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Energy Efficiency Criteria for Green Highway

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ABSTRACT

Construction of highways has had negative environmental impacts. Thus, the concept of green highway was introduced in Europe as a part of sustainable development efforts. It has been long known that construction of regular highways leads to greenhouse gas emission from logging activities, cut and fill, excavation and road premix laying. Literature review shows there are several rating systems for energy efficiency; the latter constituting important criteria in the development of green highways. Energy efficiency refers to reduced usage of energy, , renewable energy as well as alternative energy as well as the and policies related to energy saving and renewable energy. This paper aims to identify the criteria and sub-criteria of energy efficiency for green highway development in Malaysia. These criteria are obtained from available rating systems and from literature. Data was obtained through survey questionnaire method. The LATAR Highway, one of the main concession company for highway development in Malaysia, was the respondent. This study reported five criteria of energy efficiency: technology and design, renewal energy, policy and plan, utilising solar energy, and reduce usage.

Keywords: Criteria and sub-criteria, energy efficiency, green highway, rating systems

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INTRODUCTION

Transportation is one of the key factors for growth and development of Malaysia's economy (Al-Mofleh, Taib, & Salah, 2010). The concept of green highway

first emerged in the West to improve their environment, transportation system, ecosystem, urban growth, public health and also the communities (Mohd Affendi et al., 2013; Zakaria et al., 2013). Green highway refers to a particular design of highways that improves the quality of the country infrastructure (Bryce, 2008).

According to Sharrard, Asce, Matthews, Asce, and Roth, (2007), the construction sector relies on four energy sources, namely diesel, fossil fuel, electricity and natural gas. Diesel fuel and electricity have been found to be the largest contributor of air pollution. Acquiring materials and equipment for the construction, maintenance and rehabilitation of highways (Cass & Mukherjee, 2010) have contributed to massive air pollution. In order to reduce emissions, careful planning is needed from the design, construction, operation and maintenance, use and decommissioning phase (Moir, Grenfell, Johnson, & Jowitt, 2012). This paper focuses on identifying the criteria for energy efficiency of green highways.

Overview of Green Highway

Green highway is a roadway design based on relatively new concept that incorporates transportation functionality and ecological requirements (LLM & UTM, 2014). Zakaria et al. (2012) described green highway as a roadway planned and designed to integrate transportation functionality and ecology. Green highway is also synonymous with transportation corridors which use low impact development tools, recycled materials, and locally sourced resources in transit right of ways to meet regulatory requirements for stormwater management and highway design (Weinstein, Pawlish, English, Bitting, Lukes, & Kloss, 2008). It is also a system of roads that mitigate negative impact on the environment to a level past minimum standards (Bryce, 2008).

Criteria of Energy Efficiency

Based on the guideline and rating systems available, the criteria of energy efficiency is listed in Table 1.

Greenroads is the first green road rating system established in United States in 2007. It is used to measure the responsive rate of green highway and it is a voluntary third party rating system for road project which seeks to recognise and reward roadway projects. Greenroad rating system focuses light pollution and lighting efficiency. The purpose is to reduce the energy used for lighting. According to University of Washington (2011), the greenroad rating system was proposed for installing lighting system with luminaires that meet or exceed the 2009 energy star standard for roadway lighting. It was aimed to reduce or eliminate lighting pollution and ensure energy efficiency.

New York State Department of Transportation's (NYSDOT'S) has established Green Leadership in Transportation and Environmental Sustainability program (GreenLITES). It functions as a tool to advance the Department's efforts to better align sustainability in planning, design,

