Jurnal Teknologi

Full Paper

SUSTAINABLE DESIGN AND CONSTRUCTION ELEMENTS IN GREEN HIGHWAY

Raja Rafidah Raja Muhd Rooshdi[a*], Muhd Zaimi Abd Majid[b], Shaza Rina Sahamir[c]

[a]Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[b]UTM Construction Research Centre, Institute for Smart Infrastructure and Innovative Construction, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia
[c]Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

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

*Corresponding author
raja_rafidah@yahoo.com

Abstract

Sustainable development principles have been implemented in various sectors including construction. Proper development and operation of infrastructure projects such highways can contribute significantly to the mission of sustainable development. Previous studies shown that most of conventional highways are unsustainable in many ways. Highways are facing severe challenge such as deteriorating condition, congestion, energy supply, and shortfall of funding for maintenance and capacity expansion to meet increasing demand. However at the same time, they consume huge amount of natural minerals and energy and generate waste and emission which contributing to climate changes and global warming. Therefore, sustainable design, construction, operation and maintenance have become priority these day. The aim of this paper is to determine critical elements for sustainable design and construction based on ranking of the priority level of the weighted value of each criteria. The questionnaires survey were developed and distributed to related respondents in order to obtain the agreement level for the element. The data was analysed using SPSS with factor analysis method. Result from the analysis shown the criteria, weightage and score for main criteria for sustainable design and construction activities for green highway.

Keywords: Green highway, Sustainable design and construction, weightage factor

1.0 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 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 change by design, construction and management of road, parking and other facilities.

Highway system is an inevitable component for present mobility and economic development, however the development of existing highway had caused many issues on environmental impact, economics and social. There were an innovation in management practices adopted to improve the issues, but the improvement were still insufficient and the highway development continues facing persistent threats such deteriorating conditions, green gas houses emissions, pollution and financial scarcity.

2.0 OVERVIEW OF GREEN HIGHWAY TOOLS

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 recognized 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 country that already has the rating system is 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* [6], Green Leadership in Transportation and Sustainable (Green*LITES*) [7] and Illinois-Livable and Sustainable Transportation (I-LAST) [8]. The evaluation for the green highway is not yet available in Malaysia.

Table 1 show the summary of existing green highway rating system that focused on design and construction which all the tools were focused on transportation and infrastructure works. There were 6 rating tools had been analysed. Most of the tools focused on transportation and had more than 5 main criteria.

Table 1 Summary of existing green highway rating system that focused on design and construction

Rating system	Content of related element
CEEQUAL [9]	Most of the element focus on client, design and construction stages
AGIC [10]	Focus on GHG emission, pollution and waste management during construction only.
INVEST [11]	Focus on pollution management such air, noise and water and divided design into rural and urban design.
Greenroads[6]	Criteria for design included in several main criteria as sub criteria and more focus on construction activities.
Green Lites [7]	One of the main criteria emphasized on design which is sustainable sites
I-LAST [8]	Main criteria of design and construction had been separated as main criteria.

3.0 RESEARCH METHODOLOGY

3.1 Literature Review

Clark *et al.* [12] state that the rating system consist the explanation of different certification level and the total points that needed to obtain them. 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 [13] have developed the sustainable items for highway design based on LEED and Global Reporting Initiative (GRI). 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.

3.2 Expert Discussion and Questionnaires

Ever 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 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. Soderlund [14] and Washington [15] studies has 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.

3.3 Factor Analysis

Once the criteria had been finalised through questionnaires and expert discussion, the data had been analysed 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 analysed.

This data set show Cronbach's Alpha is 0.922 with 29 variables. There is high internal consistency for the data set that the Cronbach's Alpha is more than 0.7. [16]. The data were analysed 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 [17] recommended accepted values greater than 0.5 as acceptable. According to [18], the value of KMO between 0.7 until 0.8 are good.

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.

3.4 Factor Score

The method used for calculating the factor score is by using a refined method that aims to maximize the validity and originality by producing factors that are highly correlated with a given factor and to obtain unbiased estimates of true factor score [19]. The selection of types of score is by using a regression score whereby, according to the regression terminology, independent variables in regression equations are the standardized observed value of the items which will be represented by mean value for each element. The formula for computing the factor score was developed by [20] which stated:

$$F = Z \times B \qquad \text{Equation (1)}$$

Where F is the row vector of m estimated factor score; Z is the row vector of n standardized observed variables; and B is the matrix of regression of weight for the m factor of n observed variables. In this case, F is the factor score, Z is factor loading value for each element and B is mean value for each element.

3.5 Weightage of Element

The weighting factor analysis of sustainable design and construction activities elements was calculated based on the formula that has been developed by [21] below:

Weightage of each criteria =

$$\frac{\text{Total factor score in each element}}{\text{Total factor score for all elements}} \qquad \text{Equation (2)}$$

The total of factor score in each element is divided by total factor score in all elements to obtain the weighted in the element. The higher the weightage value gives an indication of the most importance of the element towards developing green highway design and construction. Moreover, the highest weightage showed the main importance and consideration of element to implement green highway.

Table 2 shows the simple results of the weightings on each main and sub criteria. Based on the weightage result the highest weighted criterion is construction waste management and the lowest is erosion and sedimentation control and alignment selection. After having this statistical result, those criteria had been discussed with the highway expertise to ensure all the weightage are reasonable in Malaysian practice in highway development. According to the expert discussion, the construction waste management were agreed as the highest weighted criteria but he lowest weighted criteria were equipment and machineries 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 criteria 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 shows that they are related to each other and had same level of important during design and construction of green highway.

4.0 CONCLUSION

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.

