UNIVERSITI PUTRA MALAYSIA

EVALUATION OF ONSITE CARBON FOOTPRINT IN LANDSCAPE DEVELOPMENT STAGES BASED ON LIFE CYCLE ASSESSMENT IN PUTRAJAYA, MALAYSIA

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FRSB 2019 3

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By

FARA DIBA BINTI BADRUL HISHAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

December 2018

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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December 2018

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Carbon footprint has become very significant in our landscape development due to the large number of buildings and facilities. In order to increase carbon stock, carbon footprint from landscape lifecycle has to be reduced. Nevertheless, policies and plans that focus onsite carbon footprint in landscape development are still lacking. Therefore, this study presents the onsite carbon footprint evaluation of landscape development that was recently constructed in the Promenade Precinct 8, Putrajaya using Life Cycle Assessment. The Objectives of this study is to identify the stages, elements and attributes that increase onsite carbon footprint in landscape development stages; to assess the onsite carbon footprint in landscape development stages; to examine the contribution of stages, elements and attributes towards onsite carbon footprint and to propose an onsite carbon footprint reduction guideline in landscape development stages. Document analysis and field measurement were conducted, and data collected were analysed using SMART PLS (Partial Least Squares). The finding reveals that the construction stage produces the highest amount of carbon footprint with a value of 152884 $kgCO_2$. As for the elements in landscape development, the highest amount comes from hardscape construction with a total of 58403 $kgCO_2$. Lorry is the highest attribute that increases carbon footprint with a total amount of 99139 $kgCO_2$. The guidelines focus on landscape development and would enhance the current assessment strategies in Malaysia. It can be implemented to offer a better understanding in mitigating the impact thus increasing carbon sequestration for improving the quality of life in the present and future developments.

Abstrak tesis yang dikemukakan kepada Senat, Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENILAIAN JEJAK KARBON DALAM PEMBANGUNAN LANDSKAP BERDASARKAN PENILAIAN KITAR HAYAT DI PUTRAJAYA, MALAYSIA

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Jejak karbon sangat penting dalam pembangunan landskap pada masa kini disebabkan oleh banyak bangunan dan kemudahan yang disediakan. Dalam rangka menambah stok karbon, pengeluaran karbon yang berasal dari kitaran hayat landskap perlu dikurangkan. Malangnya, kurang penumpuan diberikan kepada jejak karbon untuk pembangunan landskap. Oleh itu, kajian ini memberi tumpuan kepada jejak karbon untuk pembangunan landskap. Kajian ini membentangkan analisis jejak karbon dalam pembangunan landskap di Promenade Precinct 8, Putrajaya Objektif kajian ini adalah untuk mengenal pasti peringkat, elemen dan item yang menyumbang jejak karbon dalam pembangunan landskap; untuk menilai jumlah jejak karbon dalam pembangunan lanskap; untuk mengkaji sumbangan setiap peringkat, elemen dan item terhadap jejak karbon dan mencadangkan garis panduan pengurangan jejak karbon dalam pembangunan landskap. Analisis dokumen dan pengukuran di lapangan telah dijalankan dan data dianalisis dengan menggunakan *SMART PLS (Partial least squares)*. Penemuan kajian menunjukkan peringkat pembinaan memberi jumlah tertinggi jejak karbon dengan nilai 152884 kgCO_2. Selain itu, bagi elemen dalam pembangunan lanskap, jumlah tertinggi adalah pembinaan landskap kejur dengan jumlah 58403 kgCO_2. Lori menjadi item tertinggi dalam penigkatan jejak karbon dengan jumlah 99139 kgCO_2. Garis panduan ini memberi tumpuan kepada pembangunan landskap dan akan meningkatkan strategi penilaian semasa di Malaysia. Garis panduan ini dilaksanakan bagi menerapkan pemahaman yang lebih baik untuk mengurangkan impak dan meningkatkan penyerapan karbon bagi meningkatkan kualiti hidup semasa dan masa depan.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude and appreciation to my supervisors, Prof. Madya Dr. Mohd Fairuz Bin Shahidan, for the continuous support of my Ph.D study and related research, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. Their wealth of knowledge, advice, and encouragement has made my doctoral endeavour possible. Besides my advisor, I would like to thank the rest of my thesis committee Prof. Madya LAr Dr Suhardi Bin Maulan and Prof. Madya Dr. Mohamad Fakri Zaky Bin Ja'afar for their insightful comments and encouragement, but also for the hard question which encourage me to widen my research from various perspectives.

