ASSESSMENT OF CARBON FOOTPRINTS IN ROAD OPERATION AND MAINTENANCE ACTIVITY

RIDZUAN BIN MOHAMED RADZI

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Construction Management)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

DECEMBER 2019

DEDICATION

To my beloved wife Shahira Zainal Abidin and my children; Nur Irdina, Muhammad Irfan, Muhammad Iqbal & Nur Afrina.
Thank you for your patience and endless support.

To my parents; Hajjah Hafifah Abdul Hamid & Haji Muhammad Radzi Saad and to my mother in-law Puan Che Puteh Abdul Rahman and families for their continuous encouragement and supports.

To all my friends, thank you for the great and endless supports along the way. “Grade together on time”.

ACKNOWLEDGEMENT

I wish to express my sincere appreciation to my supervisor Prof. Ir. Dr. Rosli Bin Mohamad Zin for encouragement, guidance, critics and support.

Secondly, I would like to acknowledge all of the expert panels, respondents, colleagues who have contributed toward their ideas and their opinion for this study. This study will be meaningless without them.

Sincere appreciation also extends to all who have provided assistance in collecting data especially personnel from JKR and concession company.

ABSTRACT

By the year 2030, Malaysia has pledged to reduce emissions (GHG) by 45%. In Malaysia, human activities and mobility via road networks will increase substantially with rising urbanization and living standards. As we know, road networks operate 24-hour and require maintenance all the time. Consequently, significant carbon emissions from operations and maintenance activities are generated annually in tandem with the increase in road users. This study aimed to identify sources of carbon emissions from operations and maintenance activities by collecting fuel usage during O&M from the concession companies. The total emissions of CO_2 resulting from the operation and maintenance activities in the state of Perak. The study results will make an impact on related government agencies and concession companies during the federal road operations and maintenance process. This study aimed to provide a framework for the importance of carbon emissions from a Perak Federal Road to help define potential targets for reductions. The results of this study show feasible carbon-reduction mitigation strategies for concession companies engaged in maintenance work contracts. Besides, the sources of carbon emissions from operations and maintenance activities are essential to establish since there is no study focus on carbon emission assessment for O&M in Perak. Activities for O&M are defined as RO1-Pothole Patching, Road Shoulder Maintenance, RO3-Grade Cutting, Road Furniture Maintenance, RO5-Maintenance of Bridges and Culverts, RO6-Drainage and RO7-Routine Inspection of Roads. Roughly 1 million liters per year of fuel are consumed after examining the equipment used. Fuel usage is 675,59 litres/kilometres. The daily fuel consumption averages 3,900,27 litres/day and a total of 2 631.47 tons/CO_2 carbon emissions result from the O&M activities are produced annually as well as 1.75 tons of CO_2/km. The gross carbon emission is 8,10 tons/day. Ultimately, the amount of carbon dioxide emissions from fuel consumption depends on the length of the road and equipment for each process. Fuel-efficient and well-maintained vehicles/machinery are considered to be one factor that can reduce fuel consumption in O&M activities to make O&M activities more efficient and reduce carbon emissions.

