounding hardscapes, provision of landscapes can all lead to the modification of the location of the outdoor space. More so, the local air conditions can by some degree be altered by the outdoor space design details (Ali & Patnaik, 2018; Djekic et al., 2018).

Climatic factors greatly influence the amount and type of physical activities taking place by a person in an outdoor urban environment. It also affects the livability of an area and the number of commercial and recreational events that are carried out there. People might tend to spend most of their time outdoors if the microclimatic conditions are thermally comfortable, consequently saving energy by reducing the use of air conditioning and the ventilation systems (Lai, Guo, et al., 2014; K. Li et al., 2016; Obradovich & Fowler, 2017).

Meanwhile, the willingness of people to walk depends not only on the environmental conditions but also on the habits of the local community in doing their activities. While the hot and wet environmental climatic conditions give a certain degree of comfort for pedestrians in tropical countries they can also pose problems deterring the habit of people to walk. Basuki (2017) discusses a possible way to quantitatively determine a benchmark assessment scale of the willingness to walk of urban population in the city of Yogyakarta, Indonesia. He

concludes that the willingness to walk is less than 225 meters. Another study on walking comfort in hot and humid climate found that a walking distance of 321 meters in average is considered as the comfortable distance (Koerniawan & Gao, 2015). Correspondingly, it is also found that citizens of Johor, Malaysia are willing to walk for no more than 252 meters (Permana et al., 2017). However, these results are quite different from the other studies that people normally are willing to walk for 5 minutes (400 meters) and more (El-Geneidy et al., 2014; Hess, 2011; Hsu & Tsai, 2014; Zhao et al., 2003).

Remarkably, Azmi and Karim (2012) collected assessments from the field experts, such as architects and town planners, on how the walkability of the urban population in Putrajaya and Shah Alam is affected by the Clarence Perry Neighbourhood Design Principle. The findings show that the adaptation of the Neighbourhood Design concept in urban neighbourhood is not suitable for tropical country such as Malaysia. This is because generally Malaysians are not willing to walk the suggested 400-meter distance in order to reach the community facilities provided in the neighbourhood centre. Most of the respondents commented that the community facilities in the neighbourhood centre are not well planned and that the walking lifestyle of Malaysians has not been cultured. The respondents think that the pedestrian walkways lack covered paths and not well connected therefore creating uncomfortable conditions to walk in such tropical Malaysian climate. In conclusion, from the experts' perception, hot and humid climate is the main factor affecting urban residents' willingness to walk thus resulting in reduced walkability in the neighbourhood (Azmi & Karim, 2012; Ghaffarianhoseini et al., 2019; Nasir et al., 2018; Potchter et al., 2018).

1.1.2 Low Carbon City Concept Worldwide

The term "low-carbon economy" was first introduced by the UK Department of Trade and Industry in a new energy policy paper titled "Our energy future – creating a low-carbon economy" in February 2003 where low-carbon practices on international level had been put forward (UK Government, 2003). In order to practice and benefit from low-carbon economy, reduce emissions and adapt to the climate change, cities need to take actions to achieve the ambitious goals set in the Paris Agreement. The 21st Conference of Parties (COP) in Paris made a strong point on urgent transformative actions by the world's cities which account for approximately three quarters of greenhouse gas (GHG) emissions through their energy use and actions of their citizen. It is stated that if current 158 climate change commitments to the United Nations (UN) are all met, it will still lead to 2.7 ºC warmer by year 2100, which is considerably higher than the targeted below 2 ºC goal by most governments at the Paris summit. Therefore, these governments need to increase their climate action accordingly (Jeffery et al., 2015).

