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Research paper

Sustainable Design and Construction Activity as Element for Green Highways in Tropical Climate

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Abstract

In Malaysia, the National Green Technology Plan (NGTP) was launched in 2009 as the main agenda to promote green technology initiatives. Various green initiatives have been taken to support global efforts in maintaining the world's ecological balance. However, most green initiatives that have been implemented in this country have been mainly related to buildings. Reviews of the literature revealed that tropical countries still lack studies on green highway project development. One of the elements of a green highway is the 'Sustainable Design and Construction Activity'. Hence, this research has been carried out in order to determine the criteria and sub-criteria intended for the element of Sustainable Design and Construction Activity for green highways in a tropical climate. This research was under taken using the exploratory mixed method which consisted of a qualitative aspect for the preliminary survey and a quantitative aspect for the main study using a questionnaire as the research instrument. 10 experts were interviewed for the preliminary survey, whilst 143 respondents from local authorities and highway concession companies related to highway development and construction were involved for the main survey. The main data collection was analysed by using Factor Analysis. It was found that 6 criteria and 31 sub-criteria were related to the 'Sustainable Design and Construction Activity' element of green highways. The criteria were Pollution Prevention, Life Cycle, Noise Mitigation, Infrastructure Planning, Design Innovation, and Quality Management. These criteria and sub-criteria are significant enough to be used as an indicator in assessing green highways in a tropical climate under the element of 'Sustainable Design and Construction Activity'.

Keywords: *sustainable design, construction activity, green highway, tropical climate*

1. Introduction

Ministry of Technology, Green Technology, and Water launched the National Green Technology Policy in 2009 as a driver to accelerate the national economy and promote sustainable development in the 10^{th}, 11^{th}, and 12^{th} Malaysia Plans (KeTTHA, 2014). The objective of the policy is to ensure the sustainable development and conserve the environment. One of the areas emphasised in this Green policy is the transportation sector that mainly focuses on transportation infrastructure. Furthermore, the 4^{th} strategic thrust highlighted the crucial research, development, innovation, and commercialisation on green technology.
To date, most of the attention and effort in the development of sustainable construction in countries all over the world has been devoted to buildings (Huang&Yeh, 2008). Furthermore, the experience and knowledge acquired in the process of developing sustainable or green building is expanding; whereas, the ways to facilitate green highway construction is very limited. The initiatives for green highways are still lacking on the implementation guidelines, rating tools, and frameworks (Mohd Affendi, et al., 2013). Consequently, green highway approaches have been introduced in developed countries, such as the United States and the United Kingdom, to improve the environment quality and reduce the negative impact to the environment. However, these approaches are only suitable for four-season climate countries. Due to the characteristics of the tropical climate being different from the four-season climate, the existing green highway approaches, unfortunately, are not suitable to be used for countries that have a tropical climate such as Malaysia. Therefore, there is a need for a study on the development of a green highway assessment for tropical climates.
There are many elements taken into consideration in green highway development, such as the sustainable design and construction activity (Soderlund, et al., 2008, GreenLITES, 2008), environmental management (Soderlund, et al., 2008,Bryce, 2008.; I-Last, 2008; and(Muench, et al., 2011), energy efficiency (Greenroads, 2007; GreenLITES, 2008; and RMRC &UMW, 2010), material and technology (Soderlund, et al., 2008; GreenLITES, 2008; I-Last, 2008; and RMRC &UMW, 2010), as well as the social and safety elements (Muench, et al., 2011). Due to the limited paging requirement, this paper only focuses on the element of the Sustainable Design and Construction Activity even though the main research activities cover all the related elements. Thus, the objective of this paper has been to determine the criteria and sub-criteria for the Sustainable Design and Construction Activity, which is one of the elements of green highways in a tropical climate.

2. Literature Review

The lifecycle of a highway construction project includes the planning, construction, and maintenance processes. Throughout the analytical overview from the existing research, the definition of a green highway is different from the perspective of each researcher.

