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Pavement Technology Elements in Green Highway

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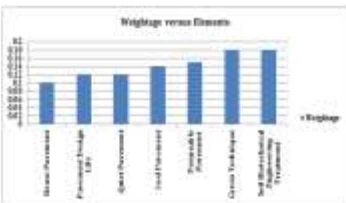

Abstract

A technology that has been experienced during the construction of a pavement has indicated the improvement in exploring the advanced technology pavement. Types of technologies of pavements applied are always related to the high performance of the pavements during the life span. Indeed, the application of technology in pavement has insisted to reduce the rate of environmental problems such as global warming, abundance of solid waste and so on. The development of technologies in pavement has been identified by the expert in highway engineering as one of the initiatives in response the sustainability requirement that later on will be applied to implement green highway concepts. Nowadays, the process of selecting a variety of green pavement technology element is becoming more challenging to be evaluated qualitatively. This paper aims to determine critical pavement technology element based on ranking of priority to achieve the objective of the green highway design. It is necessary to determine the critical elements in order to identify which elements will most contribute to the green practices based on the priority level of the weighted factor value. Therefore, a questionnaire survey was developed and distributed to the respondent in order to obtain the agreement level for the element. Based on the weighted analysis, it has been shown that the soil erosion control element has achieved first ranking in order to implement green highway and followed by permeable and cool pavement.In conclusion, the identification of critical elementsof green pavement technology is the main key towards sustainable development in the future.

Keywords: Pavement technology; weightage factors; critical element.

1.0 INTRODUCTION

The Malaysian highway network is a 'backbone' of the economic development of the country. This highwaynetwork has connected from one place to another place. The development of highway technology has expanded over the years with the effective advanced planning, intelligent construction and efficient maintenance technique [1]. However, in current efforts to pursue transformations in highway technology, there are still low awareness towards environmental effect and did not consider this environmental impact during construction of highway [2]. The problems related to the pavement will arise, such as short design life, hot surface temperature, abundance of solid waste, noise disruption, water pounding on the pavement and slope failure actually will reflect on the environmental issues. This statement has been supported by Bryce [3] where it is stated that highway constructions have a large negative impact on the surrounding ecosystem and overall environmental quality. The environmental issue has attracted a great attention from all the parties since global warming and climate change have contributed to serious environmental degradation and given harmful to the surroundings. According to Santero et al [4], the longer design life of pavement will decrease the tendency of global warming potential to occur and it has proven to be more environmentally efficient. Moreover, incoming radiation absorbed by the pavement will maximize the ambient temperature, resulting in the urban heat island effect due to increasing surrounding temperature. Therefore, high temperature will increase energy demand that creates another environmental problem which is known as photochemical smog [5]. Abundant of waste material after pavement construction also contribute to environmental problems with the increasing of disposal rate. Based on the report by Collins and Ciesielski [6], 82% of recycling rate for asphalt concrete (AC) pavement layer has resulted only 18% of the disposal rate at the End of Life (EOL) phase, which is quite low compared to 75% of recycling rate that will cause 25% of disposal rate. Besides, slope failure also creates serious environmental issues by not considering planting the vegetation along the highway. More precisely, roots vegetation has influenced slope stability by increasing soil cohesion and friction [7].Due to the concern of environmental issues, therefore people are starting to extract and applied another sustainable practices during the construction of pavement that focused on a new technology instead of conventional techniques [8]. The varioustypes of technology used in highway pavement have created the initiatives to identify the priority on which the element should be the main consideration in developing green highway. The collection of different types of technologies in pavement is becoming the vital task in order to classify which critical element can contribute tothe green design requirement during implementation of Green Highway. Therefore, the aim of the paper is to determine the critical elements of pavement technology based on the weighted analysis. The contribution of each element towards green project can be identified by determiningof weighting factor that indicated the priority level of that element. The objective of weighting factor is to determine the level of importance of the elements in the development of green highway concepts. The process of identifying this element can be classified as one of the keys to sustainable construction development since this pavement technology element will be used as fundamental sources to develop Malaysia Green Highway Rating System.

