Jurnal Teknologi

Full Paper

ASSESSMENT INDEX TOOL FOR GREEN HIGHWAY IN MALAYSIA

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Article history
Received
2 July 2015
Received in revised form
20 October 2015
Accepted
23 October 2015

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Graphical abstract

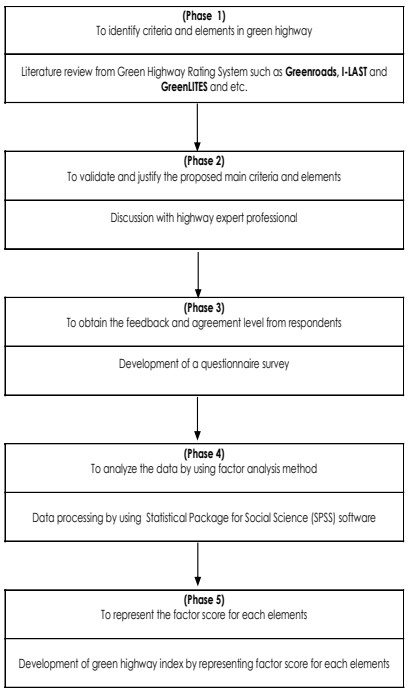

Figure 1 Research flow

Abstract

Green highway is a highway project that has been designed and constructed with the sustainability requirements and global standard. Basically, green highway is one of the major parts for sustainable concept where three major aspects are addressed which are economic, social and environment. The main focus for economic aspect is to increase profitability by making more efficient use of resources especially material, improve the quality of life by fulfilling the nation's need for social aspect while protecting the environment from the impact of CO_2 emission and using of natural resources efficiently for the purpose of environment aspect. Therefore, it is important for highway stakeholders to incorporate sustainable criteria in their projects. The implementation of sustainable concept in highway needs to be evaluated by green highway rating tool assessment. Thus, the purpose of this study is to establish a tool to assess and certify a green highway in Malaysia. The data for this study was obtained through group discussion with highway experts and questionnaires that were distributed to identify the sustainability factors. Then the data were analyzed using factor analysis method. The findings of this study indicated that, there are five major sustainable factor which are Sustainable Design and Construction Activities, Social and Safety, Energy Efficiency, Environmental and Water Management and Material and Technology that are included in the development of green highway rating system.

Keywords: Green highway, sustainability, green highway rating system, factor analysis

1.0 INTRODUCTION

Highway projects are closely linked with people's everyday life. It is also the uppermost infrastructure of a country and plays an essential role in a nation's social and economic development [1]. In Malaysia, the highway network is referred to as the 'backbone' of the economic development of the country. This highway infrastructure has served a major role of commuting people and goods from one place to another.

The development of highway technologies has expanded over the years with the execution of sustainable Material, policy, effective advance planning, intelligent construction and efficient maintenance techniques [2,3]. In order to achieve the sustainability, three major aspect needs to be focused which are economic development, environmental, and social [4]. However, in an effort to pursue transformations in highway technology, there is still low awareness towards the environmental effect during the construction of highways and lack of consideration to the environmental impact on the immediate communities. This is because the conventional method of highway construction always involves massive earthworks which brings the negative impact to the surrounding environment. Although the Environmental Impact Assessment (EIA) had been used to control the carbon emission, the results are not significant.

In order to minimize the greenhouse effect caused by carbon emission, green technology is one of the effective solutions that should be introduced to the highway developers. Green technology is part of the sustainable development which applies the knowledge of environmental science in conserving the natural resource, while at the same time it can sustain the need for the present and future generations. Moreover, carbon emission can be reduced by implementing green highway concept, which is the part of green technology that has low carbon energy and environmental friendly, but it is still a new concept in the highway construction in Malaysia [5]. Besides, growing concerns the depletion of natural and non-renewable material for construction [4] and increasing cost of natural resources production have encouraged the researchers to investigate and initiate in finding an alternative solution to replace the conventional material construction. In economic view, the application of waste material is seen to provide high potential to replace the conventional material as it has indicated good performance as well as natural resources. Therefore, the economic resources play an important role to deliver high quality performance of highway thus fulfill nation's need as a part of social aspect requirement.

A guideline or index related to green highway can be introduced in Malaysia to ensure that green criteria can be measured and more applicable to be implemented. Therefore, the study has been carried out in order to achieve and develop a sustainable highway through an assessment tool. The green highway assessment tool is developed specifically for the Malaysian tropical weather, environment, culture and social needs in order to measure the classification of highway, according to its criteria, sub- criteria and elements for sustainable purpose. In order to achieve a sustainable highway; planning, design, construction and assessment of highway needs to be integrated with the local ecological protection consideration, therefore helps to avoid subsequent environmental destruction and excessive resource consumption.