2.1 Green Highway

A green highway includes more sustainable practices than modern construction techniques, and consists of maximising the lifetime of a highway (Bryce, 2008). Later, Krebs (2009) defined a green highway as an effort to go beyond compliance and leave the project area 'better than before' through community partnering, environmental stewardship and transportation network improvements in safety and functionality. A green highway can also be defined as the watershed driven storm water management; life cycle energy and emission reduction; recycle, reuse, and renew; conservation and ecosystem management; and the overall societal benefits (Malaysian Highway Authority, 2010).
A green highway is defined as a roadway project that has been designed and constructed to a level of sustainability that is substantially higher than the current practices (Muench, et al., 2011). In addition, a green highway is the highway constructed using materials that emit no or only a low concentration of pollutants and are environmental friendly (Reddy, 2011). A green highway can also be defined as the approaches for helping developers achieve a friendly environment, ecological responsiveness, and social responsibility to improve long-term profitability and gain a sustained competitive advantage (Zhang, et al., 2011). Others define a green highway as an initiative to promote the use of cleaner fuels (Washington Department of Transportation, 2013) and roadway design based on a relatively new concept that incorporates transportation functionality and ecological requirements (LLM & UTM, 2014).

2.2 Tropical Climate

A tropical climate is a non-arid climate having an average temperature above 18°C (Maps of the World, 2015). The examples of tropical climate areas are rainforests, Savannas, and Semi-arid regions. Tropical climates are known as hot and humid weather conditions. Sunlight and excessive rainfall are characteristics of the tropical climate that helps in the growth of luxuriant vegetation. Other than Malaysia; Indonesia, Thailand, Singapore, Laos, Vietnam, Brunei, Myanmar, Cambodia, and the Philippines also experience tropical climates (Maps of the World, 2015).
Malaysia experiences the climate of the equator. An equatorial climate is hot and humid throughout the year. Malaysia records high temperatures, which are almost identical throughout the year. The annual temperature is between 26°C to 27°C. The temperature is different to the highland areas which experience a lower temperature of about 18°C. Besides that, Malaysia receives heavy rainfall of about 2000mm to 3000mm per year (Sham, 1983).
The characteristic features of the climate of Malaysia are uniform temperatures, high humidity, and copious rainfall. Winds are generally light. Situated in the equatorial doldrums area, it is extremely rare to have a full day with a completely clear sky, even during periods of severe drought. On the other hand, it is also rare to have a stretch of a few days with completely no sunshine except during the northeast monsoon seasons (MOSTI, 2013).
The tropical climate characteristics are as follows:
i) Wind flow -Though the wind over the country is generally light and variable, there are some uniform periodic changes in the wind flow patterns according to the month of the year. The southeast monsoon starts from end of May and continues until the end of September. Whereas, the northeast monsoon begins in the early part of November and continues until the end of March, and there are two shorter periods of inter-monsoon seasons (Ministry of Science Technology and Innovation (MOSTI, 2013).
ii) Temperature - Tropical climates experience high temperatures which remain around the same throughout the year. The mean annual temperature is about 26°C to 27°C (Ministry of Science Technology and Innovation (MOSTI, 2013). It experiences a small annual temperature range due to the temperature being rather even throughout the year. Besides that, it receives sunlight throughout the year and the humidity of air is high at about 85%. The sky is usually covered by thick clouds and the nature of the islands surrounded by the sea also contributes to the small annual temperature range (Sham, 1983).
iii) Rainfall - The seasonal wind flow patterns coupled with the local topographic features determine the rainfall distribution patterns over the country. During the northeast monsoon season, the exposed areas like the east coast of Peninsular Malaysia, Western Sarawak, and the northeast coast of Sabah experience heavy rain spells. On the other hand, inland areas or areas which are sheltered by mountain ranges are relatively free from its influence. It is best to describe the rainfall distribution of the country as differing according to the seasons (Ministry of Science Technology and Innovation (MOSTI, 2013).
iv) Humidity – The relative humidity of the air is always high because the temperature is always high and there is a low temperature range. Thus, the air always contains a lot of water vapour. The air humidity is the ratio between the water vapour present in the air and the amount of water vapour that the air can hold at a certain temperature. The air humidity varies following the temperature. When the air temperature rises, humidity decreases and vice versa (Ministry of Science Technology and Innovation (MOSTI, 2013).