Table 1
Criteria and sub-criteria of energy efficiency

Reference	Criteria	Sub-criteria
Greenroad Rating System (2007)	Energy and Environment Control	Light Pollution
GreenLites (2008)	Energy and atmosphere	Light Efficiency
		Reduce electrical consumption
		Stray light reduction
WISE (2008)	Life cycle energy and emission reduction	Reduced life cycle energy consumption
		Reduced emission
		Replace original material to consume less energy
Greenroad manual (2010)	Energy efficiency	Improve energy efficiency of operational system
BE2ST (2010)	Energy Use	Reduce energy consumption
Envision (2012)	Energy	Reduce energy consumption
		Use renewable energy
		Commission and monitor energy system
I-Last (2012)	Lighting	Reduced electrical consumption in 7 elements
		Stray light reduction
MyGHI (2014)	Energy Efficiency	Management policy
		Rest and service area
		Toll Plaza
		Compound and carpark
		Interchange

construction, and maintenance operations with long term needs. GreenLites also has sub criteria related to energy to reduce electrical consumption and stray light. Several measures can be adopted to minimise usage of electricity. This can be achieved for example, by using solar or battery power for street lighting and warning signs; replacing overhead sign lighting with higher type retro-reflective sign panels; and using Light Emitting Diode for street lighting and bus stop.

Washington Internship for Students Engineering (WISE) was introduced by University of Missouri in 2008. The WISE focused on life cycle energy and emission reduction (Bryce, 2008) to provide better air quality and save the energy. It also proposed to use alternative material and replace the original material with others that consume less energy but provide the same function.

Greenroads manual was published on 2011 by University of Washington. It was an improvement of the earlier version of the

2007 Greenroads. It serves as a guideline during design and construction phases in addition to quantifying sustainable attributes of a roadway project (Muench, Anderson, Hatfield, Koester, & Söderlund, 2011). The purpose is to improve energy efficiency of operational system, reduce the lifetime energy consumption of lighting system for roadway by using alternative materials. It also sets a standard requirement for installation of lighting system by using luminaires that meet or exceed 2009 energy star.

Another rating system is Building Environmentally and Economically Sustainable Transportation (BE2ST) which is a manual initiated by University Wisconsin in 2010. This is a data based program linked to open sources. It provides six main elements of green highway and targets reduction of energy consumption by 10% (Recycled Materials Resource Centre, 2010). The target is to reduce energy from the material, construction, operation and maintenance work.

ENVISION aims for reduced energy consumption; use of renewable energy, commissions and monitors energy systems. The purpose of energy reduction is achieved by controlling energy conservation through reducing overall operation and maintenance throughout the project's life cycle. Commission and monitor system would ensure efficient functioning and extend life by specifying the commissioning and monitoring of performance of energy systems.

I-Last only focuses on lighting. The sub-criteria of lighting relate to reduced electrical consumption and stray light reduction (Illinois Department of Transportation, 2010). It proposes seven ways to reduce electrical consumption: using alternative energy sources to power street lighting, warning signs and remote intelligent system (ITS) component; retrofitting the existing street lighting with high efficiency types; replace regular signs with retro-reflective ones to eliminate sign lighting; retrofit existing sign lighting with high efficiency types; use of high efficiency street lighting on new installation; use of alternative energy sources for bus stops; and use of high efficiency traffic signal which is Light Emitting Diode (LED).

In 2014, Malaysia introduced Malaysia Green Highway Index (MyGHI) as an assessment on green highway. The MyGHI is a manual on the sustainability of roadway design and implementation of green construction practices. The MyGHI has several sub criteria for ensuring energy efficiency in the areas of management policy; rest and service; toll plaza; compound and carpark; and interchange (LLM & UTM, 2014). Ratings are based on specific locations. The aim is to reduce electrical consumption by installing and using energy efficient electrical devices.

According to the "Preliminary Guide to Nurture Green Highway in Malaysia", there are five sub-criteria for energy efficiency: solar energy; Light Emitting Diodes (LED) for street lighting; Rest and Service area; Interchange; and Electrical Toll Collection

(ETC) (Salleh, 2010). Solar energy is an alternative energy that can be used to generate electricity (Zakaria et al., 2013). The sunlight absorbed by the solar panel is converted into electricity to light the streets and other facilities in rest and service area, toll plaza and interchange. Light Emitting Diode (LED) is an alternative material that can be used to reduce electrical consumption and it can be installed Rest and service area and interchange because it is economically viable and reliable. The advantages of using the LED for street lighting are its reliability, low maintenance cost, energy saving, save environment and new lighting possibilities. The Electrical Toll Collection system (ETC) was later introduced to be installed at toll booths to prevent long queues that contribute to environmental pollution (Salleh, 2010).

