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DEVELOPMENT OF AN EMBODIED CARBON DATABASE FOR CONSTRUCTION MATERIALS IN MALAYSIA

BY

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ABSTRACT

Excessive carbon dioxide emission has threatened the world globally as it has caused global warming and natural phenomenon since several decades ago. Several ideas to decrease the output of carbon dioxide that consists of operational carbon (OC) and embodied carbon are many and one of them is to develop a database of embodied carbon (EC) emission to control and mitigate embodied carbon emission. Currently, there is no such database in Malaysia despite the carbon dioxide production is consistently rising and the country is one of ASEAN countries with a high amount of carbon dioxide production. The aim of this research is to introduce a local database for EC emission in Malaysia by recommending components of the database and suggesting measures that can be applied to ensure its relevance and clarity of its data. Three objectives need to be fulfilled in this research are: to identify the relevancy of a local database for EC emission in Malaysia; to develop appropriate measures that can be implemented to ensure the accurateness of data; and to propose important components and features of the local database that are suitable to be used in Malaysia. The research applied an in-depth interview sessions as a method to collect data and analyse the data collected with a qualitative method. Five respondents from different background that are knowledgeable with embodied carbon have interviewed. Based on interview sessions, the research has firmed that the database is relevant in Malaysia despite the EC emission is not give a big impact to the atmosphere in the country. The database can provides more reliable and accurate data that are suitable to be used in the country. Nevertheless, there are several problems that can affect the quality of data such as non-standardised, complex, and non-compliance in a manufacturing process. The scarcity of available data also can affect the accurateness of data. Thus, the involvement of the government is the most recommended to solve those problems. The research also has suggested a number of features and components that are suitable to be included in the database. Components such as EC value, list of materials, carbon calculator, indexing system, EC data for transportation activity, and price of materials are recommended. In addition, free-access database and integration with other green rating tools features in the database also are recommended as it can make the database more functional and usable to many professions. The findings from this research that introduce the local EC database will help to control embodied carbon emission, to encourage green building in Malaysia, and to increase awareness regarding a systematic database for EC emission by all related professionals in Malaysia.

خلاصة البحث

لقد هدد انبعاث ثاني أكسيد الكربون المفرط العالم بأسره لأنه تسبب في ظاهرة الاحتباس الحراري والظاهرة الطبيعية منذ عدة عقود مضت. هناك العديد من الأفكار لتقليل ناتج ثاني أكسيد الكربون الذي يتكون من الكربون التشغيلي (OC) والكربون المجسّد، وهناك واحدة منها تتمثل في تطوير قاعدة بيانات لانبعاثات الكربون المجسدة (EC) للتحكم في انبعاثات الكربون المجسدة وتخفيفها. حاليا، لا توجد قاعدة بيانات من هذا القبيل في ماليزيا على الرغم من أن إنتاج ثاني أكسيد الكربون في ارتفاع مستمر والدولة هي واحدة من دول الآسيان مع كمية عالية من إنتاج ثاني أكسيد الكربون. الهدف من هذا البحث هو تقديم قاعدة بيانات محلية لانبعاث الجماعة الأوروبية في ماليزيا من خلال التوصية بمكونات قاعدة البيانات واقتراح تدابير يمكن تطبيقها لضمان ملاءمتها وضوح بياناتها. يجب تحقيق ثلاثة أهداف في هذا البحث وهي: تحديد مدى ملاءمة قاعدة بيانات محلية لانبعاثات المجموعة الأوروبية في ماليزيا؛ لوضع التدابير المناسبة التي يمكن تنفيذها لضمان دقة البيانات؛ واقتراح المكونات والميزات المهمة في قاعدة البيانات المحلية المناسبة للاستخدام في ماليزيا. لقد طبق البحث جلسات مقابلة متعمقة كوسيلة لجمع البيانات وتحليل البيانات التي تم جمعها بطريقة نوعية. وقابلت خمسة مستطلعين من خلفيات مختلفة لديهم دراية بالكربون المجسّد. استنادًا إلى جلسات المقابلة، أكد البحث أن قاعدة البيانات ذات صلة في ماليزيا على الرغم من أن انبعاثات المجموعة الأوروبية لا تعطي تأثيرًا كبيرًا على الأجواء في البلاد. يمكن أن توفر قاعدة البيانات بيانات أكثر موثوقية ودقة مناسبة للاستخدام في البلد. ومع ذلك، هناك العديد من المشاكل التي يمكن أن تؤثر على جودة البيانات مثل غير موحدة ومعقدة وعدم الامتثال في عملية التصنيع. ويمكن أن تؤثر ندرة البيانات المتاحة أيضا على دقة البيانات. وبالتالي، فإن مشاركة الحكومة هي الأكثر الموصى بها لحل هذه المشاكل. واقترح البحث أيضًا عددًا من الميزات والمكونات المناسبة لإدراجها في قاعدة البيانات. يوصى بمكونات مثل قيمة EC وقائمة المواد وآلة حاسبة الكربون ونظام الفهرسة وبيانات EC لنشاط النقل وسعر المواد. بالإضافة إلى ذلك، يوصى أيضًا باستخدام قاعدة