2.3 Green Highway Approaches

There are several green highway approaches available which are Greenroads, Washington Internships for Students of Engineering (WISE), GreenLITES, Building Environmentally and Economically Sustainable Transportation (BE2ST), Illinois Livable and Sustainable Transportation (I-LAST), Greenroads Manual, and Malaysia Green Highway Index (MyGHI). Every approach has its own criteria and rating method for green highways. The criteria may be the same or may differ from one to another approach depending the climate.

2.3.1. Greenroads

Greenroads is the first green road rating system and was established in the United States in 2007. It is a voluntary third party rating system for road projects which seek to recognise and reward the roadway projects. Greenroads consist of 54 credits in 6 categories. The categories of Greenroads are sustainable design, material and resources, stormwater management, energy and environmental control, construction activities, and innovation(Soderlund, et al., 2008). For a sustainable design, the sub-categories are the alignment selection, context sensitive design, traffic flow improvement, roadway safety,long-life pavement design, and public input. Meanwhile, the sub-categories for construction activities are reduce diesel emissions, reduce fossil fuel dependency, temporary stormwater control, noise mitigation planning, paving emissions, paving construction, and quality process.

2.3.2 Washington Internship for Students Engineering (WISE)

Washington Internship for Students of Engineering (WISE) is a concept written for the Washington Internship for Students of Engineering (WISE) programme. It was published in August 2008 at the University of Missouri, the United States. WISE provides five key areas of concept for green highways. In Figure 2.1 below, it shows the key areas of the concept for green highways. The key areas consist of watershed driven stormwater management, lifecycle energy and emissions reduction, recycle, reuse and renew, overall societal benefits and conservation, and ecosystem management. Combinations of the five key areas establish the concept of green highway fruition (Bryce, 2008). Each of the key areas defines the specific subjects that relate to the development of the green highways. This approach considers recycle, reuse, and renew as the construction activity.

2.3.3 GreenLITES

The New York State Department of Transportation (NYSDOT) is committed to improving the quality of their transportation infrastructure in ways that minimise impacts to the environment, including the depletion of irreplaceable resources (Green LITES, 2008). The New York State Department of Transportation introduced GreenLITES in September 2009 as a self-certification programme that distinguishes transportation projects based on the extent to which they incorporate sustainable design choices. This certification programme builds on other environmental initiatives already begun by the Department and is the next step in a long-term commitment to evaluate and refine practices to encourage sustainable choices in project designs. The GreenLITES programme has 5 main categories which are sustainable sites, water quality, material and resources, energy and atmosphere, and innovation. Sustainable sites are similar to sustainable design and construction activity with sub-categories including alignment selection; context sensitive solutions; land use or community planning; protect, enhance, or restore wildlife habitats; as well as protect, plant, or mitigate for removal of trees and plant communities.

2.3.4 Illinois Livable and Sustainable Transportation (I-LAST)

The Illinois Livable and Sustainable Transportation (I-LAST) system was developed in January 2010 as a Rating System and Guide. I-LAST is a sustainability performance metric system developed by the Joint Sustainability Group of the Illinois Department of Transportation (IDOT), the American Council of Engineering Companies–Illinois (ACEC-Illinois), and the Illinois Road and Transportation Builders Association (IRTBA). I-LAST is not an official policy or procedure of the Illinois Department of Transportation. It is purely advisory in nature, intended to ascertain and document sustainable practices proposed for inclusion on highway projects. I-LAST has eight categories of green highways which are planning, design, environment, water quality, transportation, lighting, materials, and innovation (I-LAST, 2008). For the design category, the sub-categories are the alignment selection and context sensitive design.

