DEVELOPMENT OF A COMPUTER BASED GREEN HIGHWAY ENERGY EFFICIENCY INDEX ASSESSMENT FOR MALAYSIA

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To my beloved parents, wife, son, sibling and friends for their never ending care and supports.

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ABSTRACT

Green assessment tools are needed to improve behaviour, promote sustainable practices, and indicate the sustainability status of construction projects. The establishment of Manual of Malaysia Green Highway Index (MyGHI) in year 2014 was based on five main criteria which includes energy efficiency. There are significant claims that energy efficiency is very important to be considered when reducing carbon emission, and crucial to highway development. Electronic tools for MyGHI are necessary to expedite the evaluation of all criteria including energy efficiency in information technology era. This research developed computer based assessment tools of energy efficiency performance rating for MyGHI. Energy efficiency was identified as one of the most important criteria in green assessment tools. A thorough comparative review process on green highway assessment tools has been done by using cross-nation comparison. Energy Efficiency factors and elements that are suitable for Green Highway were identified using Questionnaire survey of 5-point Likert scale method and verified by several experts through focus group sitting. The data were analysed using Factor Analysis of Statistical Package for the Social Sciences version 17 (SPSS v.17) software. Later, the analysis was extended by developing the scores and weightage that resulted in five criteria, eleven sub-criteria, and twenty three elements with a total score of sixty four for Green Highway Energy Efficiency Index (GHEEI). Subsequently, a computer-based programming of GHEEI by using Visual Basic 6.0 that is suitable for web application was developed. This computer-based programming of GHEEI helps to visualise an audit assessment process, indicate the score performance of energy efficiency for highways and enhance the current implementation of MyGHI. In conclusion, this innovative research outcome assists stakeholders to speed up the decision-making process in planning and implement sustainability oriented highway projects that considered energy efficiency by a computer-based programming of GHEEI evaluation tool.

ABSTRAK

Alat penilaian Hijau diperlukan untuk menambah baik sikap, menggalakkan amalan lestari, dan menunjukkan tahap kelestarian projek pembinaan. Pengenalan Manual Indeks Lebuhraya Hijau Malaysia (MyGHI) pada tahun 2014, berdasarkan lima kriteria utama termasuk kriteria kecekapan tenaga. Terdapat tuntutan bahawa kecekapan tenaga adalah sangat penting dalam pengurangan pelepasan karbon dan kepentingan terhadap pembangunan lebuhraya. Alat-alat elektronik diperlukan oleh MyGHI bagi mempercepatkan penilaian semua kriteria termasuk kriteria kecekapan tenaga dalam era teknologi maklumat. Kajian ini membangunkan alat penilaian berasaskan komputer bagi menilai kadar prestasi kecekapan tenaga MyGHI. Kecekapan tenaga dikenal pasti merupakan salah satu kriteria paling penting dalam alat penilaian hijau. Proses perbandingan yang ketara antara alat penilaian lebuhraya hijau telah dilakukan menggunakan perbandingan antara beberapa negara. Faktor dan elemen Kecekapan Tenaga yang sesuai digunakan dalam Lebuhraya Hijau diperolehi melalui tinjauan soal selidik menggunakan kaedah Skala Likert 5-mata dan disahkan oleh pakar- pakar melalui kaedah duduk fokus secara berkumpulan. Data telah dianalisis melalui analisis faktor menggunakan perisian Pakej Statistik untuk Sains Sosial versi 17 (SPSS versi 17). Selepas itu, analisis dilanjutkan dengan pembangunan skor dan pemberat, dengan memperolehi lima kriteria; sebelas sub- kriteria; dan dua puluh tiga elemen dengan jumlah skor enam puluh empat untuk Indeks Kecekapan Tenaga Lebuhraya Hijau (GHEEI). Langkah seterusnya, alat penilaian GHEEI berasaskan pengaturcaraan komputer dengan menggunakan Visual Basic 6.0 yang sesuai untuk aplikasi web telah dibangunkan. Alat penilaian berasaskan pengaturcaraan komputer GHEEI ini membantu dalam menggambarkan proses audit penilaian, menunjukkan prestasi skor kecekapan tenaga bagi lebuhraya dan menggalakkan pelaksanaan penilaian MyGHI. Kesimpulannya, hasil penyelidikan inovatif ini akan membantu pihak berkepentingan untuk mempercepatkan proses membuat keputusan dalam merancang dan melaksanakan projek-projek lebuhraya berorientasikan kelestarian dengan mempertimbangkan kecekapan tenaga melalui alat penilaian berasaskan pengaturcaraan komputer GHEEI.