Acknowledgement

The authors gratefully acknowledge the support of this research from MOSTI, MOHE, UniversitiTeknologi Malaysia grant (Vote: 00G22), Research Management Centre, Construction Research Alliance, Construction Research Centre, Faculty of Civil Engineering UTM and Malaysian Highway Authority.

Table 2 Weightage of elements

Main criteria	Element	Factor Loading	Mean	Factor score	Total factor score		Weightage
Construction Management Plan	Provide Construction and Demolition Waste Management Plan (CWMP) during roadway construction	0.97	4.12	3.98	19.99		0.28
	Use efficient method of waste minimization	0.73	4.10	2.98			
	Use efficient method of water conservation	0.64	3.85	2.47			
	Provide Site Recycling Plan as part of the CWMP during construction	0.64	4.01	2.55			
	Use construction equipment that reduce emissions of localized air pollutants	0.60	3.77	2.25			
	Dust Control	0.54	3.90	2.11			
	Use water tracking system	0.52	3.60	1.86			
	Use appropriate approach for waste disposal on-site	0.43	4.17	1.77			
Noise mitigation control	Use alternative construction methods with low-noise or quieter machineries	0.89	3.90	3.49	9.16		0.13
	Use proper noise mitigation techniques on-site	0.79	3.86	3.03			
	Operate stationary equipment 50 ft from noise sensitive receptor	0.71	3.72	2.64			
Equipment and machineries efficiency	Paving Emission Reduction	0.83	3.63	3.02	8.14	71.31	0.11
	Fossil Fuel Reduction	0.81	3.55	2.89			
	Equipment Emission Reduction	0.62	3.62	2.24			
Quality management	Provide Site Maintenance Plan	0.81	4.24	3.44	11.96		0.17
	Provide Quality Management System to improve construction quality	0.72	4.13	2.99			
	Contractor Warranty	0.69	3.92	2.69			
	Provide Environmental Training On-Site	0.68	4.20	2.84			
Context sensitive design	Design to adjust highway features using design flexibility	0.78	3.86	3.00	8.06		0.11
	Design to utilize visual enhancement	0.72	4.02	2.90			
	Design to avoid impact to socio-economic resources	0.55	3.96	2.16			
Erosion and sedimentation control	Provide Erosion and Sedimentation Control Plan	0.87	4.15	3.59	7.06		0.10
	Use efficient method of temporary erosion and sediment control	0.83	4.16	3.47			
Alignment selection	Design to provide >100 ft buffer between highway and high quality area	0.85	3.68	3.11	6.94		0.10

References

[1] Constandopoulos, J., & Nation, M. 2010. *Towards Sustainable Roadways.* Sinclair Knight Merz, from http://www.globalskm.com/Insights/AchieveMagazine/Issue1-2010/article9.aspx.

[2] Griffith, A., & Bhutto, K. 2009. Better Environmental Performance: A Framework For Integrated Management Systems (IMS). *Management of Environmental Quality: An International Journal*. 20(5): 566-580.

[3] WISE. 2011. *Greenroads Manual V1.5*. Washington: Washington Internship for Students Engineering.

[4] McLennan, J. F. 2004. *The Philosophy of Sustainable Design*. Kansas City, Missouri: ECOtone.

[5] Bryce, J. 2008. *Developing Sustainable Transportation Infrastructure*. Washington Internships for Students of Engineering, ASTM.

[6] Muench, S., Anderson, J., Hatfield, J., Koester, J. and Söderlund, M. 2011. *Greenroads Manual Seattle*. WA: University of Washington. 1(5).

[7] NYSDOT. 2008. *Green LITES Project Design Certification Program.* https//www.nysdot.gov/programs/greenlites.

[8] IDOT, I.A. 2010. Illinois–*Livable and Sustainable Transportation Rating System and Guide*. Illinois Department of Transportation.

[9] AGIC. (n.d.) 2013. *Infrastructure Sustainability Rating Framework*. From https://www.sustainableinfrastructure.org/rating/.

[10] CEEQUAL. 2010. *CEEQUAL assessment manual*. From http://www.ceequal.com/downloads.html.

[11] Built, A. S., & National, E. (n.d.) 2014. Sustainability Performance Assessment by Road Agencies, (2014). From http://www.sbenrc.com.au/wp-content/uploads/2015/01/SBEnrc-Project-1.22-Sustainability-Performance-Assessment-Report-2014.pdf.

[12] Clark, M., Paulli, C., Tetreault, Z., & Thomas, J. 2009. *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.

[13] Tsai, Calista Y., and Andrew S. Chang. 2012. Framework for Developing Construction Sustainability Items: The Example Of Highway Design. *Journal of Cleaner Production*. 20(10): 127-136.

[14] Soderlund, M. 2007. *Sustainable Roadway Design-A Model for an Environmental Rating System*. Master of Science, University Of Washington.

[15] Washington, U. O. 2011. *Greenroads Manual*. Washington: University Of Washington.

[16] Hair. F. J, Black C. W, Babin J.B., Anderson E. Rolph 2009, *Multivariate Data Analysis.* 7th Edition. Prentice Hall. (February 23, 2009).

[17] Kaiser, H. F. 1974. An index of Factorial Simplicity. *Psychometrika*. 39: 31-36.

[18] Hutcheson, G. D. and Sofroniou, N. 1999. *The Multivariate Social Scientist: Introductory Statistics Using Generalized Linear Models.* London: Thousand Oaks, Calif. Sage Publications.

[19] Hershberger, S. L 2005. Factor score. In B. S Everitt and D.C Howells (Eds.). *Encyclopaedia of Statistics in Behavioural Science.* New York: John Wiley. 636-644.

[20] Maletta, H., & Aires, B. 2007. Weighting. *Spsstools*, 1(March), 1–19. Retrieved from http://www.spsstools.net.

[21] 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. doi:10.1080/02533839.2008.9671412.