Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 20 (2014) 180 – 186

Procedia Environmental Sciences

4th International Conference on Sustainable Future for Human Security, SustaiN 2013

An evaluation of sustainable design and construction criteria for green highway

Raja Rafidah Raja Muhammad Rooshdi[a]*, Nurizan Ab Rahman[a], Nazurah Zahidah Umar Baki[a], Muhd Zaimi Abdul Majid[a], Faridah Ismail[b]

[a]*Department of Civil Engineering, UTM, Johor Bharu 81300, Malaysia*
[b]*Department of Quantity Surveying, UiTM, Shah Alam 40450, Malaysia*

Abstract

Sustainability has been widely debated in the construction industry in recent years. Though various assessments have previously been developed to help improving sustainability of construction projects, those assessments seem missed the base network for cities and buildings which are highways. Therefore, there is the need to select variety of design and construction activities criteria for green highway and determine the weightage factor for every criterion in order to categorize which criteria that most contribute to the green practices based on the priority. The aim of this paper is to explain the determination of weightage for criteria of design and construction activities. The methodology processes begin with data collection by using questionnaires distribution to the expertise who involve in highway development and also green issues. There were 140 respondents had been chosen to fill in the questionnaires survey. The data had been analysed using SPSS with factors analysis method. Results from the analysis show the evaluation of the criteria base on the important criteria in design and construction action of green highway.

Keywords: Evaluation methodology; sustainable design and construction; green highway

1. Introduction

In earlier decade, sustainable development idea has grown up from numerous environmental movements. Recently sustainable issues have been widely discussed especially in construction industry. Sustainable development

* Corresponding author.
E-mail address: raja_rafidah@yahoo.com

doi:10.1016/j.proenv.2014.03.024

is a key issue in order to meeting the environmental objectives and fulfils the demand of the large infrastructure projects due to increasing numbers of population growth and urban density [1]. Sustainable design can be one of the factors that can minimize the impacts of the highway to the environment. Noise, ground and water pollution, habitat disturbance, land use, air, climate change vibration and contamination to plant and wildlife are the effects of construction and vehicle emissions [2]. The impact can be changed by design, construction and management of road, parking and other facilities.

The green highway rating system was introduced to determine the level of greenery and environmental friendly of the highway. Since roads run through the landscape, road have point source impact and linear effect. *Greenroads* is the first green highway rating system that has been established in United States. It is a voluntary third party rating system for road project which seeks to recognize and reward the roadway projects that exceed the public expectation for environmental, economic and social performance [3]. In the rating system, in order to maintain, support or endure the long term maintenance of responsibility, sustainable design becomes one of the most important criteria for giving a credit [4]. Washington Internship for Students Engineering (WISE) has introduced the green highway rating system. The rating system is to make sure the highway design is sustainable, environmental friendly and giving less impact of environment damage [3] which can be used for developing and classifying an environmentally and economically sustainable highway [5]. In the modern highway design, the new technology such as advance planning, intelligent construction and transport system and maintenance technique has been used to reduce the impact of highway to the environment.

Nowadays, green rating system becomes a popular tool to confirm the green credential of building. Most countries have developed their own green building rating system. The countries that already have the rating system are United States, Canada, Australia, United Kingdom, Hong Kong, Japan, Taiwan, Singapore, Philippine, European, Korea, India and Australia. Malaysia also owns the green building rating system which is GBI. With the successful implementation of green building rating system, the rating system has been widened into the highway. There are three rating system for the highway that has been found which is *Greenroads*, Green Leadership in Transportation and Sustainable (Green*LITES*) and Illinois-Livable and Sustainable Transportation (I-LAST). The evaluation for the green highway is not yet available in Malaysia.

2. Criteria

As development of criteria for green highway, there were several green rating tools which are *Greenroads*, *Green*LITEs, and I-LAST had been reviewed as a summary of green highway criteria. The criterion are sustainable site, water efficiency, energy and atmosphere, material and resources, indoor environment quality, innovation and design, project requirement, access and equity, construction activities, pavement technology, custom credits, planning, design, transportation, lighting, management, and environmental. Clark et al. (2009) state that the rating system consist the explanation of different certification level and the total points that needed to obtain them [6]. Starting with the least green to exceptional green, most of the certifications are distinguished by four different levels. There are some common criteria that can be found in every green rating system such as sustainable site, water efficiency, energy efficiency, materials and resources and innovation. Tsai and Chang (2011) have developed the sustainable items for highway design based on LEED and Global Reporting Initiative (GRI) [7]. The development process of this item involved the addition, integration and removal of the preliminary 45 items. The 45 techniques and 15 materials items have been categorize into 14 disciplines which consist of various number of technique and material items. The sustainable criteria includes of geometrics and alignment, earthworks, pavement, drainage, retaining walls, slope protection, landscape ecology, transportation facilities, maintenance, bridges, sound insulation, tunnels, electrical and mechanical and lighting. But those criteria were different in every project especially during design and construction activities stage. Therefore, this paper attempts to identify the criteria and sub criteria according to the stage of construction by means of the nominal group technique which generate and prioritize a large number of issues within a structure that gives everyone an equal voice.