Cities are developing in an unprecedented rate, particularly in the developing world and it is expected that by 2050, around 70% of the total world population will live in cities (Tan et al., 2019). Therefore, national policies worldwide are

moving towards low-carbon city development paths that can stimulate economic productivity and climate action. The term “Low-carbon City” (LCC) was developed as a result of the increasing call for carbon reduction and climate change mitigation in cities (Gomi et al., 2010; Lou et al., 2019). These days, low-carbon practices are widely applied on a city level spanning from general planning and vast policy aspects to definite measures in specific fields. For example, in the United States, 1017 cities have signed on to meet targets of GHG reductions set by the Kyoto Protocol. A 2017 national survey from the 85th United States Conference of Mayors with the responses from 102 cities from 35 states stated that 69% generates or obtains renewable electricity to supply city buildings or operations and further 22% are determined to do so (The U.S. Conference of Mayors & Center for Climate and Energy Solutions, 2017). Meanwhile, Stockholm succeeded in cutting emissions by 35% from 1993 to 2010, while increasing its economy by 41% (Floater et al., 2013). Likewise, one of the prosperous cities of Brazil, Curitiba achieved 25% lower GHG emissions and 30% lower fuel consumption than the national average due its approach to land use and transport planning (Conke & Ferreira, 2015). Some other major countries also have prioritized low-carbon developments such as China, Japan, India, Singapore, Germany, Denmark, Sweden, Canada, Mexico, South Africa, Kenya and many more (Gomi et al., 2010; Lou et al., 2019).

In a report by the CDP (formerly known as the Carbon Disclosure Project) and C40 Cities Climate Leadership Group (C40) which connects more than 80 of the world’s megacities and is committed in addressing climate change, stated that 533 cities from 89 countries disclosed climate change related data in 2016 through the CDP’s cities program. Thereupon, 190 cities have a carbon emissions reduction plans and policies. These changes in turn highlight the extraordinary climate actions being taken by governments (CDP, 2016).

1.1.3 Low Carbon City Concept in Malaysia

During the 15th COP held by the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen on December 2009, Malaysia made a voluntary statement to reduce CO^2 emissions by 40% by 2020, as compared to the country’s 2005 levels (KATS, 2015).
Incidentally, prior to the 15th COP, in July 2009, the Malaysian government released the National Green Technology Policy (NGTP) which was the country’s one of many initiatives to accelerate the national economy and promote sustainable development. Simultaneously, the government aimed to develop Putrajaya and Cyberjaya as the forerunner townships in green technology. For that reason, NGTP began to fulfill their key goals in creating green township guideline, green rating system, energy and water saving actions in government buildings in Putrajaya, and many more other related activities (KeTTHA, 2010).

In order to measure performance of the cities and townships, especially their contribution towards lowering the carbon emission levels of the country, the Ministry of Energy, Green Technology and Water (KeTTHA), the project

implementer for NGTP, has initiated the Low Carbon City Framework and Assessment System (LCCF) as part of their several initiatives for 2010-2011 to reduce the overall carbon footprint of the country. LCCF is a conceptual and technical framework that bridges the gap between existing green policies of the government with the building rating tools available. LCCF consists of four main elements, namely Urban Environment (UE), Urban Transport (UT), Urban Infrastructure (UI), and Building (B). These four elements, further divided into 13 performance criteria and 35 sub-criteria, help the users to understand the cities' carbon footprint. Furthermore, the general LCCF Checklist is created by KeTTHA in order to measure the suitability of certain development, city, or township for inclusion in the list of LCC program. The LCCF Checklist is usually filled by Local Authorities for existing city, and Developers for new projects with <50 to >90% score. The policy foundation for LCCF development was set by the NGTP. Putrajaya, the new Administrative Centre of Malaysia, was officially launched in August, 1995 and is one of the major cities that implemented the LCCF concept of a green city from its inception (KeTTHA, 2011).

The main strategies of LCCF are to reduce the carbon footprint and energy consumption in four main areas, namely, urban environment, urban transport, urban infrastructure and buildings. Putrajaya's aim therefore is to minimize the usage of private vehicles and increase the walkability by providing pedestrian friendly facilities and encourage active commuting. Nonetheless, contradicting findings were discovered by researchers that the designers for Putrajaya did not pay due attention to fully utilize the microclimatic design (Azmi & Karim, 2018; Qureshi & Ho, 2011)

