AN ASSESSMENT TOOL OF SUSTAINABLE DESIGN AND CONSTRUCTION ACTIVITIES FOR GREEN HIGHWAY

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

DECEMBER 2019

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim,

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed to my understanding and thoughts. I wish to express my appreciation and gratitude to my supervisor Professor Dr. Muhd Zaimi b. Abd Majid for his continuous guidance, support, and encouragement throughout my Ph.D. journey. Without his support, this thesis may never be completed. I am also very thankful to other lecturers for their guidance and advice.

I would like to express my special thanks to my husband and parent who always encourages me to finish my journey.

Finally, I also appreciate all my colleagues and friends who have contributed their support, guidance, encouragement, and contribution to these research projects.

ABSTRACT

The construction industry is one of the major contributors to the CO_2 emission which cause environmental impacts on the earth's climate. Malaysian government is committed in reducing the CO_2 by 40% in 2020 and 45% by 2030 as compared to the levels in 2005. Hence, there is a need to reduce the impact on the environment. Currently, there is no specific tool or standard of green highway assessment for the tropical region. Therefore, the main objective of this study is to develop an assessment tool for sustainable design and construction activities for highway development. Basically, the approach used in this study is to identify the significant criteria for sustainable design and construction activities and to determine the weightage and score for each criterion. The development of an assessment tool was based on the score for each criterion and the validation of an assessment tool was carried out by using the case studies. The significant criteria on established sustainable design and construction activities for green highway consist of construction management plan, noise mitigation control, equipment and machinery efficiency, quality management, context-sensitive design, erosion and sedimentation control, alignment selection, reused and recycled non-hazardous materials, recycled materials for subgrade improvement/soil stabilization and usage of local materials generated through survey and expert discussion. Questionnaires were developed and distributed to 140 respondents consisting of highways experts from concessionaires company, consultants, and engineers to obtain the agreement levels of listed criteria of sustainable design and construction activities for green highways. The weightage and score point were obtained on analyzed data using factor analysis from the Statistical Package for Social Science (SPSS) version 20 software. The weightage of each criterion was used to rank the criteria based on the importance of the criteria at the design and construction activities stages. The results showed that there are seven main criteria of design and construction activities for green highway development. Construction management plan is the most important criteria for achieving green highway development in Malaysia and followed by noise mitigation, equipment and machinery, quality management, context sensitive design, erosion and sedimentation control and alignment selection. All the main criteria and sub criteria had been developed into an assessment tool as a scorecard. In conclusion, the development of scorecard as an assessment tool of sustainable design and construction activities had been validated and is essential for green highway in Malaysia.

