



APPLICATION OF CARBON FOOTPRINT ANALYSIS
TO EVALUATE CARBON DIOXIDE (CO₂) EMISSIONS
FROM ROAD TRANSPORTATION: A CASE STUDY OF
FEDERAL TERRITORY OF PUTRAJAYA

BY

SYAHIDAH AMNI BINTI MOHAMED

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International Islamic University Malaysia

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ABSTRACT

In tandem with rapid urbanization, transportation sector plays as a major consumer to energy consumption; indicating the heavily dependent on fossil fuel which have relatively high carbon intensity thus contribute to the significant increment in emission of greenhouse gas (GHG) mainly carbon dioxide (CO₂) from the sector. Consequently, the term carbon footprint has become widely used over the last few decades in response to an abatement action against the threat of global climate change due to CO₂ emissions. Hence, the research aims to explore an application of Carbon Footprint Analysis as an environmental accounting tool to evaluate CO₂ emissions from transportation source. Three objectives formulated are (i) to explore the causal-relationship of CO₂ emissions from road transportation and its relation to carbon footprint concept, (ii) to measure CO₂ emissions from road transportation, and (iii) to employ Carbon Footprint Analysis to evaluate the environmental implications of road transportation CO₂ emissions. A mixed method approach of sequential exploratory strategy with documentation reviews, interviews and travel diary survey were used as methods of data collection. Using the Federal Territory of Putrajaya as a case study site, the research attempts to stimulate the problems of CO₂ emissions in the context of assessing the CO₂ emissions from road transport and appraise the emissions in response to Putrajaya Green City (PGC) 2025. In the first phase of data analysis, an emissions inventory conducted based on operational boundaries delineated according to World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD) GHG Protocol for Scope 1 and Scope 3. Using the distance-based method, the results shows the CO₂ emissions for Scope 1 is 15,090.8 t/CO₂/year while Scope 3 emission is 334,477.9 t/CO₂/year. It revealed that 87.03% of CO₂ emissions attribute from commuting activities due to the dominance of car as the preferred mode of transport. Carbon footprint analysis performed in the second stage using component-based approach which inherent ecological footprint concept to evaluate demand for energy land required to sequester the emissions from built land. The carbon footprint in Putrajaya was calculated to be 3,772.7 ha per year. Besides, carbon footprint per person in Putrajaya accounted for 0.004 ha per person. This implies that area demanded for providing transport infrastructure used is not exceeding area supplied by ecosystem generative capacity. In other words, carbon footprint in Putrajaya is still small and did not exceed or overshoot biocapacity. Aggregate indicator of footprint therefore can be viewed as a benchmark of environmental performance of Putrajaya towards the planning for Low Carbon City (LCC).