1.2 Problem Statement

Health wise, it is very important for people to stay physically active via regular lifestyles like walking, cycling, sports and other recreational activities because the absence of it leads to fatal outcomes where it is said to cause 6% of deaths globally and ranks as the fourth leading risk factor (WHO, 2010). As reported by the World Mortality Report 2015, the inactive lifestyle at leisure time, during work hours, or at home leads to growing number of overweight and obesity which are recognized as a foremost determinants for major Non-Communicable Disease (NCD) such as Cardiovascular Diseases (CDV), cancers, Chronic Respiratory Disease (CRD) and diabetes worldwide, and Malaysia is not an exception (UN, 2017). According to the World Health Organization (2018), governments' lack of investment in building built environments that promote physical activities may contribute to further negative impacts on the community well-being and NCDs.

The 66th World Health Assembly the World Health Organization (WHO) Global Action Plan for the Prevention and Control of NCDs 2013-2020 was endorsed in May 2013. When collectively executed by member states, international partners and WHO, it will contribute in reduction of mortality, morbidity and disability due to NCDs. The action plan delivers a coordinated and rational action at local and global levels to reach the nine voluntary global targets, comprising of 25%

relative decrease in premature mortality due to NCDs by 2025. The main emphasis of this action plan is on four major types of NCDs as of cardiovascular diseases (CDV), cancers, chronic respiratory diseases (CRD) and diabetes, and on four factors contributing to nearly three quarters of the risk for chronic diseases like poor nutrition and physical inactivity, which lead to obesity, and harmful use of alcohol and tobacco. Essentially, these factors are considered as "lifestyle issues" that can be addressed to prevent NCD (WHO, 2013). However, the Malaysian population are not sufficiently physically active (Y. Y. Chan et al., 2017; Y. Y. Chan, Sooryanarayana, Mohamad Kasim, et al., 2019; Poh et al., 2010). As reported by the Third National Health and Morbidity Survey (NHMS), over the last three decades, the amount of physical activity among the Malaysian population have extremely decreased while the Type 2 diabetes quadrupled (IPH, 2008) and obesity has risen by 280% (Rampal et al., 2007).

According to the NHMS, an alarming trend of overweight and obesity was prevalent in Malaysian adults aged 18 years old and above. The studies did not list consistently all the occupations but was in agreement with what was reported by the NHMS 2011, that one category that is most widespread among the administrative government or semi-government workers is obesity (IPH, 2011). In Malaysia, 73% of the total deaths recorded were caused by NCDs with an estimation of 35% deaths among Malaysians aged less than 60 years, which is mainly in the working population (IPH, 2015). The rapid development of the built environment in cities is seen to suggest positive association with most type of NCDs compared to the rural areas. This is said to be partly due to decrease in physical activities (Angkurawaranon et al., 2014; Koch, 2017; Teh et al., 2015). Reports have shown that sedentary-bound office workers are the majority among obesity sufferers worldwide due to lack of physical activities during working and their break hours (Addo et al., 2015; N. Cheng, 2016; L. Heinen & Darling, 2009).

Increasing body of works have supported the effectiveness of active green transport like walking, cycling or/and using public transport as part of the commuting for the functional travel purpose rather than leisure in decreasing the occurrences of NCDs. Based on a systematic review of twenty-four controlled trials and observational studies by Saunders, people who tend to use active green transport on regular basis are associated with clinically substantial risk reductions in obesity, diabetes, CVD, and hypertension and all-cause mortality (O'Donovan et al., 2018; Saunders et al., 2013). In a study with 263 540 participants with a mean age of 52.6 across United Kingdom, commuting by cycling was linked with a decreased rate of all-cause mortality and adverse CVD and cancer effects. Whereas walking was associated with decreased risks of CVD occurrences independent of other measured key features (Celis-Morales et al., 2017). Moreover, different aspects of the residential environment stimulate different physical activity behaviours. A high level of satisfaction with the local infrastructure may encourage the residents to engage in higher levels of active transportation. It is suggested that local infrastructure facilities to be designed so as to ensure accessibility by both walking and cycling (Crane et al., 2016; Keall et al., 2015; Y. Song et al., 2017; Stronegger et al., 2010).