ABSTRAK

Industri pembinaan merupakan salah satu penyumbang besar kepada pelepasan CO_2 yang menyebabkan kesan alam sekitar terhadap iklim bumi. Selain daripada itu, kerajaan Malaysia juga telah komited untuk mengurangkan pelepasan CO_2 sebanyak 40% pada tahun 2020 dan 45% menjelang 2030. Oleh itu, terdapat keperluan untuk mengurangkan kesan terhadap alam sekitar. Pada masa kini, tiada piawaian penilaian lebuh raya hijau di rantau tropika. Oleh itu, objektif utama kajian ini adalah untuk membangunkan sistem penilaian bagi reka bentuk dan aktiviti pembinaan yang lestari untuk pembangunan lebuh raya. Pada asasnya, pendekatan yang digunakan adalah dengan mengenal pasti kriteria penting bagi reka bentuk dan aktiviti pembinaan yang lestari untuk menentukan nilai pemberat dan skor bagi setiap kriteria. Pembangunan sistem penilaian ini adalah berdasarkan kepada markah untuk setiap kriteria dan pengesahan alat penilaian yang dijalankan dengan mengaplikasikan sistem penilaian ke dalam kajian kes. Kriteria penting reka bentuk dan aktiviti pembinaan yang lestari untuk lebuh raya hijau yang dihasilkan daripada perbincangan bersama pakar terdiri daripada pelan pengurusan pembinaan, kawalan pengurangan bunyi bising, kecekapan peralatan dan jentera, pengurusan kualiti, konteks reka bentuk sensitif, kawalan hakisan dan pemendapan, pemilihan penjajaran, guna dan kitar semula bahan tidak berbahaya, kitar semula bahan untuk penambahbaikan subgred/penstabilan tanah dan penggunaan bahan-bahan tempatan. Borang soal selidik telah disediakan dan diedarkan kepada 140 responden yang terdiri daripada pakar lebuh raya daripada syarikat konsesi, perunding dan jurutera bagi mendapatkan maklum balas bagi kriteria yang telah disenaraikan bagi reka bentuk dan aktiviti pembinaan yang lestari untuk lebuh raya hijau. Nilai pemberat dan skor diperolehi daripada data telah dianalisis menggunakan faktor analisis dari perisian Statistical Package for Social Science (SPSS) versi 20. Nilai pemberat setiap kriteria telah digunakan untuk menentukan kepentingan kriteria pada peringkat reka bentuk dan pembinaan. Hasil kajian menunjukkan terdapat tujuh kriteria utama reka bentuk dan aktiviti pembinaan untuk pembangunan lebuh raya hijau. Pelan pengurusan pembinaan adalah kriteria yang paling penting untuk mencapai pembangunan lebuh raya hijau di Malaysia dan diikuti dengan pengurangan bunyi, peralatan dan jentera, pengurusan kualiti, reka bentuk sensitif konteks, kawalan hakisan dan pemendapan dan pemilihan penjajaran. Semua kriteria dan sub-kriteria utama telah dibangunkan menjadi alat penilaian sebagai kad skor.Kesimpulannya, pembangunan kad skor sebagai alat penilaian reka bentuk dan aktiviti pembinaan yang mampan telah disahkan dan adalah penting untuk lebuh raya hijau di Malaysia.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Global issues are often associated with the environment. The environmental issues are caused by many factors like construction activities. It had caused environmental impact such as climate change. Mukherjee and Cass (2012) stated that the construction sector accounting for 131 million metric tons of CO^2 is equivalent to the Environmental Protection Agency (EPA) for all eight contributed categories related to the energy demand. Its theory on responsibility and abatement against the threat of global climate change has also sparked public discussion. It had a tremendous increase in public appearance and worsens over the last few years.

According to Wiedmann and Minx (2007), the carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. Since carbon footprint has been defined widely, it covers a bigger scope or 'tiers'. The scope covers direct emission from the organization itself until discharged from other indirect activities.

Generally, carbon dioxide is also used as an indicator of greenhouse gas as it has by far the biggest share in the total amount (Henkel and Haag, 2010). Hertwich (2005) had stated that there are eight categories of activities that contribute to greenhouse gas emissions: construction, shelter, food, clothing, mobility, manufactured products, services, and trades. Meanwhile, categories by Hertwich and Peters (2009) had been comprised by Al-Mofleh, et al (2009) who pointed out that most of the energy demand is dominated by two superior consumers: the transportations and industrial sectors. These two sectors consume almost 80 percent of total final energy demand. According to Wiedmann and Minx (2007), the carbon

footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. Since carbon footprint has been defined widely, it covers a bigger scope or 'tiers'. The scope covers direct emission from the organization itself until discharged from other indirect activities.

1.2 Background of research

The whole world is leading to sustainable development and it includes Malaysia. Malaysia is one of the parties of the United Nations Framework on Climate Change and has ratified the Kyoto Protocol on 4 September 2004. According to Chin Haw et al (2006), the Kyoto Protocol entered into force on 16th of February 2005 and in 1997, called for stronger action in reducing Green House Gases or GHG emission in the post-2000 period. Malaysia has been following the negotiations and development of climate change issues very closely due to the numerous implications that may arouse from the agreements achieved.

The economic development in Malaysia leads to the high growth of advanced technology in the industrial and transportation sectors. Nevertheless, due to rapid development in Malaysia, some factors have created problems to the environment. As pointed out by Almselati et al (2011), the population growth of cities and urbanization has led to an increment in travel demand, which at the same time created problems to the environment. Since a member of the public is now aware of the importance of the environment, sustainable development focusing on infrastructure should be emphasized in Malaysia.

Sustainable development is no longer new to the environmental issues and has continued to rise throughout the world including Malaysia. Chong et al (2009) defined sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is also supported by National Strategies for Sustainable Development (2004) where they similarly stated that sustainable development is the development

However, the construction industry is not only focusing on building, but also the infrastructure.

As a developing country, Malaysia is not bound to any commitments towards reducing its GHG emissions under the Kyoto Protocol. However, Malaysia has committed to reducing 40 percent of carbon footprint emissions by 2020 as compared to 2005, as announced by Prime Minister during Climate Change Conference (COP 15) in Copenhagen. According to World Bank Group (2011), carbon dioxide emissions in Malaysia has increased from the year 1960 until the year 2008. The emissions remain on the increase because of the energy demand due to rapid development.