2.0 RESEARCH METHODOLOGY

In order to achieve the objectives, this research consists of five phases as shown in Figure 1. Phase 1 consists of reviewofexisting rating system for the pavement element identification such as I-LAST, GreenLITES, Greenroads etc. The selection of pavement elements was proposed during discussion with professionals in the highway field and improved by the experts

carried as in Phase 2. The elements that have been approved by the experts were used to develop the questionnaire in Phase 3. The aim of the questionnaire survey is to obtain feedback and the agreement levels for those elements. Then, the agreement level data were analyzed by using Statistical Package for Social Science (SPSS) for statistical method. The weightage that has been calculated through the factor loading by using this software has provided as an indicator to determine which element gives importance for green design in Phase 4. Therefore, the critical element will be determined based on the weighted value in Phase 5.

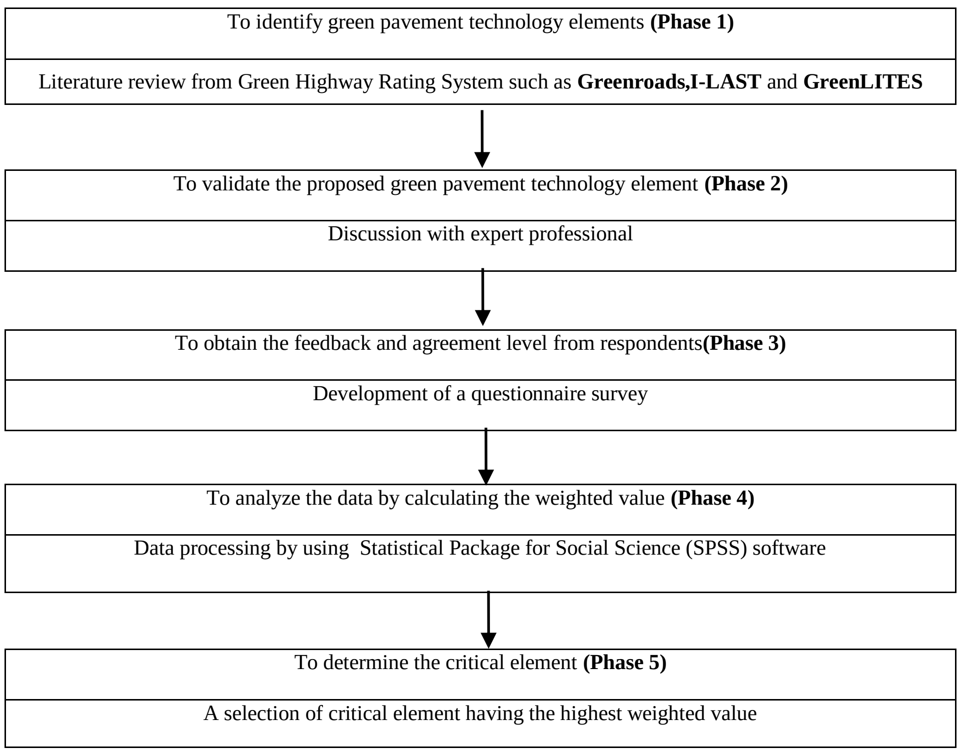

Figure 1 Research flow

2.1 Review From Green Highway Rating System

The reviewof existing Green Highway Rating System is essential to determine the potential pavement technology elements. The identification of an element needs to fulfil the green design objectives and can be further used to classify the critical element in green pavement. Basically, the discovering of highway rating tool has selected a few of advanced technology used in pavement design and can be categorized as the new green element. A comparison of the advance pavement technologies in highway rating tools are shown in Table 1 below. Based on the various types of existing green rating system, only Greenroads has emphasized the new green technology used in pavements and material part. Besides Greenroads, the other rating system only focusing on a materials' part instead of pavement technology by introducing (3R's) concept which are reduce, reuse and recycling (3R's) in order to apply in material management.