2.3.5 Building Environmentally and Economically Sustainable Transportation (BE2ST)

Building Environmentally and Economically Sustainable Transportation (BE^2ST) is a manual initiated by the University of Wisconsin in 2010. This manual is a data-based programme which is linked to several publicly open sources. BE^2ST provides six main components for green highways. The components consist of material reuse or recycling, energy use, water consumption, global warming potential, life cycle cost, and hazardous waste(RMRC &UMW, 2010),. There is no category related to sustainable design and construction activities considered in this approach.

2.3.6 Greenroads Manual

The Greenroads Manual was published in 2011 by the University of Washington. It is an enhancement of the Greenroads that was published in 2007. This Greenroads Manual contains the details of each Project Requirement (PR) and Voluntary Credit (VC) that is included in the Greenroads Rating System. The Greenroads Manual could be used as a guideline during the design and construction phases. The Greenroads Manual helps to quantify the sustainable attributes of a roadway project. The Greenroads Manual has developed five main criteria for green highways, such as Environment & Water, Access & Equity, Construction Activities, Material & Resources, and Pavement Technologies. Under the criteria for Construction Activities, the sub-criteria are quality management system, environmental training, site recycling plan, fossil fuel reduction, paving emissions reductions, water tracking, and contractor warranty(Muench, et al., 2011).

2.4 Sustainable Design and Construction Activityas Element for Green Highway in Tropical Climate

Table 1 shows the Sustainable Design and Construction Activity as one of the elements considered in green highways for tropical climates. Based on previous research, this category was divided into nine criteria and thirteen sub-criteria. Those criteria included the construction management plan, noise mitigation control, equipment and machinery efficiency, quality management, context sensitive design, erosion and sedimentation, alignment selection, pollution reduction, and life cycle. This element functions to reduce the impacts to the natural environment by means of the sustainable design and construction activity. It also supports the increase in capacity and provides benefits to society related to highway development.

All assessments on the existing green highway approaches, except for BE2ST, show that there is need for the context sensitive design for the development of green highways. This shows that this item is important in the development of green highways. In the designing and developing of highways, the environment is the most important criteria to be considered for developing green highways (New York State Department of Transporation, 2009). This relates to the criteria of environmental impact reduction where all the assessments are needed. The function of developing a green highway is to minimise the impact to the environment (Michigan, 2008).

Meanwhile, nature and the emission reduction for the equipment and machinery efficiency has been noted as important criteria for all assessments, except for the GreenLITES and I-Last systems. The production of emissions will have a negative impact on the surrounding ecosystem and overall environmental quality (Bryce, 2008; Zakaria, et al., 2012). Additionally, Kibert (2001) reported that, 6% of the total U.S. Industrial greenhouse gas emissions were produced by the construction sector in 2002 (Kibert, 2001). Out of that, 13.4% were produced by the construction of highways, streets, and bridges. The Malaysia construction industry has been amongst the biggest threat to the environment in the form of greenhouse gas emissions (Klufallah, et al., 2013). The construction industry of Malaysia was also included as the 30^{th} in the world ranking of the production of carbon emissions (Klufallah, et al., 2013). In the vision of 2020, the construction industry aims to reduce the carbon emissions up to 40% (Klufallah, et al., 2014).

The weather of the tropical climate contribute to heavy rains which could cause landslides, flash floods, erosion, sedimentation, and other catastrophes (Che Ahmad & Husin, 2015). Additionally, air pollution is also another issue that needs to be solved. The largest contributor to air pollution in Malaysia are mobile sources, such as motor vehicles, that contribute 70% to 75% of the total air pollution (Afroz, et al., 2003). Due to the construction of highways involving a lot of machinery, they need proper planning to minimise the production of gas emissions from the machinery involved and also from vehicles.