ABSTRAK

Menjelang tahun 2030, Malaysia telah berjanji untuk mengurangkan pelepasan (GHG) sebanyak 45%. Di Malaysia, aktiviti seharian manusia dan penggunaan rangkaian jalan raya akan meningkat dengan ketara dengan peningkatan urbanisasi dan taraf hidup. Seperti yang kita tahu, rangkaian jalan raya beroperasi 24 jam dan memerlukan penyelenggaraan sepanjang masa. Akibatnya, pelepasan karbon dari aktiviti operasi dan penyelenggaraan jalan meningkat setiap tahun seiring dengan peningkatan pengguna jalan raya. Kajian ini bertujuan untuk mengenal pasti sumber pelepasan karbon daripada aktiviti operasi dan penyelenggaraan dengan mengumpul penggunaan bahan api semasa O&M daripada syarikat-syarikat konsesi serta menentukan jumlah pelepasan CO_2 yang terhasil daripada aktiviti operasi dan penyelenggaraan di negeri Perak. Hasil kajian akan memberi impak kepada agensi-agensi kerajaan yang berkaitan dan syarikat-syarikat konsesi semasa operasi dan penyelenggaraan jalan persekutuan. Kajian ini bertujuan untuk menyediakan satu rangka kerja bagi membantu menentukan sasaran yang berpotensi dalam mengurangkan pelepasan karbon jalan persekutuan. Keputusan kajian ini dapat menunjukkan dalam strategi ke arah pengurangan karbon bagi syarikat-syarikat konsesi yang terlibat dalam kontrak kerja-kerja penyelenggaraan. Selain itu, sumber pelepasan karbon daripada aktiviti operasi dan penyelenggaraan adalah penting untuk dikenalpasti kerana tidak ada fokus kajian kepada penilaian pelepasan karbon bagi O&M di Perak. Aktiviti untuk O&M ditakrifkan sebagai RO1-Penampalan Lubang Jalan, RO2-Penyelenggaraan Bahu Jalan, RO3-Pemotongan Rumput, RO4-Penyelenggaraan Perabot Jalan, RO5-Penyelenggaraan Jambatan dan Pembetung, RO6-Longkang dan RO7-Pemeriksaan Rutin Jalan. Kira-kira 1 juta liter setahun bahan api digunakan oleh jentera dan mesin, penggunaan bahan api adalah 675,59 liter / kilometer, purata penggunaan bahan api setiap hari adalah 3,900,27 liter / hari dan pelepasan karbon CO_2 sebanyak 2,631.47 tan CO_2/sehari dihasilkan oleh aktiviti operasi dan penyelenggaraan jalan setiap tahun dan juga 1.75 tan CO_2 bagi setiap kilometer dan pelepasan karbon sehari adalah sebanyak 10.08tan sehari. Kesimpulannya, jumlah pelepasan karbon dioksida daripada penggunaan bahan api bergantung kepada panjang jalan dan peralatan bagi setiap aktiviti. Kenderaan cekap bahan api dan diselenggarakan dengan baik adalah sebagai salah satu faktor yang boleh mengurangkan penggunaan bahan api dalam aktiviti O&M dan akan menjadikan aktiviti O&M lebih cekap di samping dapat mengurangkan pelepasan karbon.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

JKR	-	Public Work Department
O&M	-	Operation and Maintenance
PWD	-	Public Work Department
CO_2	-	Carbon Dioxide
UNFCCC	-	United Nations Framework Convention on Climate Change
IPCC	-	Intergovernmental Panel on Climate Change
MOW	-	Ministry of Works
FHWA	-	The Federal Highway Administration of the U.S. Department of Transportation

LIST OF SYMBOLS

CO_2	-	Carbon Dioxide

CHAPTER 1

INTRODUCTION

1.1 Background

The construction of infrastructure has a significant impact on the country because it functions as a physical facility providing facilities to link basic life systems such as transport, electricity, communication, education and other systems. Roads, barrages, sanitation, water supply, telecommunication networks, bridges and tunnels are one of the primary infrastructures and will always be part of the government's commitment to develop and maintain social needs. Sustainable solutions to environmental and social obligations of infrastructure would increase social acceptance and are also built for longer life expectancy and infrastructure services themselves. Sustainable infrastructure design, taking into account many sustainable factors, will contribute to long-term operation and maintenance due to higher start-up costs. This is consistent with earlier studies which have considered the high cost of green technology the most important obstacles to the initiative (Chan, et al 2015). Although the initial cost of green building may be higher than traditional schemes, long-term cost savings in operations and maintenance are generally believed to lead to reducing these costs in return of investments (Robichaud, 2010).

The Centre for Sustainable Transportation defines a sustainable transport system as one that allows individual and community basic access requirements to be met safely and in a way that is in harmony with human health and ecosystems, and with equity in and between generations; affordable, operating efficiently, offering a choice of mode of transportation, and supporting a vibrant economy; and restrict liberation and balance in the ability of the planet to absorb it (Oswald & Waksmunski, 2015). Infrastructure provides connectivity and supports a variety of

essential basic systems to community life. Hence, sustainable infrastructure will be a better choice for stabilizing social, economic and environmental.

Most facilities providers have been very much supportive of sustainable infrastructures, as it is important for future generations to protect their environment. It is no secret that the construction of any infrastructure such as dams, airports, roads and ports has a major influence not just on the environment but also on the socio-economic situation of a country. The construction and operation of the road itself in the transport sector has a high impact on the three environmental aspects, the climate, social, and economic. In addition to the significant impact of the combustion of vehicle carbon fuels. Although many concentrates on the planning, design and construction phases of the road, regular road maintenance is critical in the operational phases. The road cycle involves the planning, design, construction, operation maintenance and repair phase. The operational and maintenance phase may last up to 40 years, covering most of the 35-year duration, while an average of 5 years for the planning, design and construction phase. The operation and maintenance stage should therefore be regarded as a significant contributor to road sustainability.