بيانات الوصول المجاني والتكامل مع ميزات أدوات التقييم الأخضر الأخرى في قاعدة البيانات لأنها يمكن أن تجعل قاعدة البيانات أكثر وظيفية وقابلة للاستخدام في العديد من المهن. ستساعد النتائج التي توصل إليها هذا البحث والتي تقدم قاعدة بيانات EC المحلية على التحكم في انبعاثات الكربون المجسدة، وتشجيع المباني الخضراء في ماليزيا، وزيادة الوعي بشأن قاعدة بيانات منهجية لانبعاثات EC من قبل جميع المهنيين ذوي الصلة في ماليزيا.

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 dissertation for the degree of Master of Science (Asset and Facilities Management).

…….....
Khairusy Syakirin Has-Yun Hashim
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 dissertation for the degree of Master of Science (Asset and Facilities Management).

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…….
Azrin bin Mohd Din
Head, Department of Quantity Surveying

This dissertation 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 (Asset and Facilities Management).

……..
Abdul Razak Sapian
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.

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This dissertation is dedicated to my parents for laying the foundation of what I turned out to be in life.

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LIST OF SYMBOLS

%	Percent
α	Conversion factor
°C	Degree Celsius
CH_4	Methane
CO_2	Carbon dioxide
CO_{2e}	Carbon dioxide equivalent
$kgCO_{2e}$	Kilogram carbon dioxide equivalent
$kgCO_{2e}$/km	Kilogram carbon dioxide equivalent per kilometre
$kgCO_{2e}$/kWh	Kilogram carbon dioxide equivalent per kilowatt-hour
kWh/h	Kilowatt per hour
MJ/kg	Megajoules per kilogram
N_2O	Nitrous oxide
tCO_2	Metric tonnes carbon dioxide

AASHTO	American Association of State Highway and Transportation Officials
ALCAS	Australian Life Cycle Assessment Society
ASTM	American Society for Testing and Materials
AusLCI	Australian Life Cycle Inventory Database Initiative
AusAgLCI	Australian Agriculture Life Cycle Inventory
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Method
BQ	Bill of Quantities
CESMM3	Civil Engineering Standard Method of Measurement, Third Edition
CESMM4	Civil Engineering Standard Method of Measurement, Fourth Edition
CIBSE	Chartered Institute of Building Service Engineers
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Programme
EC	Embodied carbon
ECO-CM	Embodied Carbon of Construction Materials
EE	Embodied energy
HKUST	Hong Kong University of Science and Technology
IBS	Industrialised building system
ICE	Inventory of Carbon and Energy
iCIM	Interoperable Carbon Information Modelling
ISO	International Organization for Standardization
KKR	*Kementerian Kerja Raya Malaysia*
LCA	Life cycle assessment
LCAP	Life cycle assessment profile
LCI	Life cycle inventory analysis