In Malaysia, the Malaysian Highway Authority or "Lembaga Lebuhraya Malaysia (LLM)" was established to supervise and execute the design, construction, regulation, operation and maintenance of inter-urban highways, to impose and collect tolls, to enter into contracts and to provide for matters connected there-with [6]. The development of green highway assessment tools is parallel with the vision of LLM which to become a world class in highway development, management and regulatory affairs. LLM may enhance employees and concessionaire awareness, skills and expertise through the launching of the assessment tool.

2.0 BACKGROUND

A green highway assessment tool is developed to provide evaluation for green practices which is implemented in highway that highlights the environmental and economic aspect. According to Bujang *et al*. [4], highway rating system can be defined as a tool for sustainable guideline, which covers overall process in highway developments either in planning, designing, construction, operation, or maintenance. The various advantageous in the design and construction of new surface transportation systems, as well as the improvement of existing surface transportation systems [6] is proved by the development of green highway assessment tool. An assessment tool should be developed with supporting roles from several agencies especially government sector as they have full authority to make sure the green concept are long lasting.

In 1998, US Green Building Council (USGBC) developed the first green assessment which is Leadership in Energy and Environmental Design (LEED). All the listed criteria adopted in LEED has emphasized on sustainable development [8]. In order to improve the quality of transportation infrastructures by minimizing their environmental impact, including the depletion of irreplaceable resources, The New York State Department of Transportation (NYSDOT) has developed GreenLITES (Leadership In Transportation and Environmental Sustainability, which is also one of the project rating programs. GreenLITES is a self-certification program that distinguishes transportation projects based on the extent to which they incorporate sustainable design choices. Similar

approach is used in GreenLITES to recognize and encourage environmentally sustainable practices in transportation [9]. Sustainable sites, water quality, material resources, energy & atmosphere and innovation are all categories that are included in the rating system. The Greenroads was actually a project based rating system (performance metric), that originated from the University of Washington and has been developed in several versions since the initial research work in 2007. This research was done with the assistance of a number of industry groups and consultants, by contributing data and commentary by means of pilot projects, case studies and public comments. The guide is applicable to be used for new, reconstructed, and rehabilitated roadway projects. The certification levels included in this rating system are Certified, Silver, Green, and Evergreen [8] where this certification is awarded when the involve project fulfilling all the requirements and a number of the optional credits.

Building Environmentally and Economically Sustainable Transportation-infrastructure-highway (BE²ST) was developed by the Recycled Materials Resources Centre (RMRC), which is located at the College of Engineering at the University of Wisconsin. There a few sub-elements in the system, which are greenhouse gas emission, energy use, waste reduction, water consumption, hazardous waste, life cycle cost, traffic noise and social cost of carbon saving. Stakeholders have the option to assign weight, based on the importance and analyzed by using Analytical Hierarchy Process (AHP) [11]. Illinois Livable and Sustainable Transportation (I-LAST) was established by Illinois Department of Transportation. I-LAST has 8 categories including planning; design; environmental; water quality; transportation; lighting; materials; and innovation [10]. It employs a self-scoring system using a hierarchical methodology, where a point from one to three is awarded for each element. In 2012, the Federal Highway Administration had established FHWA Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) meanwhile, Institute for Sustainable Infrastructure Ranking System/Harvard Zofnass Program had developed Envision. While, Department of Civil & Environmental Engineering at Jackson State University Mississippi proposed their Greenway as green highway assessment tools [13]. Table 1 shows the list of rating system consist of manual from Federal Highway Administration (FHWA) which are Greenroads, BE2ST, Sustainable Infrastructure Project Rating System (SIPRS), Sustainable Transportation Environmental Engineering and Design (STEED), GreenLITES, I-LAST and STARS [14].

Table 1 Summary of Attributes Considered by Major Rating System [8]

Attributes	FHWA	Greenroad	BE2ST	SIPRS	STEED	GreenLITES	I-LAST	STARS
Water	✓	✓	✓	✓	✓	✓	✓	✓
Run off Quantity	✓	✓		✓	✓	✓	✓	✓
Water quality	✓	✓		✓	✓		✓	✓
Aquatic Habitat	✓	✓		✓	✓			
Air	✓	✓	✓		✓			
Light		✓	✓	✓	✓	✓	✓	
Noise	✓	✓	✓	✓	✓	✓	✓	
Carbon			✓	✓		✓	✓	
Materials	✓	✓	✓	✓	✓	✓	✓	✓
Local materials	✓	✓	✓	✓	✓	✓		
Recycling		✓	✓	✓	✓	✓		
Waste	✓	✓	✓	✓		✓		
Energy	✓	✓	✓	✓	✓	✓	✓	✓
Electricity	✓				✓	✓	✓	
Fuel	✓					✓		
Ecology	✓	✓		✓	✓	✓	✓	✓
Community	✓							
History					✓			
Other mode	✓	✓		✓	✓	✓	✓	✓
Lifecycle cost	✓	✓	✓	✓	✓			✓
VMT reduction					✓			✓