Particularly, I would also like to express my deepest gratitude to Ministry of Higher Education and Community College for the scholarship throughout this study. My special thanks to Dr. Mohd Harris Bin Mohd Ismail, Dr. Sharifah Nadiyah Binti Razali, Dr. Zool Hilmi Bin Mohamed Ashari, En Zalami Bin Rashid and En Ady Hameme Bin Nor Azman for their professional guidance and encouragement to keep up the momentum to conclude my doctoral journey. My appreciation also goes to many of my friends and colleagues, for their valuable input and help. Last but not least, my great deep gratefulness to my lovely husband, Bambang Isdianto Bin Sugino who blessed me with his love, patience, support and understanding in completing this study. To my kids Qairah Al Syifaa, Qoid Ar Rayyan and Qori Al Barr, hope my journey will inspired all of you to be a better person. I would like to thank my family especially my mother Norhayati Binti Mohd Arof for her pray and supporting me spiritually throughout writing this thesis and my life in general.

I certify that a Thesis Assessment Committee has met on 21 December 2018 to conduct the final assessment of Fara Diba Binti Badrul Hisham on her thesis entitled "Evaluation of Onsite Carbon Footprint in Landscape Development Stages Based on Life Cycle Assessment in 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 Doctor of Philosophy.

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LIST OF ABBREVIATIONS

CO_2	Carbon Dioxide
GHG	Green House Gases
GDP	Gross Domestic Product
GB1	Green Building Index
GTMP	Green Technology Master Plan
IEAP	International Emission Analysis Protection
IPCC	Intergovernmental Panel on Climate Change
IPMA	Importance-Performance Analysis
IOA	Input–output assessment
ISO	International Organisation for Standardization
KeTTHA	Ministry of Energy, Green Technology and Water
kWh	Kilowatt-Hours
LCA	Life Cycle Assessment
LCCF	Low Carbon City Framework
MESTECC	Ministry of Energy, Science, Technology, environment and climate change
NPS	National Park Service
PLS	Partial Least Square
SEAP	Sustainable Energy Action Plan
SEM	Structural Equation Modeling
SPSS	Statistical Package For Social Sciences
UNFCC	United Nation Framework Convention on Climate Change
USEPA	United State Environmental Protection Agency
WECAM	Water and Energy consumer Association of Malaysia
WRI	World Research Institute
WBCSD	World Business Council for Sustainable Development
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The rapid economic development in Malaysia contributes to urbanisation and a shift in the global climate change issues. Population and industrial revolution are the real main forces behind the expansion of CO_2 worldwide in the last two decades. Carbon is the main greenhouse gas that is responsible for the increase in global temperature and environmental change (Ahmed et al., 2014). Unfortunately, such changes are not without disadvantages as urbanisation leads to the expansion of carbon outflows. The world's urban area (covering 2% of the world's surface) is responsible for 75% of the global energy consumption and 80% of the global GHG emissions (Whitmarsh et al., 2011). Locally, the increasing urban development is expected to reach 79.6% by 2025, making the increase in CO_2 emissions by the urban sector inevitable (Hashim, 2015). Studies done by Lombardi et al., (2016) have also revealed that ocean levels around the world have increased at an average of 10°C to 20°C during the past century. Furthermore, the climate has expanded by 30% while worldwide temperature has increased by 0.3°C to 0.68°C (Ala Mantila et al., 2013; 2014) The effects of climate change are undeniably real and can be felt worldwide. The IPCC (2014) has also warned that the global climate change may lead to a rise in sea level as evidenced by the increase of 0.1 to 0.2 meters in the average global sea level during the 20th century. These problems are compounded by the fact that human have failed to respond to these issues responsibly.