Table 1: Review analysis for Sustainable Design and Construction Activity

riteria	Sub-Criteria	Green roads (2007)	WISE (2008)	Green LITES (2008)	I-Last (2008)	BE2ST (2010)	Greenroads Manual

							(2011)
Construction Management Plan	Waste Management	/	x	x	x	x	/
	Air Pollution	x	x	x	x	x	x
	Innovation	/	x	x	/	x	x
Noise Mitigation Control	Technique	/	x	/	/	x	/
	Equipment	x	x	x	x	x	x
Equipment And Machinery Efficiency	Natural & Emission Reduction	/	/	x	x	/	/
Quality Management	Management Plan & Training	/	x	/	x	x	/
Context Sensitive Design	Design Flexibility	/	/	/	/	x	/
Erosion & Sedimentation	Erosion & Sedimentation	x	x	x	x	x	x
Alignment Selection	Environmental Impact Reduction	/	/	/	/	x	/
Pollution Reduction	Air and Noise Pollution	x	/	x	x	x	x
	Light Pollution	/	/	x	x	x	/
Life Cycle	Life Cycle Assessment	x	x	x	x	/	/

3. Research Methodology

The methodology of this research has been divided into two stages, which were the preliminary study and the main study.

3.1 Preliminary Study

The preliminary exploratory study was conducted to explore and investigate the opinions and to clarify the problems that are related to the study (Chua, 2006). According to Singh, et al. (2006), the preliminary exploratory study is important in order to get more understanding about the topics that are not well known and is suitable for the beginning of an understanding approach. For this research, the preliminary exploratory study was conducted with 10 highway experts who were involved in the development of highways and had experience of more than 5 years. The purpose of this open ended interview session was to identify the elements of green highways for a tropical climate, specifically for the element of the Sustainable Design and Construction Activity.

3.2 Main Study

For the main study, the elements from the input of the open ended interview session combined with the information extracted from the literature review were used in developing the questionnaire survey form. For the Sustainable Design and Construction Activity, 33 sub-elements were identified to form the questionnaire survey. This questionnaire survey was used as the research instrument for the main study. The questionnaire survey was designed to acquire the perceptions of highway professionals and stakeholders on the elements of green highways. According to Mahmud (2009), the questionnaire survey method is widely used and the best way to get the systematic data. The Main Survey is divided into two, which are the pilot survey and the main survey.

3.2.1 Pilot Survey

The pilot survey is utilised for the content validity analysis using Cronbach's Alpha to obtain the validity of the research instrument. This analysis is conducted in order to interpret the alpha value derived from the test using the Statistical Package for the Social Sciences (SPSS) version 21. The content validity was conducted with 30 highway experts who possessed knowledge about highway development to respond to the questions in the research instrument. The accepted coefficient value in Cronbach's Alpha is between 0 to 1, and if the value exceeds 0.60, it means that the scale has internal consistency and is reliable to be used (Cresswell, 2012). The results of the pilot survey for the element of the Sustainable Design and Construction Activity showed an acceptable coefficient alpha value, which was 0.966.

3.2.2 Main Survey

For the main survey, this research used purposive sampling focusing on the professionals related to the development of highways. The population for this research came from the organisations that were involved in the development of highways in peninsular Malaysia. The organisations of the highway development were divided into two, which were the authority sector and the concession highway sector. The authority sector consisted of the Ministry of Works (KKR), Malaysian Public Works Department (JKR), Malaysia Highway Authority (LLM), and Construction Industry Development Board (CIDB). Whereas, the concession highway sectors consisted of 26 concession companies as shown in Table 2. The sample size was determined by using the table of the sampling size by Krejcie& Morgan (1970). The total population was 30 organisations so the sample size was 28. The researchers managed to obtain 143 respondents for this research.