3. Methodology

3.1. Nominal group technique

There are a lot of references for the establishment of decision criteria for the evaluation but in Malaysia there are still lacks of reference. Therefore, we used the Nominal Group Technique (NGT) devised to formulate the assessment of green highway [8]. The objective of the technique is the exploration of ideas from a team of experts for decision making [9]. Even Delphi and NGT provide advantages in obtaining: (1) independent idea generation, (2) structural feedback, and (3) independent mathematical judgment. But, NGT would draw more attention from the expert team to each idea and increase opportunity for each member to assure that his ideas are part of the group's frame of reference [8].

3.2. Expert discussion and questionnaires

Since Malaysia for the moment does not have any green highway rating system, it is therefore, needs criteria verification thoroughly. The development of these criteria is largely based on conducting a comprehensive literature review. Criteria related to sustainable design and construction activities in other green highway rating systems were chosen based on literature review. At the very beginning those sustainable design and construction criteria had been chosen separately. The criteria that had been selected through literature review were been discussed among the expertise that involve in highway development to select the most appropriate criteria. They would share their experience, opinion and suggestion on the best criteria in sustainable design and construction activities. The criteria are developed from a complete process across the project life cycle and enable all project participants to understand and contribute to the project sustainability. The comparison of 5 assessment tools had been taken from all over the world such United State, United Kingdom, Australia, Singapore and Malaysia. Most of the tools had 9 to 14 criteria that related to sustainable design and construction activities.

It shows that every tool had noted that design and construction activities had similar issues to be care about. The criteria are based on the green highway rating systems, highway project guidelines as well as a few related case studies. [10, 11] studies have been used as a guide that has similar criteria in indicating the criteria for this study. Most of the criteria for sustainable design and construction activities from those assessments had similar factors such quality, environment, waste, water, and pollution. All factors are related to each other during design and construction stage.

Table 1 show the criteria and sub criteria for sustainable design and construction activities. Those sub criteria are detailed description of each criteria. It's explained the content should be included in the criteria. As mentioned before, criteria of sustainable design and construction activities had be chosen separately. But after several expert discussions those criteria had been combined since it related to each other in design and construction stage.

3.3. Factor analysis and weighted criteria

Once the criteria had been finalized through questionnaires and expert discussion, the data had been analyzed using factor analysis to produce mean index and factor loading. A factor analysis was initially conducted on 29 items with oblique rotation (promax). However, three items were removed due cross loadings. The final model consists of 26 items. All tests are reported at the $p<0.05$ level (95% confidence level). Means have been calculated using only the number of respondents who chose a rating point answer. Reliability test are done in the beginning of the section analysis due to check the reliability of data to be analyzed.

Table 1 Criteria of sustainable design and construction.

Categories	Criteria	Sub criteria
Sustainable design	Alignment selection	Design to reduce the area of undeveloped land
		Design to provide buffer between highway and high quality area
		Design to avoid impacts to environmental resources
	Context sensitive design	Design to avoid impact to socio economic resources
		Design to adjust highway features using design flexibility
		Design to utilize visual enhancement
		Design to reduce urban heat island effect
Construction activities	Construction waste management	Waste reduction
	Air pollution control	Greenhouse gas emission reduction
		Dust control
	Noise and vibration control	Noise and vibration mitigation
	Water management	Water consumption
		Water pollution control
		Temporary erosion and sediment control
	Equipment/machinery efficiency	Fossil fuel reduction
		Equipment emission reduction
		Paving emission reduction
	Quality construction	Quality management system
		Environmental training on-site
		Contractor warranty
	Construction maintenance	Site maintenance

This data set show Cronbach's Alpha is 0.922 with 29 variables. There is high internal consistency for the data set which the Cronbach's Alpha is more than 0.7. (Hair *et al*. 2010). The date were analyzed by using KMO and Bartlett's Test to test the sampling adequacy. The KMO ranges from 0-1 with higher values indicates greater suitability, and greater than 0.750 is much better. This KMO for this data is 0.790 and Bartlett's test is significant [$\chi 2$ (406) = 2100.448, $p<0.001$] and therefore it shows that correlations between items are sufficiently large for factor analysis. As suggested by Kaiser (1974) where he recommends accepting values greater than 0.5 as acceptable [12]. According to Hutcheson and Sofroniou (1999), the value of KMO between 0.7 until 0.8 is good [13].