Thus, it is clear energy efficiency is one of the key factors of the rating system. According to Zakaria et al. (2012), energy efficiency is an important factor for the construction of the green highway and to produce low carbon emission (Gambatese & Rajendran, 2005).

METHODS

The questionnaires were distributed to concession companies such as LATAR and LKSA highway and authorities such as Jabatan Kerja Raya, Lembaga Lebuhraya Malaysia and Kementerian Kerja Raya Malaysia. A total of 142 respondents participated in this study to show energy efficiency criteria for green highway development.

Once the criteria had been finalised through questionnaires, data was analysed using factor analysis to produce mean index and factor loading. A factor analysis was conducted on 32 items. The Cronbach's alpha value was 0.953 with 32 variables, indicating high internal consistency for the data set (Rooshdi et al., 2014).

Data was analysed using Kaiser-Meyer-Olkin (KMO) and Bartlett's test. This test was aimed at identifying whether the criteria is sufficient to conduct factor analysis (De Vaus, 2002). The KMO ranges from 0 to1 with higher values indicating greater suitability, and amount greater than 0.750 is considered good (Rooshdi et al., 2014). The KMO value for this study was 0.867 and Bartlett's test was significantly large for [$x2 (496) = 6062.392$, $p<0.001$]. Therefore, the correlation between the items were sufficiently large for factor analysis. Chua (2009) recommended accepting values greater than 0.5.

Process extraction factor shows communality values are more than 0.5 for all items. Five factors had eigenvalues greater than 1, contributing about 82% of the variance in this study. The scree plot supported the criterion in retaining five factors. The result component matrix is less meaningful without rotation. Varimax rotation was performed and the component matrix shows factor 1 contains 11 items, while factor 2 contains 6 items, factor 3 contains 5 items, factor 4 have 7 items, factor 5 have 3 items. Table 2 shows rotated component matrix.

Table 2
Rotated component matrix for energy efficiency

Rotated Component Matrix[a]					
	Component				
	1	2	3	4	5
Saving energy using Sensor Motion	.858				
Saving energy using Electrical Sub-metering	.812				
Saving energy using Unit Air conditioner	.801				
Saving energy using Individual Switch	.782				
Saving energy using Light Emitting Diode (LED)	.753				
Saving energy using Natural Lighting	.698				
Saving energy using Lighting with efficiency system	.680				
Saving energy using Electrical toll collection system	.664				
Saving energy using Building energy system	.635				
Saving energy using Natural Ventilation	.632				
Stray light reduction	.539				
Wind Energy Plan		.972			
Ocean Energy Plan		.965			
Alternative energy using wind turbine		.958			
Alternative energy using ocean energy		.945			
Biodiesel Energy Plan		.878			
Alternative energy using biodiesel		.845			
Renewable energy policy			.867		
Building energy system plan			.856		
Solar Energy Plan			.841		
Energy plan for maintenance			.836		
Life cycle energy policy			.758		
Alternative solar energy for lighting Rest and Service area				.780	
Alternative solar energy for Street Lighting				.770	
Alternative solar energy for Lay-Bys				.766	
Alternative solar energy for lighting Carpark & Compound				.754	
Alternative solar energy for signage lighting Signage				.752	
Alternative solar energy for lighting Interchange				.724	
Alternative solar energy for Landscape lighting				.721	
Reduce Equipment and Machineries GHG Emission					.796
Reduce Fossil Fuel					.752
Reduce Electrical Consumption					.648
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					

In sum, there are five main factors for energy efficiency criteria for green highway development. Factor 1 represents technology and design while factors 2, 3, 4 and 5 represent renewal energy, policy and plan, utilising solar energy and reducing