The construction industry has given one of the highest impacts on the environmental issues in terms of energy usage, wastage of the products, and material used in the industry itself. In the construction industry, infrastructure construction is one of the main sources of the economy for developing countries. Stakeholders of the project should be aware of the environmental effects during the decision making in terms of the planning, designing, constructing, and maintaining, especially when it involves infrastructure construction such as roadways or highways.

Highway development and redevelopment inherently contribute to environmental impacts such as stimulation of urban sprawl, loss of open space, noise pollution, and air pollution. Therefore, an improvement of to sustain highway development is needed, as it will lead to green highway, minimal usage of fuel, and greenhouse gas reduction. Apart from that, it is necessary to have an indicator to reduce greenhouse gases during highway construction.

'Green highway' is a term that is increasingly given attention in the field of development. The ideology of 'green' itself shows the connotation towards the environment whenever the communities worldwide are concerned. Although several guidelines are prepared as guidance for highway development, Lembaga Lebuhraya Malaysia (LLM) had also published 'Preliminary Guide to Nurture Green Highway in Malaysia' at the end of 2010; this shows how LLM also responds to the world's

current interest. The guidelines include the ideas for highway designers to develop green highways in Malaysia, where most of the fundamentals are extracted from overseas projects.

The U.S. Environmental Protection Agency (EPA) defines green highways as responsibility and sustainability towards the environment in many aspects, including design, construction, and maintenance. Green highway is developed with elements like (i) watershed driven stormwater management, (ii) life cycle energy and emission reduction, (iii) recycle, reuse, and renewable, (iv) conservation and ecosystem management, and (v) overall societal benefits as according to Bryce (2008). It is also classified as highways that are constructed using materials that emit zero or low concentration of pollutants and environmental friendly. In the Malaysian context, green highways are also related to responsibility and sustainability towards the environment; however, it involves larger aspects including planning, designing, constructing, operating and maintaining. Those definitions show that the development of a green highway requires new improvement methods to achieve its meaning.

1.3 Problem statement

According to Asian Development Bank, highway construction development is an energy dependency development, whereby most of the activities involved in highway construction consume energy that leads to generating greenhouse gases (GHG) (Gallivan et al, 2010). Therefore, energy efficiency will help in reducing carbon emissions during construction activities. During highway construction activities, the energy will be consumed from the construction materials, fossils fuels, removal vegetation, construction machinery as well as from construction equipment. Those activities will generate carbon emissions directly and indirectly. Besides that, Fernández-Sánchez and Rodríguez-López (2010) had stated that it is necessary to have new techniques and tools in building and civil engineering sector that will allow the environmental social and economic commitment to be met. Tatari and Kurmapu

(2011) agreed that there is a need to construct an assessment to promote sustainability development as well as to gauge a sustainability performance.

As mentioned by Fernández-Sánchez (2008) in Fernandes-Sanchez and Rodriguez-Lopez (2010), there are more than 70 evaluation tools in building sector based on sustainability assessment. Besides that, most of the sustainable assessments are related to the building sector. Thus, several indicators have been developed based on infrastructure projects. Yet, there is no clear assessment of green highway construction in tropical region due to difference in terms of topography, weather, alignment, the method of construction, and the materials used in the highway construction. Therefore, there should be a development of an assessment tool of sustainable design and construction activities for future green highway development that could help reducing carbon emission consumption during the highway construction process.

Optimized planning and decision-making should be applied in any kind of assessments of construction systems. One of the effective methods is variables in sustainability assessment. Different variables are proven to be effective in the assessment of the sustainability of construction systems as it is related to the economy, environment, and social. By using these variables and criteria in the assessment, the selection and application of highway construction systems will be viable with more compatibility with the environment. Thus, applying appropriate sustainability assessment criteria in highway construction systems can be effective to be used and its application is necessary for the Malaysian construction industry due to the increasing development of construction.