LEAP	Long-range Energy Alternatives Planning system
LEED	Leadership in Energy and Environmental Design
LOCOG	London Organising Committee of the Olympic Games
MESTECC	Ministry of Energy, Science, Technology, Environment and Climate Change
MyCREST	Malaysian Carbon Reduction and Environmental Sustainability Tool
NRE	Ministry of Water, Land, and Natural Resources
OC	Operational carbon
PWD	Malaysia Public Works Department
RICS	Royal Institution of Chartered Surveyor
SIRIM	Standard and Industrial Research Institute of Malaysia
UK	United Kingdom
UK-GBC	UK Green Building Council
USA	United States of America

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND STUDY

Recently, the world has been shocked by the news regarding the Arctic has experienced unusually warm weather. Francis, Wilkinson, and Whiteman (2018) in the World Economic Forum have stated the temperature in the Arctic has risen around 20°C above normal or even higher. Najafi, Zwiers, and Gillett in 2016 said they have found out greenhouse gases is one of the factors that cause warm in the Arctic over the past century. Greenhouse gases based on Doll, and Baranski (2011) are the particles such as water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide, (N_2O), and other industrial gases that trap and absorb the heat in the Earth's atmosphere and radiate back to the Earth. According to Francis, Wilkinson, and Whiteman again, one of the treatments to slow down the disease progression is to cut carbon emissions throughout the world.

Carbon dioxide is the most common greenhouse gas emitted by human activities that can give an impact on nature. Based on the Royal Institution of Chartered Surveyor (RICS) (2008), 86% of greenhouse gases are carbon dioxide and usually, it is caused by human activities especially the burning fuels for energy generation. These trends could lead to the rise of global average temperature over 2°C and if it cannot be controlled, there is a 50% chance that the temperature rise would exceed 5°C. Carbon emission has two distinctive types. Operational carbon (OC) according to RICS (2012) is carbon produced from energy consumption while the building is occupied. The sources of the OC can be regulated loads such as heating, cooling, ventilation, lighting, and other

systems in a building. The OC also can be produced from an unregulated load, for example, ICT equipment, cooking, and refrigeration appliances. On the other hand, RICS (2012) also defined embodied carbon as the resultant emissions from all the activities that associated with energy consumption (embodied energy) and chemical processes during the life cycle period of the construction materials or products that includes extraction, manufacture, transportation, assembly, replacement, and deconstruction period. Thus, in order to reduce greenhouse gas in the atmosphere, the release of carbon dioxide gas should be reduced and controlled properly.

Several ideas also have proposed in order to reduce greenhouse gas emissions. One of the popular solutions for decreasing greenhouse gas emissions is to reduce the use of personal transportation. American Association of State Highway and Transportation Officials (AASHTO) has stated transportation has contributed 28% of greenhouse gases in the United States of America (USA) in 2006. AASHTO has recommended several strategies such as support biking and walking, more funding for efficient highway operations, research, and development to develop cleaner vehicles and fuels, increasing vehicle fuel efficiency and many more. Other than that, Union of Concerned Scientists (2007) also stated solutions such as improve renewable energy, improve soil management, reduce methane from livestock operation and many more also can contribute in cutting down the greenhouse gases emission.

In Malaysia, the government has initiated several endeavours as the government recognizes the threat that greenhouse gases can bring. According to Begum (2017), Malaysia's participation in the Kyoto Protocol and Paris Agreement shows that this country is very serious in responding the threat of greenhouse gases and its consequences to the environment, human, and economy of the nation. Based on Begum

again, Malaysia is very committed to reducing up to 45% of emission levels by the year 2030. Shahrul, Muhammad, and Nazia (2013) also firmed that the Malaysian government aims to reduce the carbon emission intensity of gross domestic product (GDP) up to 40% by the year 2020. Other than that, those researchers also have stated the Malaysian Policy on Climate Change has been endorsed by the Malaysian cabinet to ensure climate preservation and mitigate climate change for the nation's sustainability in both the short and long term. National Green Technology Policy also has introduced in 2009 to promote the development of the green technology sector. According to the Ministry of Natural Resources and Environment Malaysia, the Ministry of Energy, Green Technology, and Water has drafted a master plan on green technology that focusing on energy, transportation, manufacturing, building, waste, water, information and communication technology, agriculture, and forestry sectors.