Since before independence, roads have begun in Malaysia. Prior to 1957, Johor Bahru was linked in the south to Kangar in the north, and Kota Bharu to the east, linking major cities to other towns. Within 1957 the independence of the country became successful and efforts were undertaken to improve the road system by promptly planning the development, in particular the Federal government's Malaysia Plan every five years (JKR Malaysia, 2009).

Overall, almost 240,000 km of roads are maintained and the statistics show a significant annual increase. In terms of road performance and longer road lives, it is felt that road operation and maintenance play an important role. The total length of roads in Malaysia in 2000 is only 67,590.46 kilometres, while there are 237,022,353 kilometres in 2017, which indicates a significant rise of more than three-thirty percent (PWD, 2018).

The overall cost of state road maintenance in 2000 totalled RM841,900,000,00 and this increased periodically each year in line with an increase of 4,328,342,800,04 routes in 2017, more than 500 percent (PWD, Malaysia 2018). These enormous amounts of maintenance costs will not only burden the government, but will also cause public nuisance whenever renovation work is carried out. Concession firms and contractors, acting for the government to ensure the performance of roads, were responsible for maintenance (Robichaud, 2010).

Roads and highways are the country's most important infrastructure and play a key role in the social and economic development of the nation. Such infrastructures, including highways, bridges, tunnels and other related services, benefit the community as they provide connectivity between cities and towns that will improve societies ' economic and social participation. According to data from the Department of Public Works (JKR), as announced in 2017, there is 237,022,353 km of roads in Malaysia (PWD, 2018). Such roads include roads and highways in state and federal governments. According to the World Bank, in Malaysia, 20 km per 100 km2 of country area constitute the total road network, with 76 percent of roads paved. In comparison to Table 1.1, it clearly shows that 17,949,731 km are federal roads and 2 000,880 km have been added by highways. The data show state roads, with a total length of 217,071,742 km., account for almost 92 percent of Malaysia's total roads. It has been announced that RM4,328,342,800.04 has been allocated for maintenance in 2017 (PWD, 2018).

Table 1.1 Malaysia road statistic year 2017

(Source: JKR, Road Statistic year 2018)

Peninsular Malaysia	Sabah & Sarawak	Highway
Federal Road = 14,886.841km	Federal Road = 3,062.890km	= 2,000.880km
State Road = 165,326.634km	State Road = 51,745.108km	

1.2 Problem Statement

To regulate global average temperature and natural gasses in our environment including water vapor, methane, nitrous oxide and carbon dioxide (CO_2), the Earth's surface must hold these Sun heats. Such gases are used for the purpose of capturing the required amount of heat from the sun so that conditions are conducive to the life of all living creatures. Nevertheless, as the age of industrialization arrived in the late 1700s, human activities also intensified the increased presence in our environment of some of these natural gasses and other human-made gasses. Together with other artificial gases (Table 1.2), these gases increase the amount of heat that is attracted from the sun to our atmosphere and cause climate change and global warming. Through the UN Climate Change Framework Convention (UNFCCC), the United Nations has identified six gases which contributed to the development of global warming and climate change through the growing presence of them in our atmosphere (Low Carbon Cities Framework, 2017).

Table 1.2 Types of GHG in Atmosphere

(Source: Ministry of Energy, Green Technology and Water Malaysia (KeTTHA), Low Carbon Cities Framework Version 2, 2017)

No	Name of Gas	Chemical Formula	GWP (over 100 years)	Atmospheric Life Span (years)
1	Carbon dioxide	CO_2	1	100-1000
2	Methane	CH_4	23	12
3	Nitrous oxide	N_2O	296	114
4	Chlorofluorocarbons	CFCs (various)	6000 - 14000	45-1700
5	Hydro fluorocarbons	HFCs (various)	12 - 1200	0.3-260
6	HFCs (various)	SF_6	22000	3200

CO_2 is the biggest and best-known of the six gasses involved in climate change, even though the majority of the gasses have a greater impact on global climate change in equal quantities compared to CO_2. A ton of methane, for example, is 23 times heavier than a ton of CO_2. However, carbon dioxide has been chosen for the benchmarking gas and the world's potential for warming is 1 compared to 23 methane. Global warming is essentially an excessive atmospheric CO_2 epidemic, which acts like a blanket that absorbs heat and warms the earth and eventually causes the sea level to rise, as shown in Figure 1.1.