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LIST OF ABBREVIATIONS

ACEM	-	Association of Consulting Engineers of Malaysia
BEI	-	Building Energy Intensity
BE^2ST	-	Building Environmentally and Economically Sustainable Transportation Infrastructure Highway
CGC	-	Credit Guarantee Corporation Malaysia Berhad
CIDB	-	Construction Industry Development Board
COP	-	United Nations Framework Convention on Climate Change
CO_2	-	carbon dioxide
EE	-	Energy Efficiency
EEi	-	Energy Efficient index
EIA	-	Environmental Impact Assessment
EMP	-	Energy Maintenance Plan
EMS	-	Energy Management Systems
ETC	-	electrical toll collection system
EWM	-	Environmental and Water Management
GBI	-	Green Building Index
GDP	-	Gross domestic product
GHEEI	-	Green Highway Energy Efficiency Index
GHG	-	Greenhouse gas
GPC	-	Green performance strategies
GreenLITES	-	Green Leadership in Transportation and Environmental Sustainability
GreenPASS	-	Green Performance Assessment System
GreenRE	-	Green Real Estate
GTFS	-	Green Technology Financial Scheme
GUI	-	Graphics User Interface

HID	-	High Intensity Discharge
HVAC	-	Heating, ventilation, and air conditioning
IAQ	-	Indoor Air Quality
ID	-	Identity
IEC	-	International Electro-technical Commission standard
I- LAST	-	Illinois - Livable and Sustainable Transportation
IR	-	Ingénieur
ISI	-	Sustainable Infrastructure
ISO	-	The International Organization for Standardization
ITS	-	Intelligent Transportation Systems
JKR	-	Jabatan Kerja Raya Malaysia
KESAS	-	The Konsortium Expressway Shah Alam Selangor Sdn Bhd
KeTTHA	-	Kementerian Tenaga, Teknologi Hijau dan Air
KKR	-	Kementerian Kerja Raya Malaysia
KMO	-	Kaiser-Meyer-Olkin
kVA	-	kilovolt-ampere
LCCF	-	Low Carbon Cities Framework and Assessment System
LED	-	Light Emitting Diodes
LITRAK	-	Lingkaran Trans Kota Holdings Berhad
LLM	-	Lembaga Lebuhraya Malaysia
lm/w	-	lumens/watt
LPD	-	Lighting Power Density
MHA	-	Malaysia Highway Authority
MT	-	Material and Technology
MyCREST	-	Malaysian Carbon Reduction and Environmental Sustainability Tool
MyGHI	-	Malaysia Green Highway Index
MS	-	Malaysia standard
M&E	-	Mechanical and electronic
NLA	-	Natural Lighting Area
OLE	-	Object Linking and Embedding
OTTV	-	Overall Thermal Transfer Value
PAM	-	Pertubuhan Akitek Malaysia
PFIs	-	participating financial institutions

pHJKR	-	Penarafan Hijau JKR
PLUS	-	Projek Lebuhraya Utara Selatan Berhad
PSKLM	-	Association of Highway Concessionaires Malaysia
REHDA	-	Real Estate and Housing Developers'Association
SCRS	-	sustainable corridor rating system
SDCA	-	Sustainable Design and Construction Activities
SDE	-	Senai–Desaru Expressway
SPSS	-	Statistical Package for the Social Sciences
SQL	-	Structured Query Language
SR	-	Surveyor
SS	-	Social and Safety
RSA	-	Rest and Service Area
RTTV	-	Roof Thermal Transfer Value
UTM	-	Universiti Teknologi Malaysia
UV	-	Ultraviolet