Although the prototype city of Malaysia, Putrajaya accomplished a certain degree of Low Carbon City (LCC) planning criteria like green active transport infrastructure design to promote cycling, walkability and use of public transport, studies have found that most of the TLCC residents are hesitant to adopt the aforementioned mode of transportation (Abas, 2018; Siti Fatimah Hashim et al., 2017; Wan Omar et al., 2011). Physical inactivity in the cities have been reported to be linked with how the occupants perceive their outdoor thermic conditions particularly through the encouragement to walk in tropical places (Böcker et al., 2016; C. B. Chan & Ryan, 2009; Kim et al., 2014; Makaremi et al., 2012; Makoto, 2009; Nasir et al., 2015; Pilcher, 2002; G.-S. Song & Jeong, 2016). Therefore, there is a need to understand TLCC office workers' hindrance towards walking or using the available pedestrian facilities. The study assumes that the respondents' walking preferences may be influenced by their thermal perceptions and the surrounding built environment of their workplace.

1.3 Research Gap

Few studies have been previously done to evaluate pedestrians' perceptions of their walking environment within the workplace vicinity. Walking from and to work is a potential strategy for increasing the physical activity levels among workers. Also studies have shown that the provision of convenient access to public transport, sustainable and safe pedestrian and cycling infrastructure within workplace vicinity are directly associated with increased commuter walking (Adams et al., 2016; Adlakha et al., 2015; Batista Ferrer et al., 2018; L. Yang et al., 2017). It is widely accepted that the urban and built environment in which we live have a great influence on our lives and well-being. That is why it is important for designer decision makers to be aware of the direct and indirect impacts their decisions have on longstanding health and societal welfare, because mostly it is contributed by environmental factors (Fitzpatrick et al., 2018; E. Lee et al., 2019). The research by Rappaport and Smith (2010) found that up to 70% to 90% of chronic diseases are due to ecological conditions.

1.4 Research Questions and Objectives

This study aims to understand TLCC office workers' hindrances toward walking or using the available pedestrian facilities. This study adopts the assumption that the respondents' walking preferences may be influenced by their thermal perceptions and the surrounding built environment of their workplace. Specifically, this study aims to answer the following research questions:

1. Does the hot and humid weather influence office workers' willingness to walk in TLCC?
2. Does the surrounding buildings' green transport infrastructure influence office workers' willingness to walk in TLCC?
3. Does the design of the green transport infrastructure in TLCC encourage office workers that suffer from non-communicable diseases to walk?

The objectives of this study are as follows:

1. To investigate the walking behaviour of office workers' in TLCC based on their thermal perception assessments and meteorological monitoring at the measured sites.
2. To investigate the physical inactivity among TLCC office workers based on different green transport infrastructure and urban form settings near surrounding built environment of their works.
3. To assess the awareness level of TLCC office workers in identifying the effects of inactive lifestyle with NCD occurrences.

1.5 Scope and Limitations of the Study

The study focused on Putrajaya TLCC office workers' willingness to walk to work and how they perceived the outdoor thermal environment near their workplaces in terms of thermal comfort because they account for the highest population to suffer from NCDs and obesity. The theoretical framework developed in this study considered only office workers. However, relying on self-report measures for assessing the perceptions of the physical environment and commuter information, may have led to some error and biasness in the respondents' measurements.

Questions about perceptions of the environment at the respondents' workplaces were asked. Nonetheless, the residential neighbourhood environment and the route environment between the workplaces and respondents' residences may also be important in determining the commuter walking behaviour which is not within the scope of this study.

1.6 Significance of the Study

Weather conditions are demonstrated to be one of the determinants to affect walking behaviour (Clark et al., 2014). The findings from different studies show that the thermally comfortable weather variables like average temperature and overall precipitation can significantly contribute to better perceptions of the walking environment whereas the extreme weather figures like high outdoor temperature may be perceived as a barrier for performing outdoor physical activities (R. N. R. Ariffin & Zahari, 2013; Hung et al., 2010). Nonetheless, there is a need to find out to what extents are the existing TLCC criteria contribute to improve pedestrians' thermal comfort. The findings will be beneficial to instructors in low carbon city management and policy makers, as well as to human bio-meteorological researchers, and architects as well as urban planners when planning and designing towards livable tropical cities that promote walkability.