Table 2: Sector and Organisation of Purposive Sampling

Sector	Organisation
Authority	Ministry of Works (KKR)
	Malaysian Public Works Department (JKR)
	Malaysia Highway Authority (LLM),
	Construction Industry Development Board (CIDB)
	Besraya (M) SdnBhd
Concession Highway	Syarikat Mengurus Air Banjir&Terowong
	SenaiDesaru Expressway Berhad
	LebuhrayaKajang Seremban SdnBhd
	Linkedua (M) SdnBhd
	LebuhrayaLingkaranLuar Butterworth
	PROLINTAS Express SdnBhd
	Metramac Corporation Sdnbhd
	Penang Bridge SdnBhd
	Konsortium Expressway Shah Alam Selangor SdnBhd (KESAS)
	PLUS Expressway Berhad
	Syarikat Grand Saga SdnBhd
	LingkaranTranskota Holdings Bhd (LITRAK)
	MTD PRIME SdnBhd

	New Pantai Expressway SdnBhd
	SistemPenyuraianTrafik KL Barat SdnBhd (SPRINT)
	ProjekLintasan Shah AlamSdnBhd (PROLINTAS)
	ProjekLintasan Kota SdnBhd (AKLEH)
	MRCB Lingkaran Selatan SdnBhd
	Lebuhraya Assam Jawa Taman RimbaSdnBhd
	SKVE Holding SdnBhd
	SistemLingkaran-LebuhrayaKajangSdnBhd (SILK)
	KonsortiumLebuhraya Utara-Timur Kuala Lumpur SdnBhd (DUKE)
	ProjekLebuhraya Utara Selatan Bhd (NKVE)
	JambatanaKeduaSdnBhd
	Kuala Lumpur – Kuala Selangor Expressway SdnBhd (LEKAS)

4. Results and Discussion

An analysis was conducted with 33 items to determine the criteria and sub-criteria for the Sustainable Design and Construction Activity as one of the elements of green highways in tropical climates. The Kaiser-Meyer-Olkin (KMO) value was used to measure the appropriateness of the correlation matrix of the factor analysis. Maleta & Aires (2007) suggested that a KMO value closer to 1 is a solid correlation and produces a good factor analysis, and the recommended minimum acceptable value is 0.6. The 33 items for the element of the Sustainable Design and Construction Activity obtained was 0.894 for the KMO value (Table 3), which was suitable to be used. In addition, the Bartlett's test of Sphericity, which was also used to assess the degree of the correlation amongst the set of variables, was significant enough to perform the factor analysis (Maleta & Aires, 2007). The result of the Bartlett's test of Sphericity showed a significance value of $p<0.05$, which was significant and indicated a sufficient correlation amongst the set of items to perform the factor analysis (Chua, 2009).

Table 3: KMO and Bartlett's Test for Sustainable Design and Construction Activity

Kaiser-Meyer-Olkin of Sampling Adequacy		.894
Bartlett's Test of Sphericity	Approx. Chi-Square	5264.843
	df	528
	Sig.	.000

The extraction factor process showed that the communalities value was more than 0.40 for all 33 items. This outcome showed that all of the items were suitable for the next step. After the analysis, the Varimax rotation and an examination of the scree plot, the 33 items of sustainable design and activities scale, resulted in the extraction of 6 factors. The analysis found that 6 factors had eigenvalues greater than 1, which cumulatively represented 77.5% of the explained variance of the survey data. Table 4 shows the total variance explained for the sustainable design and activities.