Table 1 Summary of existing green highway rating system that focused on pavements

Rating System	Division/Content of Element
Greenroads[9]	Divides into material and pavement technologies group. Introduced new green technology in pavement, such are Long life pavement, Permeable pavement, Warm mix asphalt, Cool pavement, Quiet pavement, Pavement Performance Tracking.
I-LAST [10]	Focused mainly on new green material only and green technique.
GreenLITES [11]	Focused on material and resources that encourage waste reduction by reusing and recycling materials.
BE^2ST [12]	About 20% of criteria emphasized of material reuse/recycling.
Sustainable Infrastructures Project Rating System (SIPRS)	Criteria have been divided into 3 main categories which are social, economic and environment. Only focused on recycling/reuse of material.
Sustainable Transportation Environmental Engineering and Design (STEED) [13]	One of the main criteria emphasized is material handling management that focused on recycling technique.

2.2 Pilot Study

During Phase 2, the first meeting also known as a first stage workshop with expert and authority was held. About 30 experts attended the workshops that have many experiences in highway construction and management. Five experts were allocated for pavement division. The participation of experts is coming from various backgrounds as an engineer, contractor and consultant/designer. The objectives of this meeting are:

a. To obtain the feedback and comment from the engineers, consultants and local authorities about the propose element.
b. To share some knowledge on highway industries and changing the idea to improve the element and sub-element.

The first draft of the proposed element was presented to all the experts in the highway engineering field and some corrections were made with suggestions from them to improve the element. This workshop was also called as ‘pilot study’ in order to test the questionnaire before distributing to the respondent. Type of questionnaire that has been produced is ‘Likert Scale’ based on the agreement level of the proposed element.

2.3 Data Collection

After the first stage of the workshop in Malacca, the sample of questionnaire was prepared and distributed to the respondent. Data collection takes about 2 weeks to be completed and this questionnaire was distributed over 22 companies including concessionaires and consultants that have experience in highway engineering. The total of respondents are 109 experts which involve in this questionnaire survey. The location of data collection is around Kuala Lumpur, Selangor, and Johor area.

2.4 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 [14]. Under the refined method, 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 (center of data) for every element. The formula for calculating the factor score was developed by [15] which stated:

$$F = Z \times B \quad (1)$$

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.

2.5 Weightage Factor For Elements

The weighting factor analysis of pavement technology elements was applied based on the formula that has been developed by [16] below:

$$\pi_{\text{sub criteria}} = \frac{\%\, factor\ score\ in\ element}{\%\ of\ total\ factor\ score\ in\ all\ elements} \quad (2)$$

The total of factor score in every 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 high importance of the element towards contributing green highway design in the future. Besides, the highest weightage resulted for main priority and consideration of element to implement green highway.

3.0 RESULTS AND DISCUSSION

The analysis of elements to produce weighted factor for every element is conducted by using Statistical Package for Social Science (SPSS) and the results are shown in Table 2 below. In SPSS, there are 4 stages that are needed to be carried out before obtaining weighted value for every element. SPSS is used for data reduction from large samples of the original data sets. Besides, this software also can generate the weighted or factor loading similar with Analytical Hierarchy Process (AHP) software that has been used byHuang and Yeh[17] in order to evaluate the element that is more focused on pairwise comparison in the questionnaire. The output from SPSS, which are mean and factor loading was multiplied in order to get a factor score. The elements were grouped accordingly based on the factor loading value and the categories were given based on the elements included in that category.