Construction is one of the main sources for carbon dioxide emission behind transportation and energy industries in Malaysia (Ministry of Natural Resources and Environment Malaysia, 2015). In order to response the excessive release of carbon dioxide in construction and building industry, Malaysia Public Works Department (PWD) and Construction Industry Development Board (CIDB) launched the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) in 2015 in order to increase the number of green buildings in Malaysia (Yusof, 2018). According to CIDB (2016), MyCREST also capable of reducing carbon emission, hence reducing the impact on the environment. The rating tool, based on CIDB, accesses the building in three phases of the life cycle that are designing, construction, and operation and maintenance period.

One of the initiatives to control the emission of carbon dioxide is by creating a database for carbon dioxide emissions. A database according to Elmasri and Navathe (2011) is a collection of related data that have implicit meaning with a variety of size and complexity depending on the usage and its function. A database such as inventory to quantify the amount of the embodied carbon release can contribute to the reduction of the gas to the atmosphere by helping the construction industry and professions in the industry to make decision process in designing sustainable planning strategies (Teh, Wiedmann, Schinabeck, Rowley, and Moore, 2015). Other than that, according to Takano, Winter, Hughes, and Linkosalmi (2014), the accurateness of life cycle assessment (LCA), a fundamental tool to evaluate environment impact of product or processes throughout its lifecycle, also depends on the a completeness and accessibility of the data set especially data regarding embodied energy (as stated by Teh, Wiedmann, Schinabeck, Rowley, and Moore, 2015). Thus, the database system also can contribute to ensuring the emission of carbon dioxide can be reduced and controlled more efficiently.

In short, greenhouse gases can bring disastrous impact to our nature if humans are not able to control its quantity in the atmosphere. While there are several gases include in greenhouse gases, carbon dioxide is the most common gas released because of human activities. Thus, relevant initiatives or programs need to be created in order to control their emission to the atmosphere. Without an efficient database system that records the amount of carbon emission from materials, it will affect the initiative itself in reducing and controlling the carbon emission. Therefore, a database is important to assist any programs or system that has initiated to combat the carbon emission problem in order to control the amount of greenhouse gas in the atmosphere, and thus can solve the problem of global warming.

1.2 STATEMENT OF PROBLEM

There are two main problems that related to the local database for embodied carbon emission in Malaysia.

The amount of carbon dioxide emission in Malaysia is high

Malaysia is one of South-East Asia that emit a high volume of carbon gases to the atmosphere. According to the GlobalEconomy.com, Malaysia has produced 242,821 kilotonnes of carbon dioxide in 2014 which is the third highest value in South East Asia behind Indonesia and Thailand, and the tenth highest value in Asia (Figure 1). Other than that, the GlobalEconomy.com also has presented a graph of the carbon dioxide emission value from 1970 to 2015. The graph (Figure 2) shows that the value of carbon dioxide emission in Malaysia is gradually increasing from 1970 until 2015. Wai, Camerlengo, and Wahab (2005) also viewed the amount of carbon dioxide emission is bad as the annual temperature in Malaysia increase significantly in the past 43 years because of the global warming effect.