Findings from this study could contribute to the National Policy on Climate Change (Environment, 2009), specifically for the sections of societal well-being and environmental protection. The outcome of the study could also complement the LCCF in consideration of pedestrian well-being since there is no specific guideline or standard for comfortable walking distance in the Malaysian urban built environment. It is hoped that findings based on the questionnaire survey responses conducted by this study about respondents' perception when walking in TLCC may contribute to improve tropical city design according to climate condition. In addition, promoting active lifestyles through the implementation of comfortable measures in the built environment for tropical weather could in the long run become one of the strategies for combating obesity in Malaysia.

1.7 Definition of Terms

1. Heat-stress—is when the human thermal environments set a body to accumulate heat and the body's thermoregulation system responds by attempting to intensify heat loss (Parsons, 2014).
2. Thermal comfort—the humans "condition of mind that expresses satisfaction with the thermal environment" (ASHRAE, 2013; I. S. ISO, 2005).
3. Thermal comfort Index—a means to define, design, and evaluate thermal environments by combining the aspects that influence human response to its surroundings and providing the single index value (Parsons, 2014).
4. Pedestrian comfort—is the pleasant feeling of comfort and contentment with physiological, psychological, and physical factors between the human body and the environment (Alfonzo, 2005; Sarkar, 2003).
5. Low Carbon City—a city that comprises of societies that consume sustainable green technology, green practices and emit relatively low carbon or GHG as compared to present day practices in order to avoid the adverse impacts on climate change (KeTTHA, 2011).
6. Walkability—refers to the built environment that provides safe, comfortable, and convenient walking conditions to the users (Abley & Turner, 2011; Litman, 2017).
7. Willingness to walk—inclined or favourably disposed in mind to move along on foot.