Table 2 Weightage factor

Category	Element	Sub-element	Mean	Factor loading	Factor Score	∑Factor Score	Weightage
Economical & Green Scenery	Pavement Design Life	Long lasting pavement design life	3.92	0.58	2.27	18.48	0.12
	Reuse Pavement (RP)	Usage of Reclaimed Asphalt Pavement (RAP) and Recycled Concrete Material (RCM)	3.65	0.52	1.90		0.10
	Erosion Control (EC)	Soil biotechnical engineering treatments	3.77	0.88	3.32		0.18
		Green techniques	3.92	0.87	3.41		0.18
Innovation Technology	Cool Pavement (CP)	Reflectance of sunlight energy (Albedo & Solar Reflectance Index)	3.45	0.73	2.52		0.14
	Permeable Pavement (PP)	Storm-water runoff quality & flow water control improvement	3.65	0.77	2.81		0.15
	Quiet Pavement (QP)	Reduction of noise level	3.63	0.62	2.25		0.12

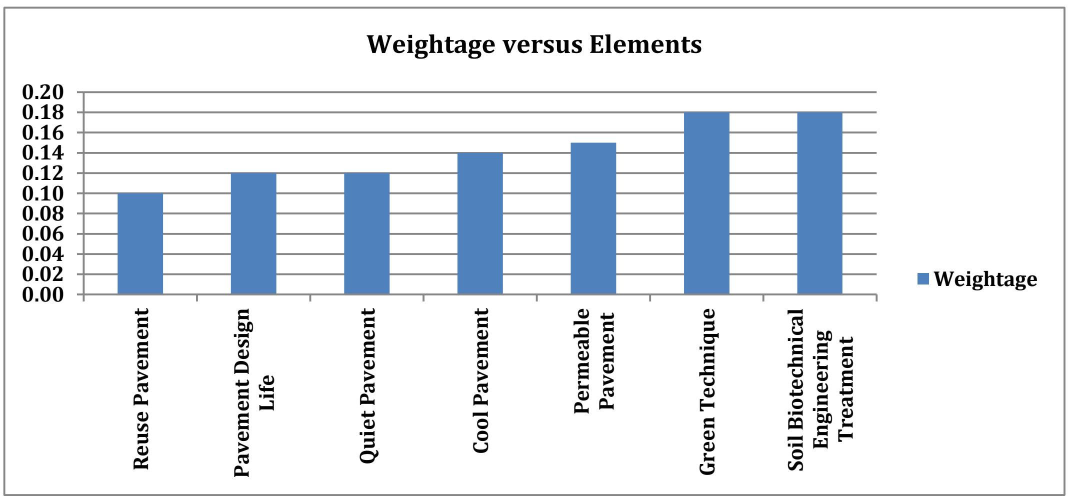

Figure 2 Weightage based on elements

Referring to Figure 2 above, the highest weighted factor was achieved by erosion control element, which consists of green technique (0.18) and soil biotechnical engineering (0.18). The highest weighted factor for erosion control represented the critical element that should be the main consideration in order to implement green highway concepts, which have been agreed by the panel of highway experts [18-22]. In the meantime, this value of weighted factor has interpreted the importance of the element that influences the allocation of score point where it will be included in the 'Malaysia Green Highway Manual' in the future. Besides, the permeable pavement is another essential technology that should be considered for the green highway concepts by giving weightage factor of 0.15. Basically, this element indicated another important technology that should be taken into consideration to implement green highway.

The weighting factor for cool pavement is 0.14, which is lower than erosion control and permeable pavement since this technology is quite new in the highway construction industry. However, the performance of cool pavement will be explored in the future, so that the cool pavement technology will become an important part to implement green highway. Pavement design life and quiet pavement have shared the same weighted factor, which are 0.12, and reuse pavement is 0.10. This value is lower compared to the other elements and gives the indication of the least importance of the elements in contributing towards green highway design.

■4.0 CONCLUSION

The importance of element in implementing green highway design concepts by determining the value of weighted factor has indicated the erosion control elements contributed major contribution in green highway construction. The weighting factor result is 0.18 and 0.18 where it has shown as the highest weighted compared to the other elements. Therefore, soil erosion control elements can be classified as the critical element in the implementation green highway. Besides, permeable pavement and cool pavement are another element that should be taken into consideration because this criterion is important to achieve the green highway concepts goals. Since the permeable and cool pavement are new techniques in highway design, therefore the weighting factors for those elements are quite high and indicated to give high important elements towards green highway design in the future.

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