LIST OF SYMBOLS

cd	-	The candela
L	-	Level
m^2	-	meter square
N	-	Number of respondent
ai	-	constant expressing the weight given to i
W	-	Watts
xi	-	variable expressing the frequency of response
π_k	-	weighting factor
%	-	Percentage
df	-	Degree of Freedom
Sig.	`	Level of Significance
Mjm-2	-	Megajoule/square meter

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CHAPTER 1

INTRODUCTION

1.0 Research Background

Highway is the one of the important infrastructure of the country and plays an essential role in a nation's social and economic development. In the past, most highway projects have been geared towards promoting economic development and creating jobs. Therefore, throughout the stages of planning, design, construction, maintenance, and replacement, the impacts on the natural environment is degrading the environmental quality (Huang and Yeh, 2008). Although some efforts like Environmental Impact Assessment (EIA) has used by authority to control the impact of pollution, but the environmental problems are still challenging.

Besides, highways are among infrastructures that facilitate transportation movement. Development of highway involved utilisation of energy along its life cycle process. According to data given by the Malaysian Highway Authority (MHA) up to December 2016, there are 31 tolled highways operating in Malaysia with a total length of 1,988.6km (MHA, 2016). It is believed that the number of tolled highways and the total length cover will increase to fulfil the increasing of demand from the road users. Thus, more carbon emission will be released into the surrounding due to highway construction activities. In order to minimise those impacts, similar to building, highway should response to green initiatives.

Uncontrolled carbon emission to the environment will tend to lead the greenhouse effect at developed area. Green Technology initiatives and actions are necessary to reduce the greenhouse effect cause by carbon emission. The term "Green Technology" was introduced in the western countries in the early 1990's. Green Technology is part of the sustainable development application whereby it utilising environmental science to conserve and recycle the natural resource needs of the present and future generation (MHA, 2010).

Green highway is one of the green initiatives that responsible to preserve the environment by using the Green Technology resources which has low carbon energy and environmental friendly. Several guideline or index related to green highway is available such as Green Road Rating System, Illinois-Livable and Sustainable Transportation (I-LAST), and Green Leadership in Transportation and Environmental Sustainability (GreenLITES). Thus, Malaysia Green Highway Index (MyGHI) was introduced to measure the greenness of the highways in Malaysia. These assessment tool is possible to measure the performance and classification of highway according to certain standards for sustainable purposes. Whilst, MyGHI is developed specifically for the Malaysia tropical weather, environment, cultural and social needs (LLM and UTM, 2014).

In establishing the assessment in MyGHI, Energy Efficiency is one of the fundamental elements of green highway development and considered as one of the important criteria in reducing carbon emission. In the aspect of energy consumption in highways, it includes embodied energy of materials, manufacturing, construction, operation and maintenance process. Thus, it is highly desirable to enhance energy efficiency in highways.

In order to apply energy efficiency in Malaysia highways development, the tools used may include energy management system, energy monitoring and available

technologies in the industry. The system is the platform for the users to execute the task systematically and the green technologies will assist in linking the output to the system.

While in term of considerations, there are some barriers that might affect the potential improvement of energy efficiency in Malaysia. The policies of government, awareness of nation, marketing strategic of company will accelerate the energy efficiency application in highway development.

Thus, applying the Energy Efficiency criteria in the Malaysia green highway will help to measure the classification of highway in term of energy efficiency. Energy Efficiency requirements are needed to be fulfilled in order to better meet the energy saving and low carbon emission.

1.1 Problem Statement

Many countries have established various sustainability rating tools related to highway in the literature. In the USA, researchers in Washington State have developed a Green Roads rating system in 2010 (Muench et al. 2010). While Illinois Livable and Sustainable Transportation (I-LAST) has introduced by Illinois Department of Transportation in 2010 (Illinois Department of Transportation, 2010).

Before the establishment of MyGHI in 2014, Malaysia highway has lack of agenda towards remarkable and certified Green Highway with assessment tools. However, the initiatives towards green or sustainable responsibility have been considered with some examples of green technology application (MHA, 2010). The emergence of green assessment tools helps to evaluate the green performance based on certain criteria in highway development.