Seven factors had eigenvalues over Kaiser's criterion of 1 and explained 68% of the variance. The scree plot supported the Kaiser's criterion in retaining seven factors. Given the large sample size and the convergence of the scree plot and Kaiser's criterion on seven factors that were retained in the final analysis. The table 2 shows the factor loadings. The items that cluster on the same factors suggest that factor 1 represent construction management plan, factor 2 represent noise mitigation control, factor 3 represent equipment and machineries efficiency, factor 4 represent quality management, factor 5 represent context sensitive design, factor 6 represent erosion and sedimentation control, and factor 7 represent alignment selection.

Table 2 Factor loading for each sub criteria.

Variables	*Component*							
	1	2	3	4	5	6	7	8
Provide CWMP	***.966***	-.150	-.195	-.222	.085	.097	-.067	.112
Method of waste minimization	***.728***	-.371	.272	.077	-.118	.228	-.034	.082
Use efficiency method	***.643***	.176	.147	.110	-.138	-.015	-.035	-.024
Site recycling plan	***.636***	-.118	-.056	.067	.068	.192	-.026	-.068
GHG emission reduction	***.597***	.283	.094	-.171	.209	-.140	.052	-.097
Dust control	***.541***	.236	-.022	.043	-.079	.051	.212	.183
Water tracking system	***.518***	.241	.167	.140	-.003	-.260	-.232	.054
Waste disposal	***.426***	-.204	.139	.033	-.038	.351	.142	.295
Water pollution control measures on site	***.388***	.169	-.184	.053	.339	.375	-.088	-.253
Use alternative construction methods	-.077	***.893***	.019	.012	.176	-.039	-.092	.058
Noise mitigation technique	-.115	***.786***	.150	.011	.017	.081	.049	.280
Operate stationary equipment	-.078	***.709***	.179	-.154	-.251	.174	.288	-.121
Paving emission reduction	-.116	.084	***.832***	.087	-.017	.069	.056	-.059
Fossil fuel reduction	-.004	.108	***.813***	.036	-.098	-.097	.096	-.102
Equipment emission reduction	.122	.173	***.618***	-.015	.162	.030	-.156	-.161
Site maintenance	-.024	-.143	.058	***.811***	.110	.018	.148	-.032
Quality management system	-.225	-.009	.261	***.724***	.092	.168	-.251	.101
Contractor warranty	-.107	-.121	-.083	***.688***	.116	-.237	.475	-.198
Environmental training on site	.160	.132	-.035	***.678***	-.019	.073	-.150	.172
Provide NMP	.277	.262	-.278	***.375***	-.279	.188	.161	.144
Adjust highway features	-.010	.056	-.103	.136	***.778***	.099	-.241	.170
Utilize visual enhancement	.117	-.081	.045	.048	***.722***	.031	.079	-.124
Avoid impact to socio-eco	-.243	.142	.052	-.041	***.546***	.327	.216	.244
Provide erosion and sedimentation control plan	.172	.052	-.094	.098	.075	***.865***	.060	-.342
Use efficient method of erosion and sedimentation control	.137	.105	.055	-.015	.091	***.834***	.086	-.301
Provide 100 ft. buffer	-.099	.098	.049	.028	-.161	.157	***.846***	-.070
Avoid impact to environment	.044	.090	-.113	-.083	.176	.120	***.549***	.341
Reduce urban heat island	.240	-.140	.245	-.019	.355	-.198	***.414***	.171
Reduce undeveloped land	.094	.133	-.155	.070	.066	-.440	.019	***.953***

As a conclusion for there are seven main factors for design and construction activities criteria for green highway development. Each factor have their own criteria which relate to each factor. All the criteria grouping in each factor base on the feedback analysis of the questionnaires survey. Thus, the criteria were dividing equally based on the experience opinion.

Table 3 Weighted criteria.