3.0 METHODOLOGY

Figure 1 shows the methodology flow chart for this research which consists of five phases before achieving an index for the green highway in Malaysia. In phase 1, some previous researches on the sustainable concept and several relevant current transportation rating systems were explored and studied as a reference to identify the suitable main criteria and elements for the green highway. Through the literature review and comparison of current highway rating systems led to the five main criteria that needs to be considered in the green highway development, such as sustainable design and construction activities; energy efficiency; environmental and water management; material and technology; social and safety.

Phase 2 discusses the justification and validation of the proposed main criteria and elements of green highway. Therefore, a workshop which consisted of 30 members together with the highway experts, academicians, and researchers was conducted. They were divided into five main groups. Each group had gone into intensive literature review and summarized the relevant elements that are related to highway development. 27 main criteria and 58 elements were obtained, which should be considered in the green highway index.

In phase 3, the criteria and elements that were approved during the workshop were used to develop the questionnaire in order to obtain the agreement level of each element relating to green highway. The sample of questionnaires was distributed over 22 highway concessionaires and consultants around Kuala Lumpur, Selangor, and Johor regions. The total respondents involved in this study were 239 and the survey took about two weeks to be completed.

In phase 4, all the data were analyzed using factor analysis method by using Statistical Package for Social Science (SPSS) software. The output from SPSS, which are mean and factor loading was multiplied in order to get a factor score for each element [15]. Factor score is calculated using a refined method which aims at maximizing the validity and originality of the given element by producing factor that is highly correlated with a given factor [16]. The type of score was selected using a regression score whereby, according to the regression terminology, independent variables are the standardized observed value which will be represented by the mean value for each criterion. The following formula for calculating factor score has been developed by [16]:

$$F = Z \times B$$

Where,
F = Factor score
Z = Mean value of variables
B = Weighted value of variables

After factor scores for each element were obtained, a green highway index can be developed in order to measure the level of sustainability in roadway development that suits with the surrounding and tropical weather in Phase 5.

4.0 RESULT AND DISCUSSION

The assessment tool for Malaysia green highway consists of five (5) specific categories which are Sustainable Design and Construction Activity; Energy Efficiency; Environmental and Water Management; Material and Technology; Social and Safety. Table 2 shows the main and sub-criteria of each category that had been identified through the highway experts' discussion. Then, the point scores for each criterion was developed using the data obtained from the Statistical Package for Social Science (SPSS), which are the mean and weightage values.