Table 3
Framework of energy efficiency for tropical climate

Element	Criteria	Sub-criteria
Energy Efficiency	Technology & Design	Saving the energy using Sensor Motion
		Saving energy using Electrical Sub-metering
		Saving energy using Unit Air conditioner
		Saving energy using Individual Switch
		Saving energy using Light Emitting Diode (LED)
		Saving energy using Natural Lighting
		Saving energy using Lighting with efficiency system
		Saving energy using Electrical toll collection system
		Saving energy using Building energy system
		Saving energy using Natural Ventilation
		Stray light reduction
	Renewable Energy	Wind Energy Plan
		Ocean Energy Plan
		Alternative energy using wind turbine
		Alternative energy using ocean energy
		Biodiesel Energy Plan
		Alternative energy using biodiesel
	Policy & Plan	Renewable energy policy
		Building energy system plan
		Solar Energy Plan
		Energy plan for maintenance
		Life cycle energy policy
	Utilising Solar Energy	Alternative solar energy for lighting Rest and Service area
		Alternative solar energy for Street Lighting
		Alternative energy for lighting using Solar to Lay-Bys
		Alternative solar energy for Carpark & Compound lighting
		Alternative solar energy for Signage lighting
		Alternative solar energy for lighting the Interchange
		Alternative solar energy for Landscape lighting
	Reduce Usage	Reduce Equipment and Machineries GHG Emission
		Reduce Fossil Fuel
		Reduce Electrical Consumption

usage respectively. Each factor has its own criteria. All the criteria and grouping are based on the respondents' feedback.

RESULTS

Table 3 shows the framework of energy efficiency used in this study. Factor 1 is technology and design. The technology saves energy by using sensor motion, sub-metering, unit air conditioning, individual switch, light emitting diode, natural lighting, lighting efficiency system, building energy system and stray light reduction.

Factor 2 is renewal energy. It is based on the respondent's' perspective that renewal energy such wind, ocean, and biodiesel energy have good potential. The 8th and 9th Malaysia Plan targets renewable energy to reduce the nation's dependency on fossil fuels (Darus, Hashim, Nurhidayah, Manan, Azhar, Rahman, Abdul Maulud, & Karim, 2008). However, further research is required to study the use of renewable energy such as the ocean, wind and biodiesel in tropical climate. Additionally, the technology is costly and demanding; for example, to utilise wind energy, availability of strong wind is needed.

Factor 3 is policy and plan. Policies related to renewable energy are a must in addition to policies on energy system, maintenance and life cycle. These lead to effective energy saving.

Factor 4 is utilising solar energy. The energy from the sun can be used to light highways and buildings to reduce the usage of electricity. It is ideal for a tropical climate. By installing solar panels, sunlight is converted into electricity.

CONCLUSION

This study has attempted to establish a framework of energy efficiency for green highway by highlighted the relevant criteria and sub-criteria related to it. The criteria were technology and design, renewal energy, policy and plan, utilising solar energy, and reduce usage while each of this had its own sub-criteria.

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REFERENCES

Al-Mofleh, A., Taib, S., & Salah, W. A. (2010). Malaysian energy demand and emissions from the transportation sector. *Transport, 25*(4), 448–453.

Arvid Strand, P. N. (2009). Better roads increase emissions. Retrieved June 16, 2016, from http://www.transportbusiness.net/features/better-roads-increase-emissions

Brown, G. (2003). A method for assessing highway qualities to integrate values in highway planning. *Journal of Transport Geography, 11*(4), 271–283.

Bryce, J. (2008). Developing sustainable transportation infrastructure. *Washington Internships for Students of Engineering, University of Missouri*.

Cass, D., & Mukherjee, A. (2010). Calculation of greenhouse gas emissions associated with highway construction projects using an integrated life cycle assessment approach. In *Construction Research Congress*,1, pp. 1406–1415.

Chua, Y. P. (2009). *Statistik Penyelidikan Lanjutan - Ujian Regresi, Analisi Faktor, dan Analisis SEM*. Kuala Lumpur: Mc Graw-Hill Education.

Darus, Z., Hashim, N. A., Nurhidayah, S., Manan, A., Azhar, M., Rahman, A., Abdul Maulud, K. N., Karim, O. A. (2008). Potential Of Wind Energy In Sustainable Development Of Resort Island In Malaysia : A Case Study Of Pulau Perhentian (Perhentian Island). *10th WSEAS International Conference on Mathematical Methods, Computational Techniques and Intelligent Systems*, 431–435.

De Vaus, D. A. (2002). *Survey in Social Research* (5th Edition). London: Routledge.