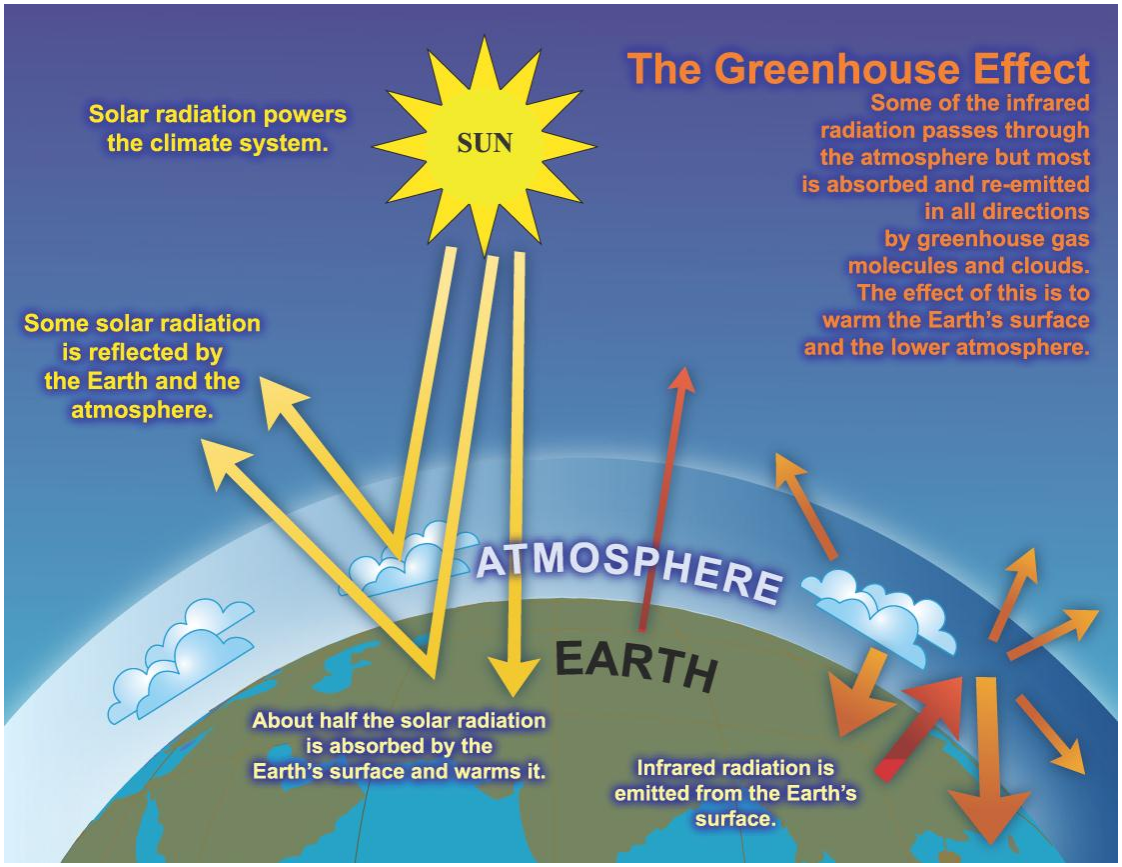

Figure 1.1 The Greenhouse Effect

(Source: https://www.ipcc.ch/site/assets/uploads/2018/02/faq-1-3-fig-1.jpg)

Global climate change is one of the most critical issues that have been faced by the people of earth. From overview, The Intergovernmental Panel on Climate Change (IPCC, 2014) expects that, the global temperatures would rise 2°C (World

Resources Institute, 2014) therefore, the need for CO_2 reduction has become the major concern as the adverse effect of such emission are experienced by the worldwide nations. In United Nation Climate Change Conference 2015 (COP21), as per Figure 1.2, Malaysia has declared to reduce GHG intensity emissions by 45% by 2030 (Inventory 2015).