ID	Criteria	Sub-criteria	Element description	Weightage/point	Total weightage/point of criteria
SDCA 1	Construction management plan	Waste management	Provide Construction and Demolition Waste Management Plan (CWMP) during roadway construction	4	20
			Use efficient method of waste minimization	3	
			Use efficient method of water conservation	2	
			Provide Site Recycling Plan as part of the CWMP during construction	3	
			Use appropriate approach for waste disposal on-site	2	
		Air pollutant	Use construction equipment that reduce emissions of localized air pollutants	2	
			Dust control	2	
		Innovation	Use water tracking system	2	
SDCA 2	Noise mitigation control	Technique	Use alternative construction methods with low-noise or quieter machineries	3	8
			Use proper noise mitigation techniques on-site	3	
		Equipment	Operate stationary equipment 50 ft. from noise sensitive receptor	2	
SDCA 3	Equipment and machineries efficiency	Natural source & emission reduction	Paving emission reduction	2	6
			Fossil fuel reduction	2	
			Equipment emission reduction	2	
SDCA 4	Quality management	Management plan and training	Provide site maintenance plan	4	14
			Provide Quality Management System to improve construction quality	4	
			Contractor warranty	3	
			Provide environmental training on-site	3	
SDCA 5	Context sensitive design	Design flexibility	Design to adjust highway features using design flexibility	3	8
			Design to utilize visual enhancement	3	
			Design to avoid impact to socio-economic resources	2	
SDCA 6	Erosion and sedimentation control	Erosion & sedimentation plan	Provide erosion and sedimentation control plan	4	7
			Use efficient method of temporary erosion and sediment control	3	
SDCA 7	Alignment selection	Environmental impact reduction	Design to provide >100 ft. buffer between highway and high quality area	3	7
			Design to avoid impacts to environmental resources	2	
			Design to reduce urban 'heat island' effect	2	

In weighted the criteria, the factor loading had been multiply with mean index. Factor loading show the important of these criteria in sustainable and construction activities category and mean index show the level agreement of respondent towards those criteria. By combining the important and level of agreement of each criterion, it show the weightage of each criteria.

4. Result and discussion

Table 3 shows the simple results of the experts' weightings on each main and sub criteria. Those criteria had been discussed after the generated with factor loading and mean index to ensure all the weightage are reasonable in Malaysian practice in highway development. The criteria of construction management plan had the highest weightage/point from other criteria. It shows that construction management plan is the most important criteria to achieve green highway development in Malaysia. The lowest weightage/point is equipment/machinery efficiency. It is because Malaysia still lack of fossil fuel sources. Most of Malaysians equipment and machineries still using biodiesel product since Malaysia is one of biodiesel and petrol producer. Quality management is a second important criterion in green highway development because as to achieve and maintain the green highway should have a good quality of design and construction method. Other criteria follow respectively based on their weightage/point noise mitigation, context sensitive design, erosion and sedimentation control and alignment selection. Those criteria had equal total of weightage/point. It show that they are related to each other and had same level of important during design and construction of green highway.

5. Conclusions

Those main and sub criteria had been developed to achieve a green highway development in Malaysia. All the criteria had related to each other during the stage of design and construction of highway. So far there are very few studies on evaluation of green highway development. Therefore, this paper attempts to establish an evaluation model for green highway for the design and construction activities category by a scientific approach to identify the decision criteria as well as the assessment of weights for them. Throughout all the criteria in design and construction activities, they are more focus on waste management and quality since we are towards achieving the green highway development.

References

1. Constandopoulos, J., & Nation, M. Towards Sustainable Roadways. Sinclair Knight Merz, 2013, from http://www.globalskm.com/Insights/AchieveMagazine/Issue1-2010/article9.aspx, 2010.
2. Griffith, A., & Bhutto, K. Better environmental performance: A framework for integrated management systems (IMS). *Management of Environmental Quality: An International Journal* 2009; **20**(5):566-580.
3. WISE. Greenroads Greenroads Manual V1.5. Washington: Washington Internship for Students Engineering; 2011.
4. McLennan, J. F. *The philosophy of sustainable design*. Kansas City, Missouri: ECOtone; 2004.
5. Bryce, J. 2008. *Developing sustainable transportation infrastructure*. Washington Internships for Students of Engineering, ASTM;2008.
6. Clark, M., Paulli, C., Tetreault, Z., & Thomas, J. *Green guide for roads rating system (S. S. D. P. Site, Trans.) A major qualifying project report for the stantec sustainable design project site*. Worcester: Worcester Polytechnical Institute; 2009.
7. Tsai, C. Y., & Chang, A. S. Framework For Developing Construction Sustainability Items: The Example of Highway Design. *Journal of Cleaner Production* 2011;1-10.
8. Delbecq, A. L., Van de Ven, A. H., and Gustafson, D. H. *Group techniques for program planning, A guide to nominal group and Delphi processes*, Green Briar Press, Wis.1986.
9. Adler, M., and Ziglio, E. *Grazing into the oracle, The Delphi method and its application to social policy and public health*. U.K.: Cromwell Press; 1996.
10. Soderlund, M. *Sustainable roadway design - A Model for an environmental rating system*. Master of Science, University of Washington; 2007.
11. Washington, U. O. *Greenroads manual*. Washington: University Of Washington; 2011.
12. Kaiser, H.F. An index of factorial simplicity. *Psychometrika* 1974;**39**:31-36.
13. Hutcheson, G. and Sofroniou, N. *The multivariate social scientist: Introductory statistics using generalized linear models*. Thousand Oaks, CA: Sage Publications; 1999.