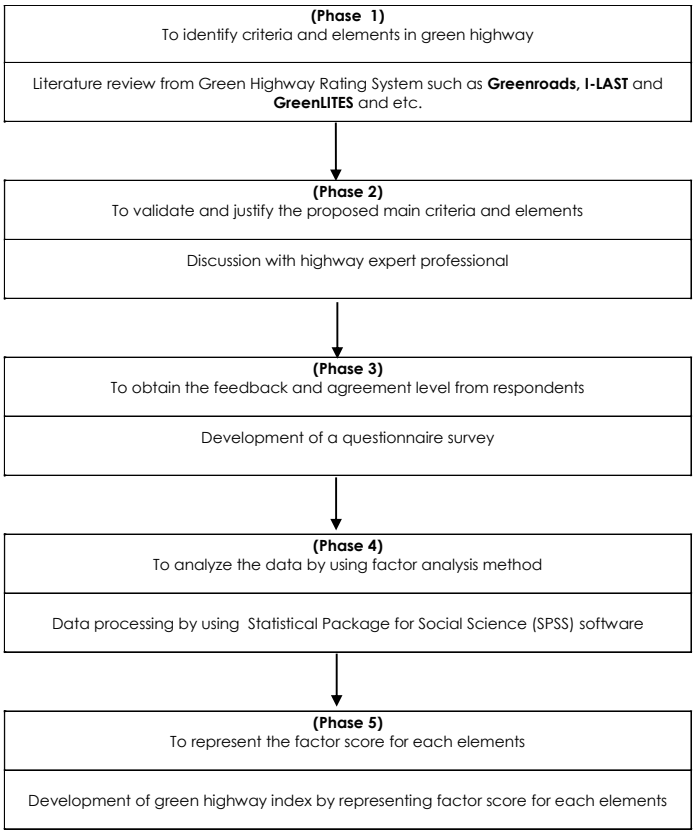

Figure 1 Research flow

Table 2 Green highway rating assessment

Category	Criteria	Sub-criteria	Points
Sustainable Design and Construction Activities	Construction Management Plan	Waste Management	13
		Air Pollutant Control	4
		Innovation	2
	Noise Mitigation Control	Techniques	6
		Mitigation at the Source	2
	Equipment and Machineries Efficiency	Natural Sources and Emission Reduction	6
	Quality Management	Management Plan and Training (Site Maintenance Plan for Existing Road)	13
	Context Sensitive Design	Design Flexibility	8
	Erosion and Sedimentation Control	Erosion and Sedimentation Plan	7
	Alignment Selection	Environmental Impact Reduction	8
Energy Efficiency	Management Policies	Renewable energy policies	6
		Commissioning and enhancement of building energy systems	10
		Energy plan for maintenance	4
	Rest & Service Area (RSA)	Reduced electrical consumption	3
		Sustainable infrastructures	9
	Toll Plaza	Toll booth	6
		Lighting zone	8
		Administration and supervision building	5
	Compound And Car Park	Energy efficiency performance	6
	Interchange	Reduced energy consumption	5
		Stray Light/ Light Pollution Reduction	2
Environmental and Water Management	Environmental Management System	EMS Certification	6
	Stormwater Runoff Quantity	Runoff Flow Control (Rate & Quantity)	10
		Disaster Cost Analysis	3
		Drainage System (Network)	2
	Stormwater Runoff Quality	Water Pollution Reduction	6
		Runoff Treatment and Water Bodies Protection	11
	Ecosystem Protection And Preservation	Habitat Restoration and Protection	5
		Site vegetation	5
		Tree and Plants Communities	3
		Ecological Connectivity	9
Material and Technology	Innovation Technology	Usage of industrial by-products	4
		Sub-grade improvement / soil stabilization	4
		Cool pavement	4
	Reduce, Reuse and Recycle	Reuse of top soil	4
		Reuse and/or Recycle non-hazardous materials	4
		Earthwork Balance	4
	Economical Materials and Pavement	Regional materials	4
		Pavement design life	3
		Recycle pavement or New sustainable techniques	4
		Permeable pavement	4
		Quiet pavement	4
	Erosion Control	Soil biotechnical engineering treatments	4
		Green techniques	4
Social and Safety	Services and Facilities	Intelligent Traffic System (ITS)	23
		Provision of basic facilities	10
		Provision of additional facilities	2
	Economy	Business Enhancement	4
		Number of Job Creation	2
		New Development	2
		Tourism	2
	Pollution Reduction	Air and Noise Pollution	3
	Public Acceptance	Perception	7
	Environment	Environmental Friendly	2
		Landscaping	2
	Management Issue	Road Safety Audit	2
	Innovation	Technology	3
		Research and Development	3
Total Points			311

The value of factor scores for each category in green highway assessment is shown in Table 3. Based on the data, Sustainable Design and Construction Activities (SDCA) obtained 69 of factor score, followed by Social and Safety (SS) with 67; Energy Efficiency (EE) with 64; Environmental and Water Management (EWM) with 60; and Material and Technology (MT) yields 51 of factor score from its elements. Meanwhile, the percentage of total factor score for these categories in green highway rating assessment include SDCA, SS,

EE, EWM, and MT are 22%, 22%, 21%, 19%, and 16% respectively.

Table 3 Factor score for each category in green highway rating assessment

Category	Factor Score	Percentage (%)
Sustainable Design and Construction Activities	69	22
Energy Efficiency	64	21
Environmental and Water Management	60	19
Material and Technology	51	16
Social and Safety	67	22
Total	311	100

5.0 CONCLUSION

The sustainability of green highway plays an important role to improve the social development and economic growth. Thus, a new tool to measure green highway must be developed to achieve more reliable, comfortable and convenient highway assessment system. Green highway rating system will help transportation planners to have a clear understanding of the applicable techniques for maximizing sustainable highway's strength. Green highway rating system has been developed with the involvement of experts from every field of highway construction and development of standard.

The developed Malaysia green highway assessment tool consists of five categories which are Sustainable Design and Construction Activities, Energy Efficiency, Environmental and Water Management, Material and Technology, and Social and Safety with 27 relevant main criteria. The result of this research is considered as a performance baseline standard for measuring the level of greenness for current or new highways in Malaysia. It has explained several fundamental criteria of green highway that are suitable to the condition and tropical weather in Malaysia. Besides, the elements in Malaysia green highway rating assessment can be upgraded in the future parallel with the times according to their stages of highway development either in planning, design, construction, operation, or maintenance.

Acknowledgement

The authors gratefully acknowledge the support for this research from Malaysia Highway Authority, Universiti Teknologi Malaysia (research grant 4B184), Malaysian concessionaire and postgraduate students of Faculty of Civil Engineering Universiti Teknologi Malaysia.

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