1.4 Research aim and objectives

This research aims to develop an assessment tool of sustainable design and construction activities for green highway development. The objectives identified for developing this assessment tool for sustainable design and construction activities of green highway development include the following:

(a) To identify and establish the criteria of sustainable design and construction activities for green highway development

(b) To determine the weightage for each criteria of sustainable design and construction activities for green highway development

(c) To determine the score for each criteria of sustainable design and construction activities for green highway development

(d) To develop an assessment tool of sustainable designs and construction activities for tropical green highway development

(e) To validate the tool of sustainable designs and construction activities for tropical green highway development

1.5 Scope of Research

This research focuses only on sustainable design and construction activities in green highways development to ensure that the objectives of this research had achieved. Sustainable design and construction activities are also the majority criteria in another green highway assessment. This research had conducted through questionnaires survey that distributed to all highway concessionaires' companies in Malaysia. The respondents of the survey were the employees from management and technical level in concessionaires' companies, consultants, and contractors who have experiences in highway development. Interviews had been conducted in parallel sessions during the distribution of questionnaires survey. The expert discussion also had been done among the experts of highway development. This research focuses only on three (3) states in Malaysia that have most highways development, which are Kuala Lumpur, Selangor, and Johor.

1.6 Contribution to the Body of Knowledge

This research attempts to contribute to the body of knowledge related to sustainable infrastructure specifically for green highway developments.

The findings of this research develop an assessment tool of sustainable design and construction activities for green highway. The assessment tool demonstrates the important criteria that need to be undertaken during the design and construction stage of highway development. Those criteria will lead to a clearer understanding of the sustainability for infrastructure development. This research provides new insights to other researchers, construction players, and the construction industry as a whole.

To researchers, apart from gaining more information on the research design process and methodology, this research is beneficial pertaining to adding more understanding of the collective knowledge of sustainable design and construction activities for infrastructure work especially in highway development. These include the benefits in terms of recognizing important criteria that could be included during the design and construction stages that might affect the sustainability development as well as the relationship between the criteria. The study identifies the main criteria and sub-criteria that should be included in the assessment tool during the design construction stages as a benchmark for sustainability for construction projects.

To construction players, this research is focusing only on the design and construction activities stages for green highway; however, the developed assessment tool for this research can be employed in other infrastructure development such as bridge and road. This assessment tool accommodates better sustainability benchmarks for highway design and construction stages because the criteria were selected thoroughly through several analytical stages. Besides, it is the first green highway assessment tools in South East Asia. In providing such appropriate and useful guidance, it potentially leads to a reduction of environmental problems caused by infrastructure construction. It also helps to reduce the emission of carbon footprint during the construction stages because all the planning for the highway projects

begin with sustainable design factors and are implemented during sustainable construction activities.

Above all, this research contributes to the recent Malaysian government initiative as outlined in the Construction Industry Transformation Programme (CITP) 2016-2020 agenda to promote high amenability to the environmental sustainability ratings and practices in achieving a low carbon, sustainable building, and infrastructure hub. With the assessment tool established in this research, it possibly is one of the initiatives to emerging the sustainable development through the construction industry. This research outcome would be part of the Green Highway Index which is used by Lembaga Lebuhraya Malaysia as an assessment tool in greening Malaysia highway.

1.7 Thesis organization

This research consists of six chapters. A brief summary of each outline is categorized as follows:

Chapter 1 comprises the introductory section that develops the direction of this investigation. It also states the research background, problems, objectives, and provides a brief discussion of the methodology and the thesis organization.

Chapter 2 encompasses the current state of knowledge by addressing the relevant literature. Areas covered in this chapter include sustainable designs and construction activities for green highway development. The literature review also covers the comparison of current green assessment for highways, the development of criteria for sustainable designs, and the construction activities criteria for green highway, and last but not least, the development of weightage and score point for each criterion. Overall, this chapter identifies the research gap, which justifies the need for this research.

Chapter 3 describes the method of research in detail including research methodology, data collection methods (namely questionnaires, interviews, model development), research information, selection of respondents, research instrumentation, expert discussion, data analysis, and validation of results.

Chapter 4 discusses the data analysis and results of the questionnaires and semi-structured interviews. Questionnaire feedback is presented, and the results are tabulated in order to answer the research questions. The data analysis and findings of the interview results illustrate the level of agreement of criteria in sustainable designs and construction industries for green highway in Malaysia. In addition, results from the expert discussion illustrate the description of the suitability of criteria and weightage for each criterion. This chapter discusses the development of an assessment tool for sustainable designs and construction activities for green highway in Malaysia. This chapter explains the assessment tool development by using software based on the agreed criterion during data collection.

Chapter 5 reviews the research objectives and development processes. This chapter also summarizes the conclusion with regard to the research outcomes based on the respective research questions. Apart from that, this chapter also analyses the contributions to the body of knowledge and its implications for both the research community and the green highway development. Finally, the recommendations for future research are proposed.

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