1.1.1 Problem Statement

The reactions shown by numerous nations including Malaysia are responsible for triggering dynamic actions in reducing carbon emission through national relief and intergovernmental systems. For example, the United Nations Framework Convention on Climate Change (UNFCC) has formed an understanding to decrease environmental groupings of Greenhouse gasses (GHGs). More than 150 governments including developing nations, conceded to a structure practice on environmental change (Fulton et al., 2017). At the international level, Malaysia has ratified the United Nations Framework Convention on Climate Change (UNFCC) in 1994 and the Kyoto Protocol in 2002. Prior to COP15, the Malaysian government has also revealed its National Green Technology Policy in 2009, a policy that was built upon the four pillars which underlines five main objectives in which the fifth states "boosting public education and awareness of green technology and promoting its widespread usage". In COP20 held in Lima, Peru in December 2014, the Prime Minister of Malaysia announced that the country has succeeded in reducing its carbon emissions intensity by 33% during the Climate Summit 2014 in New York. During the 2016 COP22 in Marrakech, Malaysia also pledged to cut its carbon emissions intensity by 45% by the year 2030. This target included the 35% reduction on an unconditional basis and a further 10% reduction which is dependent on the receipt of climate finance, technology transfer and capacity building from developed countries. In COP23 in Bonn Germany, Malaysia announced its GHG reduction target by the year 2030 with the following initiatives: Green Technology Master Plan 2017-2030, Energy Efficiency Action Plan (aims to reduce emissions of 13.113 million tones CO_2 equivalent for year 2030), Transportation Sector (The launching of the Mass Rapid Transit (MRT) phase one has successfully removed 9.9 million cars in 2017 and is estimated to remove an additional 62-89 million cars between 2020 and 2030 and enhance its Low Carbon City Framework.

Malaysia, through the Ministry of Energy, Green Technology and Water (KeTTHA), aims for a 40% GHG reduction for every GDP per capita year by the year 2020 compared to the 2005 level. Politically, such efforts have been intensified through the creation of a green technology portfolio in the form of a newly restructured Ministry of Energy, Green Technology and Water during the Ninth Malaysian Plan (2006-2010). Such efforts have also been intensified in recent years through the Malaysian government’s adoption of climate adaptation and mitigation measures in the 10th Malaysian Plan 2011-2015 (Ho, 2011). Through its commitment to reduce carbon footprint towards mitigating global climate change, the Malaysian government has also taken steps to implement its Low Carbon Cities Framework and Assessment System (LCCF) under the Ministry of Energy, Green Technology and Water (KeTTHA, 2011). Green Neighbourhood and smart Selangor are also parts of the initiatives to decrease the country’s carbon emission. In addition, there is the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) which aims to guide, assist, quantify and hence, reduce built environments impact while taking into account a more holistic life cycle view of the built environment. Thus, it is important to start measuring the carbon footprint reduction plan to attain the carbon footprint reduction goals that have been put in place by the government. As carbon footprint is not the only index or metrics of sustainability, the life cycle also intends to address a more holistic and net benefits of the socio-economic aspects of sustainability.

As a result, landscape architects are now performing a more important function in carbon sequestration and carbon neutral in the amenities it provides. Green areas have been highlighted as the source with the largest mitigation potential for carbon footprint (Chen et al., 2015; 2016). Unfortunately, according to Yue et al., (2015), the amount of carbon sequestered by the landscape compensated for only 1.9% to 2.5% of the total carbon footprint of the community, and it could still be influenced by the development factors of the landscape. Therefore, it is important to measure carbon footprint especially at landscape developments in order to increase carbon stock. The study was expanded to include landscape developments stages as nowadays, green areas contain large elements and facilities. In order to fulfil the needs of the people, landscapes are also equipped with services such as information centres, supermarkets, cafeterias, restaurants, public transportation and recreational activities (Villalba et al., 2013). However, all these elements emit carbon to the environment. As a result, they should be taken into considerations when planning the landscape to ensure a better carbon sink in landscape development stages.