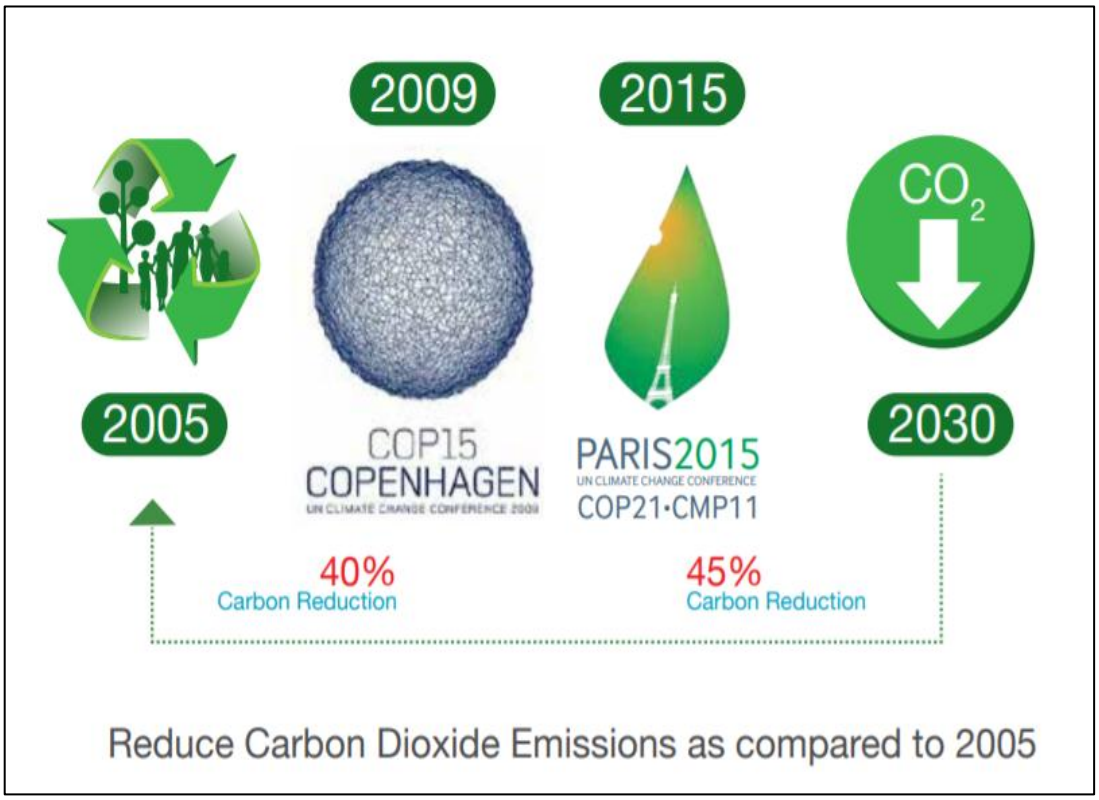

Figure 1.2 Malaysia's Commitment Towards Sustainability

(Source: https://www.greentechmalaysia.my/media/LCCF_Book-Version-2-2017.pdf (Page 22))

The infrastructure of surface transportation like roads also contributes to emissions of greenhouse gas and is responsible for CO_2 emissions. AASHTO states that transport is one of the most important environmental contributors, in particular harmful CO_2 emissions, resulting in global warming. The 2013 National Energy Balance says that the energy consumption in the transport sector has resulted in an unprecedented rise in CO_2 emissions in Malaysia to the top third in terms of CO_2

emissions from the transportation sector in ASEAN countries after Indonesia and the Philippines, up to 184,9 percent over the last 40 years (KeTTHA, 2017).

Obviously, carbon dioxide (CO_2) and other GHG pollution is responsible for the life cycle of roads, including construction, operation and maintenance and must be addressed sensitively because of their importance for business and economic factors. The level of daily road maintenance would certainly lead to the fair amount of GHG emissions. In addition, the source of dioxide carbon emissions from operations and maintenance activities is truly important and fuel consumption directly attributable to the resulting CO_2 emissions should be captured and monitored.

1.3 Aim and Objectives

This study aims to identify further, measure and calculate the carbon footprint during O&M in order to reduce greenhouse gas emission for federal roads. At the end of this study it will determine the total CO_2 emission and lastly, the amount of GHG released per O&M operation unit was calculated. The following objectives are identified to achieve this aim:

1. To identify the sources of carbon emission from Operation and Maintenance activities.
2. To collect the fuel usage from the contractor company in order to observe the fuel consumption of machineries during maintenance activity.
3. To determine the total CO_2 emission resulted from the operation and maintenance activities.