The establishment of MyGHI suited the scenario and characteristic of Malaysian highway whereby it remunerate other international highway green tools. Malaysia highway authority has taken a big step in green technology by comprehensive initiatives towards sustainable highway. In 2011, Malaysia highway authority has cooperated with Universiti Teknologi Malaysia (UTM) to embark research in developing a Green Highway Index in Malaysia. The outcome of the project is Malaysia Green Highway Index (MyGHI) (LLM & UTM, 2014). The performance of highway can be evaluated with the establishment of certification level and scorecard among five criteria.

Energy Efficiency criteria has been identified as one of the energy saving measures in MyGHI project. It is in the focus of national energy policies and should be seriously concerned with green highway development. However, there is a possibility that the company would like to evaluate the performance of highway in term of Energy efficiency only. Thus, there is a need to enhance energy efficiency in highway development by introducing "Energy efficiency index" that adapt Malaysia case study.

Meanwhile, electronic tools are needed to enhance evaluation of efficiency. This is because MyGHI manual is a written format in hard copy and time consuming to complete the evaluation process. The assessment forms and all the details are needed to be filled in hard copy and submitted to the person in charge. These procedures may result in inefficiency during the process of evaluation and they seem to have difficulties in promoting the index to the user if the MyGHI tool are only available in hard copy. Thus, there is a need to come out with a Computer based assessment tool in order to let the user be familiar with the interface and process. In relation to energy efficiency, Computer based Energy Efficiency Index assessment in Malaysia Green Highway has to be developed for the convenient of users.

1.2 Aim and Objectives

The aim of this research is to provide computer based assessment tools of Energy Efficiency performance rating in Malaysia Green Highway.

In order to achieve the above aim, several objectives are listed as the following:

i. To identify the appropriate main criteria commonly utilised in green assessment tools
ii. To establish energy efficiency factors and elements suitable to be used for green highway
iii. To develop the scoring and weightage for Green Highway Energy Efficiency Index (GHEEI)
iv. To develop a Computer based Green Highway Energy Efficiency Index (GHEEI) assessment for Malaysia

1.3 Scope of Research

The development of MyGHI involves five main criteria. MyGHI manual has been established with five main criteria. Those criteria are Material and Technology, Construction Activities and Sustainable Design, Environmental and Water Management, Social and Safety, and Energy Efficiency (LLM & UTM, 2014). Local building rating tools and oversea highway rating tools is reviewed and adopt into Energy Efficiency factors and elements of MyGHI.

This research focused on the issues regarding highway development in Peninsular Malaysia. The targeted project sites in this research are located in

Selangor, Kuala Lumpur and Johor. 140 respondents from Malaysia highway authority, highway concessionaires and highway consultants firms have been selected and undergo questionnaire survey plus validation process. The highway concessionaires are named by Malaysia Highway Authority. Their points of views, suggestions and comments have been considered in order to develop a significant outcome.

This research only focuses on the main criteria of Energy Efficiency. The other four main criteria in MyGHI are excluded in the scope of this research. The scope has been made to lead the extension of the Energy Efficiency criteria development of MyGHI from manual to Computer based assessment. The successful development of Computer based assessment tool in Energy Efficiency main criteria will become the reference or guidance to other researchers in other main criteria of MyGHI which recommended to be developed by other researchers in future research projects.

In addition, this research focuses only on highway development, while the other types of roads are not included. Although “penarafan Hijau JKR (pHJKR)” has coverage of measurement of performance of road; however, future researches are encouraged to extend the research to link the gap of the knowledge between highway and road requirements.

1.4 Significance of Research

Under this research, the first objective is the identification of main criteria that appropriate to use in Computer based assessment tools for green highway. It is important to figure out the criteria that have been considered in the current green highway assessment tools. Energy Efficiency main criteria would seem to have high consideration in current green rating tools. This is because the identified Energy

Efficiency Criteria is the basis in the development of assessment tool in this research. Identify the criteria correctly will lead to representative results after evaluation.