Table 4: Total Variance Explained for Sustainable Design and Activities

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	16.940	51.332	51.332	16.940	51.322	51.332	6.795	20.590	20.590
2	2.546	7.714	59.046	2.546	7.714	59.046	4.468	13.538	34.128
3	1.978	5.995	65.041	1.978	5.995	65.041	3.895	11.803	45.931
4	1.715	5.196	70.237	1.715	5.196	70.237	3.658	11.085	57.016
5	1.344	4.071	74.308	1.344	4.071	74.308	3.429	10.392	67.408
6	1.067	3.235	77.543	1.067	3.235	77.543	3.345	10.135	77.543
7	.974	2.952	80.495						
8	.814	2.467	82.962						
9	.735	2.227	85.188						
10	.580	1.757	86.946						
11	.476	1.443	88.389						
12	.422	1.279	89.668						
13	.417	1.264	90.932						
14	.374	1.135	92.066						
15	.335	1.017	93.083						
16	.290	.878	93.960						
17	.258	.782	94.743						
18	.225	.682	95.425						
19	.193	.584	96.009						
20	.169	.511	96.520						
21	.166	.503	97.023						
22	.153	.465	97.488						
23	.125	.380	97.868						
24	116	.350	98.218						
25	.108	.326	98.544						
26	.093	.282	98.826						
27	.083	.251	99.077						
28	.072	.219	99.296						
29	.062	.187	99.483						
30	.059	.179	99.661						
31	.053	.159	99.821						
32	.036	.108	99.929						
33	.024	.071	100.000						

Extraction Method: Principle Component Analysis

The result of the component matrix was less meaningful without the rotation. Varimax rotation was carried out at the factor loading of 0.40. The results showed that factor 1 had 12 items, factor 2 had 5 items, factor 3 had 3 items, factor 4 had 4 items, factor 5 had 2 items, and factor 6 had 7 items without removing any items. Due to the first rotation results, the second rotation was carried out at the factor loading of 0.50. The results of the second rotation are shown in Table 5. The factors were listed according to the highest loadings in each dimension with six factors that were labelled as: Factor 1 – Pollution Prevention, Factor 2 – Life Cycle, Factor 3 – Noise Mitigation, Factor 4 – Infrastructure Planning Factor 5 – Design Innovation, and Factor 6 – Quality Management as shown in Table 5. Factor 1 had 11 items, factor 2 had 4 items, factor 3 had 3 items, factor 4 had 4 items, factor 5 had 2 items, and factor 6 had 7 items. 2 items, which were Involvement Plan and Plan for Erosion and Sedimentation, were eliminated from the total of 33 items.

Based on the results of the factor analysis, the items or sub-criteria were determined in the 6 factors or criteria (Table 5). Criterion 1 was known as Pollution Prevention and contained 11 sub-criteria, which were paving emission reduction, equipment emission reduction, fossil fuel reduction, prevent soil pollution, prevent air pollution, prevent water pollution, waste disposal, waste management plan, waste minimisation, prevent light pollution, and pollution prevention plan. Pollution prevention is to inhibit pollution and its associated effects from the construction activities. Construction practices that fail to control pollution can cause damage to waterways and wetlands, kill fish, upset aquatic ecological systems and wildlife communities, and result in the contamination of the land and groundwater (Environment Protection Authority, 1996). Besides that, air and noise pollution from the construction activity may cause annoyance and affect the health of neighbouring communities. Therefore, the pollution prevention needs to be implemented from the early stages of the construction of the highway to minimise the pollution.

Criterion 2 was known as Life Cycle and contained 4 sub-criteria, which were the life cycle inventory, life cycle cost, contractor warranty, paving construction quality, and involvement plan. The life cycle aspect should be conducted to identify the actual activity and cost incurred in the development of the highway (Muench, et al., 2011). The life cycle includes the stages from planning, construction, operation, and maintenance until demolition. Cost, activity, and quality can be well planned from the beginning of the development of the highway. Therefore, the life cycle aspect is needed in the development of the highway to minimise all the unexpected costs and activities, which will also increase the quality of the project.