1.4 Scope and Limitations of the study

This study will be set on to O&M of federal roads in Perak. Main subject is focus on concession companies involved in maintenance work contracts where

contract had been awarded to base on zone. For the O&M of roads in Peninsular Malaysia, it had been divided into four zones which consists of Northern, Central, Southern and Eastern where each zone been appointed with one data collection form. In line with that, roads in the jurisdiction of Perak concessionaire are targeted for the scope of the study. Respondent targeted are the concession companies that involved in O&M Activities. The respondents also include professionals from multi-level stakeholders of road maintenance. Scope of study are focusing on the operation and maintenance work only.

1.5 Summary of Chapter

This study will be set on to O&M of federal roads in Perak. Main subject is focus on concession companies involved in maintenance work contracts where contract had been awarded to base on zone. For the O&M of roads in Peninsular Malaysia, it had been divided into four zones which consists of Northern, Central, Southern and Eastern where each zone been appointed with one data collection form. In line with that, roads in the jurisdiction of Perak concessionaire are targeted for the study.

REFERENCES

Barandica, J.M., Fernandez-Sanchez, G., Berzosa, A., et al., 2013. Applying life cycle thinking to reduce greenhouse gas emissions from road projects. J. Clean. Prod. 57, 79 e91. https://doi.org/10.1016/j.jclepro.2013.05.036 (accessed by: 05/2017).

Chan APC, Darko A, Ameyaw 2015 EE. Barriers Affecting the Adoption of Green Building Technologies. Journal of Management in Engineering, 33(3), 04016057 1–12. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000507.

Coa, T., Durbin, T.D., Russell, R.L., Cocker III, D.R., Scora, G., Maldonado, H., and Johnson, K., (2016) 'Evaluations of in-use emission factors from off-road construction equipment' *Atmospheric Environment* 147 (2016) 234-245

EEA. Final energy consumption by sector and fuel — European Environment Agency. http://www.eea.europa.eu/data-and-maps/indicators/final energyconsumption-by-sector-9/assessment; 2015 Off Website

European Commission Directorate Genera Climate Action. Road transport: reducing CO_2 emissions from vehicles - European commission. https://ec.europa.eu/clima/policies/transport/vehicles_en. 2016 Off Website

European Commission, 2015. Climate Action: Reducing Emissions from Transport. http://ec.europa.eu/clima/policies/transport/index_en.htm.

European Commission, 2015. Climate Action: Reducing Emissions from Transport. http://ec.europa.eu/clima/policies/transport/index_en.htm.

Eurostat Statistics, 2015. Greenhouse Gas Emission Statistics. http://ec.europa.eu/ eurostat/statistics-xplained/index.php/Greenhouse_gas_emission_statistics.

Fernandez-Sanchez, G., Berzosa, A., Barandica, J.M., Cornejo, E., Serrano, J.M., (2015) 'Opportunities for GHG emissions reduction in road projects: a comparative evaluation of emissions scenarios using CO2NSTRUCT', Journal of Cleaner Production 104 (2015) 156e167 from: https://www.wri.org/annualreport/2014/#around-the-world

Intergovernmental Panel on Climate Change, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment

Report of the Intergovernmental Panel on Climate Change, [Core Writing Team: R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland. http://ar5-syr.ipcc.ch/.

International Energy Agency, 2016. CO_2 emissions from fuel combustion by sector in 2014, in CO_2 Emissions from Fuel Combustion, IEA, 2016. In CO_2 Highlights 2016-Excel tables. http://www.iea.org/publications/freepublications/publication/co2- emissions-from-fuel-combustion-highlights-2016.html.

Jabatan Kerja Raya Malaysia 2009, Malaysia Roads, Government of Malaysia, Available from http://www.jkr.gov.my/app-jkr/index.php?setlang=en

Keijzer, E.E., Leegwater, G.A. de Vos-Effing, S.E., de Wit, M.S., Carbon footprint comparison of innovative techniques in the construction and maintenance of road infrastructure in The Netherlands. Science Direct. 2015. Environmental Science & Policy 54 (2015) 218–225

KeTTHA. 2017 Green Technology Master Plan Malaysia 2017 - 2030. Ministry of Energy, Science, Technology, Environment, and Climate Change Putrajaya 1-210 p.