Then, second objective which is energy efficiency factors and elements for green highway is identified by comparison among tools used in the reference, survey questionnaire and focus group sitting. These factors and elements are the requirements that might fulfilled by user in undergoing evaluation on their project. The identified factors and elements are readily to category in the next step.

After that, the scoring and weightage of energy efficiency index in green highway is developed by using the statistical analysis tool and confirmed in focus group sitting. There is a good possibility that total scoring which resulted in certification level will introduce in the research. For example, certification level from Certified, Silver, Gold to Platinum. It is seem to be the rating indicator to the Computer based Energy Efficiency Index in Malaysia Green Highway.

The forth objective is the Computer based Energy Efficiency Index assessment in Malaysia Green Highway is developed, i.e. a computerise system that need to login by user in order to evaluate the performance of highway in terms of Energy Efficiency. The classification of highway by using the established Index can benefit the construction of highway in Malaysia in response to initiatives of sustainable development.

All the four Objectives have contributed to the significant of research. None of countries in South East Asia has developed the advanced computer based Energy Efficiency assessment tools. Furthermore, this Computer based Energy Efficiency Index assessment tool is developed based on tropical climate in Malaysia. For example, Malaysia naturally has an abundance of sunshine and solar radiation. This

condition make it possible to use solar as a source of energy and can be applied to enhance energy efficiency in highway infrastructure.

1.5 Original Contribution to the Body of Knowledge

Basically, energy consumption in a highway includes embodied energy from its materials manufacturing, construction, operation and maintenance process which causes the emission of harmful gas like carbon dioxide (CO_2). Eventually, it is a significant contributor that generates an enormous amount of hazardous gas emission. Thus, it is highly desirable to enhance energy efficiency in highways where the sustainable practices should be implemented in order to overcome the carbon emission problem.

Energy Efficiency Index in Malaysia Green Highway is a part of the criteria in Malaysia Green Highway Index (MyGHI). The Malaysia Green Highway Index (MyGHI) has been established and implemented in Malaysia which can be referred as the pioneer reference and guideline in the sustainable development of Green Highway in the country.

The establishment of Computer based Green Highway Energy Efficiency Index assessment will make the index more user-friendly. Stakeholders or Self Evaluator can explore and pre-evaluate their project without the help of facilitator. In this research a standalone installer will be available for the users to install in their laptop. However, the future extension to other four main criteria will offer a complete set of assessment for MyGHI. Thus is potential to be operated in web-based assessment.

In line with the introduction of the Computer based assessment tools to the industry, the e-performance assessment can be executed and communication between all the parties will be more efficient. There is also the potential of extension to blend to other four criterions of MyGHI. Thus, it is a milestone to form a comprehensive or integrated decision support tool of highway development in Malaysia.

Furthermore, the Computer based Energy Efficiency Index has been developed specifically for the unique of Malaysia tropical weather, environment, cultural and social needs. Thus, this research is very significant contribution to the benefits of the nation.

1.6 Outline of the Thesis

This thesis consist of six Chapters. A brief summary of each Chapter is outlined as below:

Chapter 1 comprises the introductory section which illustrates the reason for the direction of the research. It also states the research background, research problems, research Objectives, methodology, scope and Original Contribution to the Body of Knowledge.

Chapter 2 comprises the literature on sustainability in the green highway. Other content of this chapter is literature on Energy Efficiency and reference to the relevant green tools in research. This chapter also included the literature on current rating tools in Malaysia.

Chapter 3 presents the research design and methodology, including the research design, the participants involved, reliability and validity of the data, the

methods of data analysis to be employed and development of Computer based assessment tool.

Chapter 4 presents the results of comparative review from literature review, the data collection from survey questionnaires, refinement and validation through expert discussions. Furthermore, this chapter also shows the steps in achieving the Objectives.

Chapter 5 proposes a framework and approaches to develop a Computer based Green Highway Energy Efficiency Index (GHEEI). User manual of GHEEI is developed in this research.

Chapter 6 presents the conclusions, recommendations for future research and closing remark of this research.

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