ملخص البحث

يؤدي قطاع النقل جنباً إلى جنب مع ظاهرة التحضر المتسارع دوراً كمستهلك كبير في استهلاك الطاقة، مما يدل على اعتماده الكبير على الوقود الأحفوري التي تحتوي على كثافة كربونية عالية نسبياً، وبالتالي تسهم هذه النسبة في الزيادة الكبيرة من انبعاث غازات الاحتباس الحراري والتي أساسها ثاني أكسيد الكربون (CO_2). ونتيجة لذلك، برز من انبعاثات الكربون مصطلح جديد يستخدم على نطاق واسع على مدى العقود القليلة الماضية، رداً على إجراءات تقليل خطر تغير المناخ العالمي كنتيجة لانبعاثات ثاني أكسيد الكربون المناسبة. وبالتالي فالبحث الحالي يهدف إلى استكشاف تطبيق تحليل البصمة الكربونية كأداة للمحاسبة البيئية لتقييم انبعاثات ثاني أكسيد الكربون من مصدر النقل. وقد تم صياغة ثلاثة أهداف، هي: الهدف الأول استكشاف العلاقة السببية من انبعاثات ثاني أكسيد الكربون من النقل البري وعلاقته بمفهوم البصمة الكربونية، والهدف الثاني قياس انبعاث من ثاني أكسيد الكربون النقل البري، أما الهدف الثالث فهو توظيف البصمة الكربونية عند التحليل للتقييم البيئي الضمني للانبعاثات ثاني أكسيد الكربون النقل البري. وقد استخدم أساليب مختلطة من الاستراتيجية الاستكشافية المتابعة مع وثائق استعرضت المقابلات، ومسح مذكرات السفر كأساليب لجمع البيانات، حيث تم استخدام الأراضي الاتحادية بوتراجايا كموقع لدراسة الحالة، يحاول البحث الحالي تحفيز مشاكل انبعاثات ثاني أكسيد الكربون. وفي سياق تقييم انبعاثات ثاني أكسيد الكربون من النقل البري رداً على بوتراجايا المدينة الخضراء (PGC) عام 2025م. ففي المرحلة الأولى من تحليل البيانات ووجد الانبعاثات، التي أجريت على أساس تشغيلية محدودة وفقاً لمعهد الموارد العالمية (WRI) ومجلس الأعمال العالمي للتنمية (WBCSD) بروتوكول الغازات الدفيئة المستدامة لنطاق 1 و 3. وذلك باستخدام الطريقة القائمة على المسافة ، فقد أظهرت النتائج أن انبعاثات ثاني أكسيد الكربون عن نطاق 1 كان $\text{CO}_2 15,090.8 \text{ t} / \text{ سنة}$ في حين نطاق 3 كان $\text{CO}_2 334,477.9 \text{ t} / \text{ سنة}$. وقد كشفت ذلك أن 87.03% من انبعاث ثاني أكسيد الكربون سمة من أنشطة التنقل بسبب هيمنة السيارة كنمط مفضل للنقل. وأما تحليل البصمة الكربونية الذي تم أدائها في المرحلة الثانية باستخدام النهج القائم على العنصر أدي إلى مفهوم البصمة البيئية لتقييم الطلب على أراضي الطاقة اللازمة لعزل الانبعاثات من الأراضي المبنية. ومن ثمّ تمّ حساب البصمة الكربونية في بوتراجايا لتكون $3, 772.7$ هكتار في السنة. إلى جانب ذلك، شكلت بصمة الكربون للفرد الواحد في بوتراجايا عن 0.004 هكتار للشخص الواحد. وهذا يعني أن المنطقة التي تطالب بتوفير البنية التحتية للنقل المستخدم لا تتجاوز المنطقة التي تمدّها النظم الإيكولوجية بالقدرة التوليدية. وبعبارة أخرى، البصمة الكربونية في بوتراجايا لا تزال صغيرة ولم تتجاوز القدرة البيولوجية. وبالتالي فإن المؤشر الكلي للبصمة يمكن اعتباره معياراً للأداء البيئي لبوتراجايا مما يساعد على التخطيط لمدينة منخفضة الكربون (LCC).

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Built Environment.

.....
Ismawi Zen
Supervisor

.....
Syahriah Bachok
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Built Environment.

.....
Mansor Ibrahim
Internal Examiner

.....
Ho Chin Siong
External Examiner

This thesis was submitted to the Department of Landscape Architecture and is accepted as a fulfilment of the requirement for the degree of Master of Science in Built Environment.

.....
Zainul Mukrim Hj. Baharuddin
Head, Department of Landscape
Architecture

This thesis was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for the degree of Master of Science in Built Environment.

.....
Alias Abdullah
Dean, Kulliyyah of Architecture
and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Syahidah Amni Binti Mohamed

Signature.....

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INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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It is hope that my research could raise the awareness among the public on the rasing concern of global climate change and application of carbon footprint concept towards achieving the sustainable development in Malaysia. *Insyallah*.