Carbon footprint research based on Life Cycle Assessment (LCA) is more likely to show a comprehensive picture of the overall carbon emission in landscape development. LCA provides a framework for studying environmental impacts throughout the lifetime of goods and services (Hu et al., 2017). LCA is clearly structured by an international standard, yet flexible for adaptation for different applications. The European Commission (2009) guidelines define carbon footprint as a sub-set of a complete LCA. LCA and carbon footprint are generally used in the industrial context, but there are also applications from agriculture and forestry (Finnveden et al., 2009; Strohbach et al., 2012). Sola et al., (2007) foe example conducted an LCA of the Montjuic Park in Barcelona, Spain.

Strohbach and Haase (2012) also assessed green area carbon footprint using Life Cycle Assessment. They found that in the period of 50 years, the net emission of carbon sinks, excluding emissions related to management and maintenance activities, was about 137-162 metric tons of carbon dioxide in average per hectare of green land. Although the amount sequestered is still small, it can be increased by reducing carbon footprint during landscape development stages (Choi et al., 2015). Hu et al., (2016) highlighted that landscaping works should centre on reducing hidden carbon footprint in the planning, design and construction management as well as in reducing dominant carbon footprint in all stages through reasonable selections of planted vegetations, shortening long distance transport and reducing high fuel consumption of machineries. Kristen et al., (2010) also mentioned that such decisions could have an influence on the carbon impact of most aspects of a landscape work, including all stages of design and land planning and at all scales from residential development to regional master plans. This also includes the ways in which practices are run, how landscape construction is implemented, how landscapes are managed and maintained, and how well designs are future-proofed to extend their life expectancy before renewal. One way in which the profession of a landscape architecture can contribute to this reduction is to consider using machineries that produce less CO_2 in their operation (Harre et al., 2007; Li et al., 2017). Therefore, landscape architects have a duty to minimise environmental consequences of their design decisions including potential consequences of global warming and to make a positive contribution towards a sustainable landscape change. Many landscape architects consider that they are already helping to reduce the effects of climate change by specifying plants which absorb CO_2; however, what is not known is how much that planted portion of an implemented landscape design might offset the environmental and the carbon impact of the machineries that are used in landscape at different stages of the developments.

Align with the issues, the established green and sustainable building rating systems around the world show that there is a need to improve the sustainable building assessment methods. Buildings, regardless of their purposes, commercial, institutional and residential, are responsible for approximately 30% of greenhouse gas emissions in the world (Jiang et al., 2015). To overcome this problem in Malaysia, the Malaysian Carbon Reduction and Environmental Sustainable Tool (MyCREST) was created. Hence, it should be the same with landscape development. Most landscape elements come from the burning of fossil fuels to build up an area while others come from the manufacturing of materials as well as during operations and long-term maintenance. In order to ensure a landscape fulfil the facilities needed for user comfort, carbon footprint in landscape lifecycle has to be reduced. Other than that, to increase carbon stock, carbon footprint that comes from landscape planning until its demolition also has to be reduced. Therefore, this study evaluated onsite carbon footprint by focusing on landscape development lifecycle. The measurements include the stages, elements and attributes that may contribute carbon to the environment. The study provides a guideline to support carbon sequestration in reducing carbon footprint in landscape developments at Malaysia.

1.2 Aim of the Study

The study aimed to evaluate onsite carbon footprint in landscape development stages through Life Cycle Assessment in proposing an onsite carbon footprint reduction guideline towards environmental sustainability in Malaysia.

1.3 Research Questions

1. What are the stages, elements and attributes that increase onsite carbon footprint in landscape development stages?
2. How much is used of the onsite carbon footprint in landscape development stages based on stages, elements and attributes?
3. What is the contribution between the stages, elements and attributes towards onsite carbon footprint?
4. What guidelines that can be proposed from the stages, element and attributes to reduce onsite carbon footprint in landscape development in Malaysia?