1.8 Research Flowchart

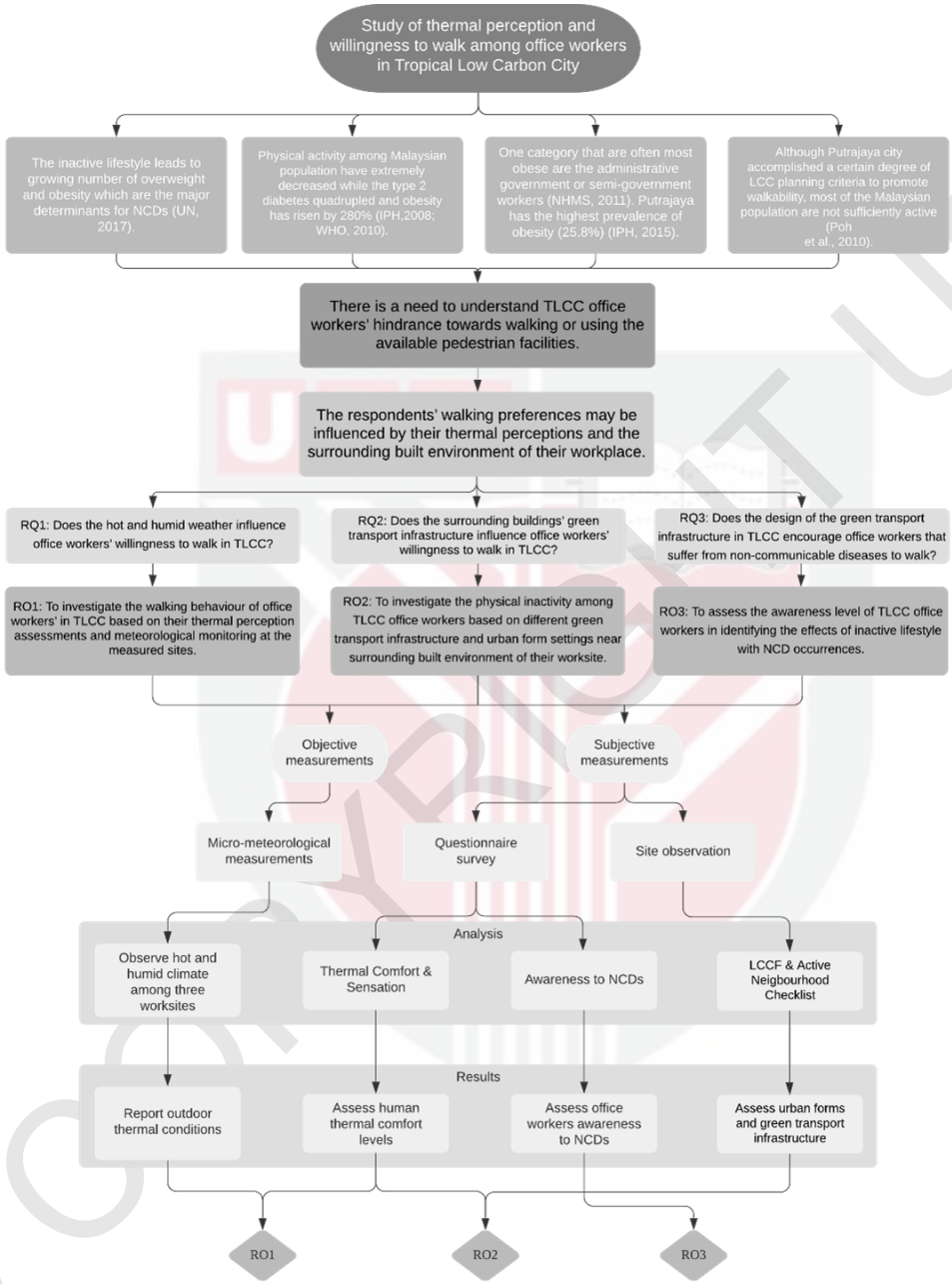

Figure 1.1: The Research Flowchart

The research work started with the identification of the research problems and gaps. Consequently, relevant research questions on influences of TLCC built environment and weather on office workers' perception on active transportation

were composed. To respond to these research questions, related objectives based on assessment, investigation, and observation of the walking behaviour and awareness level of the consequences of inactive lifestyles were constructed. Subsequently, the research methodology was designed to obtain reliable data for future analysis of the TLCC office workers' perceptions on climate and working neighbourhood built environment. In conclusion, all the collected data were methodically and scientifically analyzed applying selected multi-method approach and sampling methods in order to achieve the research objectives and derive with the conclusions on the TLCC office workers' hindrances towards using active transportation (Figure 1.1).

1.9 Thesis Structure

Chapter 1 starts with the research background highlighting the aspects on how the hot and humid climate of Malaysia affects urban people (Putrajaya) working or staying outdoors. Correspondingly, the problem statement is specifically focusing on LCC perspective due to high numbers of passive mode travelers with consequent rise in NCDs amongst its population. The Research gap is then identified i.e. the lack of studies on perceptions to active transport travelling in work areas of tropical LCC. The research questions and objectives are subsequently formed based on the aim of the study, later followed by scope, limitations, and significance of the study. The key words are identified and established in the following definition of terms. Finally, the research flowchart illustrates the entire process of the research work.

Chapter 2 provides a detailed literature review of outdoor thermal comfort, its assessment models, and the table of literature review for the past five years. Next, the general sustainable parameters in urban design for tropical climate are briefly presented. Subsequently review for low carbon transportation in the study site, its pedestrian environment, benefits of walking, and awareness to NCDs among workers of LCC concludes the chapter.

Chapter 3 focuses on the research methodology. Here justification for the selected sites, climate, their location, and synopsis description of the buildings form the basis of the research approaches that are adopted. Most importantly analysis of data collected employed selected research multi-method approaches and sampling methods. This is discussed in detail in this chapter.

Chapter 4 presents the findings and results followed by discussions for each research aim. Chapter 5 draws the conclusion of the study and discusses the outline for future research directions. It also highlights the contributions that the study has been able to derive.

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