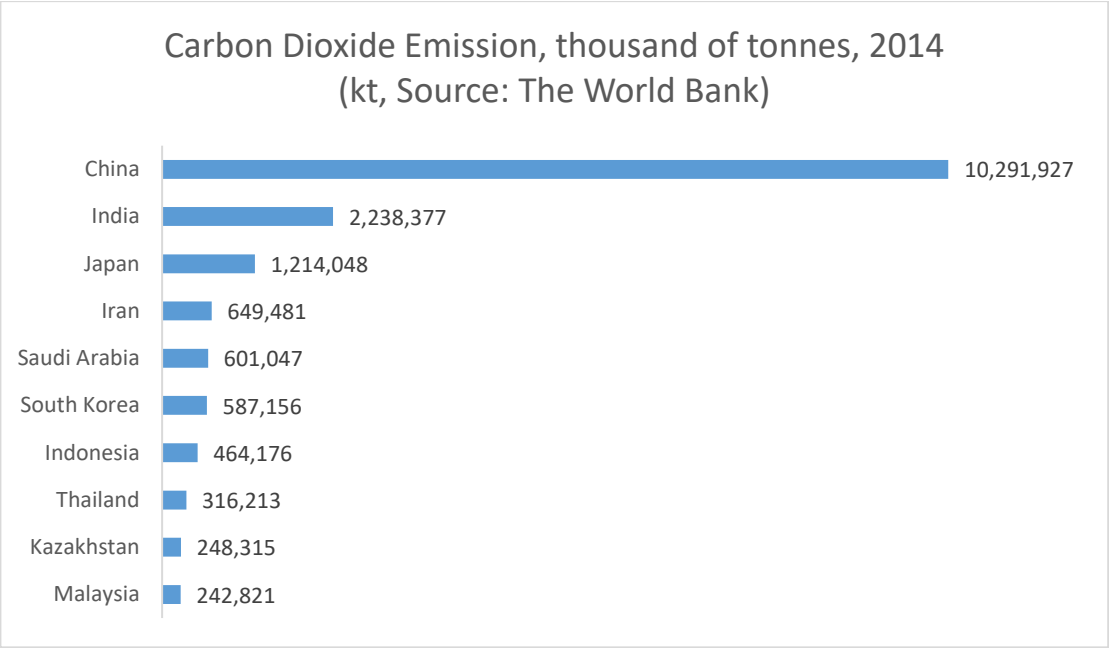

Figure 1 The amount of carbon dioxide emission among Asian countries (source: the GlobalEconomy.com)

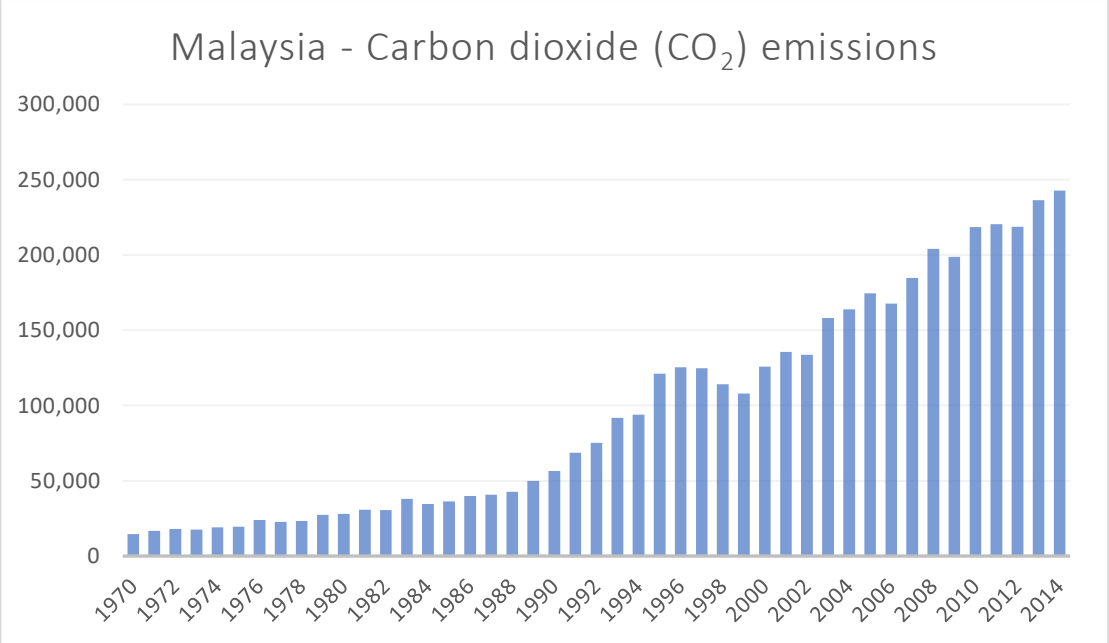

Figure 2 The amount of carbon dioxide emission in Malaysia until 2014 (source: the GlobalEconomy.com)