1.4 Research Objectives

The objectives of this study are:

1. To identify the stages, elements and attributes that increase onsite carbon footprint in landscape development stages;
2. To assess onsite carbon footprint based on stages, elements and attributes in landscape development stages;
3. To examine the contribution of stages, elements and attributes towards onsite carbon footprint;
4. To propose an onsite carbon footprint reduction guideline in landscape development stages towards environmental sustainability in Malaysia.

1.5 Significance of the Study

This study proposes new ideas and development of a guideline specifically in landscape development carbon footprint towards carbon reduction strategies by recommending development of better designs by landscape architects and practitioners. This study provides new insights on the perceptions of Malaysian urban designers especially architects, planners, landscape architects and government on the effects of carbon and element selections when designing urban areas. This knowledge is important in opening up a new perspective with regard to the technical aspects of carbon footprint reduction in landscape development. The selection of the right attributes may also minimise the impact of greenhouse gases.

1.6 Scope of the Study

The study begins with a review of global climate change and the concept of sustainability, recent international and Malaysian policies towards global climate change, followed by an elaboration on the existing carbon footprint practices, both nationally and internationally, and a review of theories related to Life Cycle Assessment (LCA). The stages, elements and attributes are first verified by experts and professionals in related fields prior to the development of the expert validation form. The stages, elements and attribute that contribute to carbon emission in landscape development are discussed based on a case study involving a landscaping area in Putrajaya. The study then synthesised the results and proposed an onsite carbon footprint reduction guideline in landscape development. Finally, the study discusses the findings and their implications for the local authorities, planners and designers to consider when taking actions to reduce onsite carbon footprint towards a more sustainable environment in Malaysia.

1.7 Limitations of the Study

This study which focused on the efforts in designing urban spaces that minimise carbon emissions from all factors have the following limitations:

1. The study focused only for direct GHG emissions are calculated for the different categories (scope 1).
2. This study was limited to carbon footprint caused by $CO_{2.}$
3. The Field Measurement study was limited to Promenade Precinct 8, Putrajaya, Malaysia that divided into twelve (12) zones.
4. There were some difficulties in obtaining the most up-to-date and accurate data.
5. Local parameters were lacking. However, this problem was circumvented by utilising suitable parameters that have already been established in other countries.

1.8 Definition of Terms

Below are the terms defined in clarifying the main concepts of this study:

i. Onsite Carbon Footprint

The term carbon footprint is defined as a measure of the exclusive total amount of carbon dioxide emissions that is directly or indirectly caused by an activity or is accumulated over the life stages. However, this study only focused on onsite carbon footprint from the direct emission of a carbon footprint from landscape development.

ii. Life Cycle Assessment

Life cycle Assessment (LCA) in this study is defined as an environmental management tool which can be used to make effective quantitative analysis and evaluation of the current environmental conflicts. It is a useful tool in gaining a complete, comprehensive, integrated understanding of resource consumption of the various activities and their impact on the environment throughout the entire process.

iii. Landscape Stages

The stage terminology may differ depending on different countries and regions, but there is a common process of managing a project through stages. As this study focused on onsite carbon footprint, the process starts from the stage when the contractor is on the site building until the completion of the project. After the project is completed, contractors are often required to maintain the project for a certain period of time which can be for months or years depending on the requirements made by the clients. Landscape architects too are often required to manage any defects (dead trees, item failures etc.)

iv. Landscape Elements

Landscape elements in this study refer to the physical elements of geophysical defined landforms such as trees, lawn, mountains, hills, water bodies such as rivers, lakes and ponds, land use, buildings and structures and transitory elements such as lighting and pergola. In short, landscape elements refer to all the above components that create activities for people. Usually, landscape elements depend on the proposal made by designers to suit user needs. To ensure that the elements are properly equipped, they should be connected to all the stages in landscape development described above.

v. Landscape Attributes

Landscape attributes in this study refer to the sources that directly emit onsite carbon to the environment. These include all the machineries, engines and accessories that use fuels to operate. Before choosing the attributes, landscape elements proposed in landscape area need to be identified. Therefore, to ensure that the right attributes are used, they should be attached to all the elements mentioned above.