Gambatese, J. A., & Rajendran, S. (2005). Sustainable roadway construction: Energy consumption and material waste generation of roadways. In *Construction Research Congress 2005: Broadening Perspectives - Proceedings of the Congress* (pp. 203–784407541).

Green, H., Can, I., & Manage, E. (2011). *After the Storm : How Green Infrastructure Can Effectively Manage*. New York, (September).

Huang, R., & Yeh, C. (2008). Development of an assessment framework for green highway construction. *Journal of the Chinese Institute of Engineers, 31*(4), 573–585.

Illinois Department of Transportation. (2010). *Rating System and Guide. Illinois - Livable and Sustainable Transportation (I-LAST)* (Version 1.0.).

Lee, J., Edil, T. B., Benson, C. H., & Tinjum, J. M. (2010). Use of BE2ST in-highways for green highway construction rating in Wisconsin. In *Green Streets and Highways 2010: An Interactive Conference on the State of the Art and How to Achieve Sustainable Outcomes* (389, pp. 480–494).

Lee, J., Edil, T., Benson, C., & Tinjum, J. (2013). Building environmentally and economically sustainable transportation infrastructure: green highway rating system. *Journal of Construction Engineering and Management*, 1–10.

LLM, & UTM. (2014). *Malaysia Green Highway Index*. Malaysia: Lembaga Lebuhraya Malaysia dan Universiti Teknologi Malaysia.

Mohd Affendi, I., Rozana, Z., Sani, B. A., Foo, K. S., Ain Naadia, M., Yazlin Salfiza, Y., … Zaimi, A. M. (2013). Fundamental Elements of Malaysia Green Highway. *Applied Mechanics and Materials, 284–287*, 1194–1197.

Moir, S., Grenfell, R., Johnson, A., & Jowitt, P. (2012). A protocol for carbon emissions accounting in infrastructure decisions. *Proceedings of the ICE - Civil Engineering, 165*, 89–95.

Muench, S., Anderson, J., Hatfield, J., Koester, J. R., & Söderlund, M. et al. (2011). *Greenroads Manual 5*. University of Washington.

Recycled Materials Resource Centre. (2010). *BE2ST-in-Highways*.

Rooshdi, R. R. R. M., Muhammad, R., Ab, N., Umar, N. Z., Zaimi, M., Majid, A., & Ismail, F. (2014). An evaluation of sustainable design and construction criteria for green highway. *Procedia Environmental Sciences, 20*, 180–186.

Rooshdi, R. R. R. M., Rahman, N. A., Baki, N. Z. U., Majid, M. Z. A., & Ismail, F. (2014). An Evaluation of Sustainable Design and Construction Criteria for Green Highway. *Procedia Environmental Sciences, 20*, 180–186.

Salleh, I. M. (2010). *Preliminary Guide to Nurture Green Highway in Malaysia*. LLM.

Sharrard, A. L., Asce, S. M., Matthews, H. S., Asce, A. M., & Roth, M. (2007). Environmental Implications of Construction Site Energy Use and Electricity Generation 1. *Journal of Construction Engineering and Management,* 133 (11), 846–854.

Soderlund, M., Muench, S. T., Willoughby, K. A., Uhlmeyer, J. S., & Weston, J. (2008). *Green Roads: Sustainability Rating System for Roadways. TRB 2008 Annual Meeting*.

Weinstein, N., Pawlish, M., English, A., Bitting, J., Lukes, R., & Kloss, C. (2008). Green Highways. In *Low Impact Development for Urban Ecosystem and Habitation Protection*.

Zakaria, R., Majid, M. Z. A., Zin, R. M., Hainin, M. R., Puan, O. C., Yaacob, H., & Adnan, A. (2012). Identification of energy efficiency criteria for Malaysia green highway. In *Proceeding of 8th Asia Pacific Structural and Construction Engineering Conference and 1st International Conference* (pp. 2–4).Kuala Lumpur, Malaysia

Zakaria, R., Seng, F. K., Muhd, M. Z., Zin, R. M., Hainin, M. R., Puan, O. C., … Moayedi, F. (2013). Energy efficiency criteria for green highways in Malaysia. *Jurnal Teknologi (Sciences and Engineering), 65*(3), 91–95.