KeTTHA. 2017 Green Technology Master Plan Malaysia 2017 - 2030. Ministry of Energy, Science, Technology, Environment, and Climate Change Putrajaya 1-210 p.

Low Carbon Cities Framework. 2017 Version 2. Ministry of Energy, Green Technology and Water Malaysia (KeTTHA), Greentech Malaysia. 5-6. Available from https://www.greentechmalaysia.my/media/

Olivier, J.G.J., Muntean, M., 2014. Trends in Global CO_2 Emissions: 2014 Report. PBL Netherlands Environmental Assessment Agency and Institute for Environment and Sustainability of the European Commission's Joint Research Centre, The Hague. http://edgar.jrc.ec.europa.eu/news_docs/jrc-2014-trends-in-global-co2-emissions2014-report-93171.pdf.

Oswald Beiler M, Waksmunski E. 2015 Measuring the Sustainability of Shared-Use Paths: Development of the GreenPaths Rating System. Journal of Transportation Engineering, 141(11), 04015026 1-10. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000796

Oswald Beiler M, Waksmunski E. 2015 Measuring the Sustainability of Shared-Use Paths: Development of the GreenPaths Rating System. Journal of

Transportation Engineering, 141(11), 04015026 1-10. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000796

Pongpeng TK and J. 2017 Effect of Sustainable Infrastructure Assessments on Construction Project Success Using Structural Equation Modelling. Journal of Management in Engineering, 33(3), 04016056- 1–12. https://doi.org/10.1061/(ASCE)ME.1943 5479.0000509.

PWD Malaysia 2013 pH. Manual Penarafan Hijau JKR. Sektor Bangunan, Bangunan Sediaada Bukan Kediaman - KB2. Jabatan Kerja Raya Malaysia. Kuala Lumpur; 0-12p

PWD Malaysia 2016 JKR Strategic Plan 2016-2020 [Internet]. Jabatan Kerja Raya Malaysia. Kuala Lumpur; Available from http://www.jkr.gov.my

PWD Malaysia. 2015 Road Maintenance Contract. Jabatan Kerja Raya Malaysia. Kuala Lumpur;

PWD Malaysia. 2018. Road Statistics 2018 Edition. Road Facilities Maintenance Branch, PWD Headquarters Kuala Lumpur, Retrieved from https://www.jkr.gov.my/my/page/dokumen-teknikal-0 Res. Lett. 4, 034011

Robichaud LB, Anantatmula 2010 VS. Greening Project Management Practices for Sustainable Construction. Journal of Management in Engineering, 27(1), 48–57. https://doi.org/10.1061/ASCÊ ME.1943-5479.0000030

Robichaud LB, Anantatmula 2010 VS. Greening Project Management Practices for Sustainable Construction. Journal of Management in Engineering, 27(1), 48–57. https://doi.org/10.1061/ASCÊ ME.1943-5479.0000030

Santero, N.J., Horvath, A., 2009. Global warming potential of pavements. Environ.

Santero, N.J., Pavements and Environment: A life-cycle assessment approach. Ph.D. Thesis. University of California, Berkeley, 2009.

Santos, G. (2017) 'Road transport and CO_2 emissions: What are the challenges?', *Transport Policy*, 59 (2017) 71–74

Sarsam SI. 2015 Sustainable and Green Roadway Rating System. International Journal of Scientific Research in Environmental Sciences, 3(3), 99–106. https://doi.org/10.12983/ijsres-2015-p0099-0106

Seo, Y.G., Kim, S.M., 2013a. Estimation of greenhouse gas emissions from road traffic: a case study in Korea. Renew. Sustain. Energy Rev. 28, 777 e787.

United Nations Environment Programme, 2016. The Emissions Gap Report 2016. A UNEP Synthesis Report, Nairobi, November http://uneplive.unep.org/theme/index/ 13#egr..

United Nations ESCAP. 2006 Sustainable Infrastructure in Asia. Vol. 66, Overview and Proceedings Seoul Initiative Policy Forum on Sustainable Infrastructure Seoul, Republic of Korea, 6-8 September 2006. 218 p.

World Resources Institute 2014, Annual Report, Available