1.9 Thesis Structure

The thesis is organised as follows:

Chapter 1 provides an overview and discussion on the problems and issues related to carbon footprint in the world and Malaysia. This is followed by a presentation of the research gap, aims, research questions and objectives that need to be addressed. The chapter also summarises the significance, scope and limitations of the study.
Chapter 2 provides an extensive review of the international and Malaysian policies towards carbon reduction. This study provides an in-depth review of theories on onsite carbon footprint and the Life Cycle Assessment (LCA). It then explores the theories

pertaining to the landscape development stages. Finally, this chapter presents the theoritical framework on onsite carbon footprint.

Chapter 3 describes the research method by providing information on the research design, variables, site location and sampling procedures. It also highlights the research procedure, validity and reliability, data collection technique and data analysis.

Chapter 4 provides an analysis of data from the literature review and the investigation on field measurement phases. The results of data analysed are discussed comprehensively by reporting the results and findings according to the research questions proposed in the implementation and evaluation phase. This chapter then continues with a discussion on developing a guideline in reducing onsite carbon footprint.

Chapter 5 discusses the research conclusion, recommendations, contributions and implications. It also discusses the proposed guideline, followed by suggestions for future research. The structure for this thesis is illustrated in Figure 1.1 below.

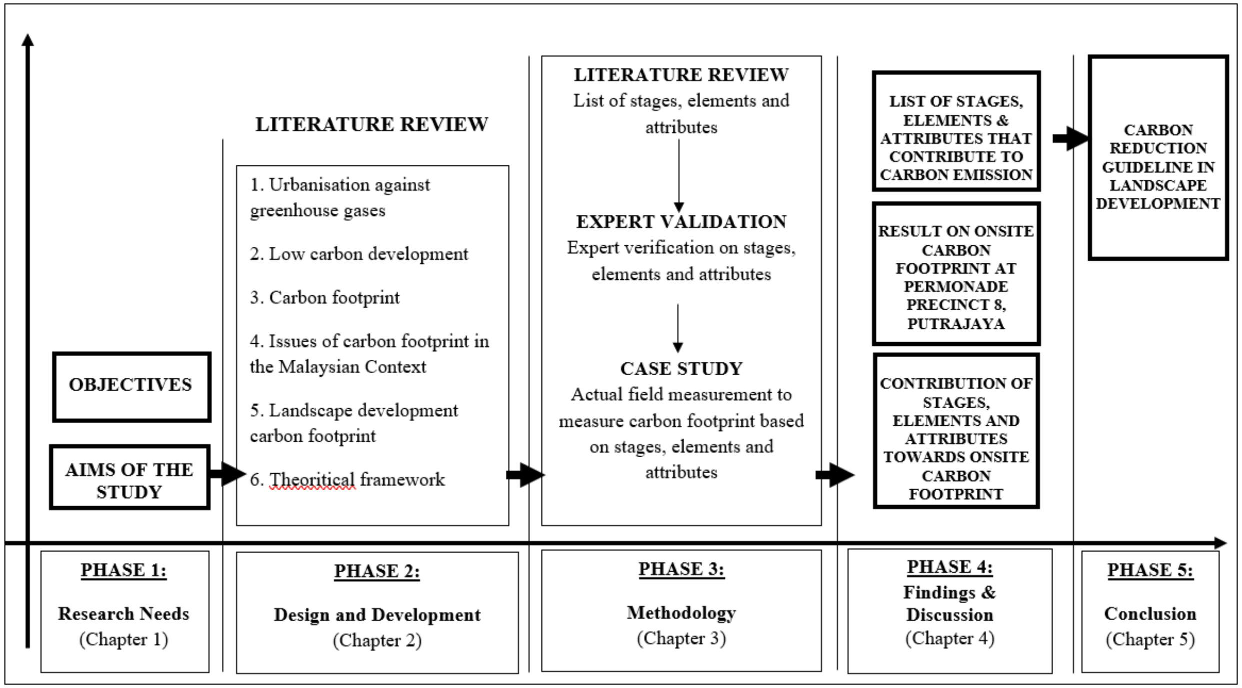

Figure 0.1: Thesis Structure

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