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LIST OF SYMBOLS

a	Fuel type
b	Vehicle type
c	Emission control technology
d	Operating conditions
$Distance_{a,b,c,d}$	Distance travelled (VKT) during thermally stabilized engine operation phase for a given mobile source activity
C	Cold start term
Ca,b,c,d	Emissions during warm-up phase
$EF_{a,b,c,d}$	Emission factors
L_s	Length of the segment s
N_s	Total number of segment s
$TF_{s,j}^{24}$	24 hour traffic flow on segment s at day j
s	Segment
j	Travel day

LIST OF ABBREVIATIONS

AADT	Average Annual Daily Traffic
BaU	Business-as-Usual
BPKM	billion passenger kilometres
CARROT	Climate Action Registry Reporting Online Tool
CBD	Central Business District
CCAR	California Climate Action Registry
CCTV	Close Circuit Television
CDIAC	Carbon Dioxide Information Analysis Centre
CDM	Clean Development Mechanism
CH ₄	methane
CM	Counter Measures
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
COP15	Conference of Parties
COPERT II	Computer Programme to Calculate Emissions from Road Transport
CVLB	Commercial Vehicle Licensing Board
DUD	Detail Urban Design
EEA	European Environment Agency
ERL	Express Rail Link

ETT	Eastern Transport Terminal
EPA	Environmental Protection Agency
GDP	Gross Domestic Population
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
HFCs	hydrofluorocarbons
ITACA	Intelligent Adaptive Traffic Control System
ITS	Intelligent Transportation System
KLIA	Kuala Lumpur International Airport
KPPCB	Koperasi Pengangkutan Putrajaya dan Cyberjaya Berhad
KTM	Keretapi Tanah Melayu
LCA	Life Cycle Assessment
LCC	Low Carbon City
LCCF	Low Carbon Cities Framework
LFPR	Labour Force Participation Rate
LRT	Light Rail Transit
LPG	Liquid Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MSC	Multimedia Super Corridor
N ₂ O	nitrus oxide
NC2	Second Initial National Communication

NGTP	National Green Technology Policy
NGV	Natural Gas Vehicles
NKEA	National Key Economic Area
PAPSB	Pengangkutan Awam Putrajaya Sdn. Bhd.
PCRT	Putrajaya Cyberjaya Radio Taxi
PFCs	perfluorocarbons
PGC 2025	Putrajaya Green City 2025
PJC	Putrajaya Corporation
PTAP	Putrajaya Transport Action Plan
PTM	Pusat Tenaga Malaysia
P&R	Park & Ride
SF ₆	sulphur hexafluoride
SOC	Soil Organic Carbon
SOV	Single Occupancy Vehicle
SPSS	Statistical Package for Social Science
TOD	Transit Oriented Development
TCM	Transportation Control Measure
TDM	Transportation Demand Management
UDG	Urban Design Guideline
UHI	Urban Heat Island
UNDP	United Nations Development Programme
UNFCCC	United Nation Framework Convention on Climate Change

VKT	Vehicle Kilometer Travelled
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute
WTT	Western Transport Terminal

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

This chapter sets out to establish a framework for the research. Subchapter 1.1 provides a background of study concerning carbon footprint and transportation emissions. In subchapter 1.2, a profile of Federal Territory of Putrajaya as case study area was briefly discussed to provide overview and capture the characteristic of the site in relation to the research topic. This is followed by subchapter 1.3 which comprehensively discusses the problems and issues pertaining to the research topic. Subsequently, in subchapter 1.4, three research questions were stated based on the problem statements identified. Further specify the research structure; subchapter 1.5 listed the aim and three objectives of the research. Then, limitation of research was stated in subchapter 1.6, followed by the significance of the research in subchapter 1.7. Additionally, subchapter 1.8 illustrates the structure of the research. Lastly, subchapter 1.9 summarizes the chapter.

1.1 BACKGROUND OF RESEARCH

In the background of research, first, researcher will elaborates the current situation or phenomena that elicit the intention of conducting this research. In the first part, the researcher provides a glimpse overview on the phenomenon of climate change facing worldwide and the rapid increase of carbon dioxide (CO₂) emissions over the past few decades as a result of human activities. Further specify the discussion, in the second part; the researcher will exemplify the main contributor of CO₂ emissions from road