Criterion 3 was Noise Mitigation which consisted of a noise mitigation technique, mitigation at the source, and prevention of noise pollution. Noise mitigation aimed to reduce or eliminate annoyance or disturbances to the surrounding neighbourhood and environment from road construction noise (Muench, et al., 2011). Noise from construction basically comes from the mobile equipment, stationary equipment, and blasting activities (Muench, et al., 2011). These noises will affect nearby property owners, residents, and also wildlife. This criterion needs to be well-thought-out as a vital element in highway construction to prevent the disturbance to the surroundings.

In criterion 4, there was Infrastructure Planning containing 4 sub-criteria, which were water tracking, land use or community planning, low impact development, and temporary stormwater control. The infrastructure planning is used to minimise the disturbance to the surrounding and also can help eliminate pollution. The infrastructure planning should take place in the development of green highways to minimise the disturbances to the environment and also the ecosystem.

The fifth criterion was Design Innovation containing 2 sub-criteria, which were design flexibility and long life pavement design. The design innovation provides the appropriate design for highway surroundings and encourages a high quality of construction (Soderlund, et al., 2008). Besides that, the design of the pavement must be for long-life usage to minimise the life cycle cost for the maintenance. Design innovation also needs to be practiced in the development of green highways to get a better design that will improve sustainability and minimise the maintenance cost.

Criterion 6 was Quality Management that consisted of the management plan, traffic flow improvement, audit, environment impact reduction, quality of live, evaluation, and management training. As stated by Battikha (2003), quality management is a set of quality activities involved in producing a product, and in processes and services, and it encompasses prevention and appraisal. The quality levels in construction become major problems to completion of the on time and within the budget (Battikha, 2003). Hence, quality management becomes important to be included in the construction of green highways in order to maintain sustainability.

Based on these factor analysis results, 2 items, which were the Involvement Plan and Plan for Erosion and Sedimentation were eliminated. These 2 items were not significant for assessing the Sustainable Design and Construction Activity for highways and were, therefore, not included as the sub-criteria.

Table 5: Factor Analysis ofCriteria and Sub-criteria for Sustainable Design and Construction Activity intended for Green Highway in Tropical Climate

Sub Criteriafor Sustainable Design and Activity	Factor loading for Criteria					
	1 Pollution Prevention	**2 Life Cycle**	**3 Noise Mitigation**	**4 Infrastructure Planning**	**5 Design Innovation**	**6 Noise Mitigation**
Paving Emission Reduction	.822					
Equipment Emission Reduction	.789					
Fossil Fuel Reduction	.700					
Prevent Soil Pollution	.687					
Prevent Air Pollution	.684					
Prevent Water Pollution	.661					
Waste Disposal	.657					
Waste Management Plan	.640					
Waste Minimization	.637					
Prevent Light Pollution	.575					
Pollution Prevention Plan	.536					
Life Cycle Inventory		.848				
Life Cycle Cost		.835				
Contractor Warranty		.665				
Paving Construction Quality		.584				
Noise Mitigation Technique			.781			
Mitigation at Source			.768			
Prevent Noise Pollution			.637			
Water Tracking				.800		
Land Use or Community Planning				.763		
Low Impact Development				.724		
Temporary Stormwater Control				.600		
Design Flexibility					.759	

Long Life Pavement Design	.691	
Management Plan		.713
Traffic Flow Improvement		.694
Audit		.662
Environment Impact Reduction		.656
Quality of Live		.653
Evaluation		.591
Management Training		.519

5. Conclusion

Green highways need high consideration to improve the environment, transportation system development, ecosystem, urban growth, public health, and also the surrounding communities (MohdAffendi, et al., 2013; Zakaria, et al., 2013). The Sustainable Design and Construction Activity is one of the elements that are taken into account in the development of green highways in a tropical climate. There were 33 items identified for this element from the input of the open ended interview session with experts in highway projects as well as items extracted from the literature review. These items were developed into a questionnaire survey which was the research instrument. The survey was responded to by 143 professionals who were related to the development of highways. The data collected were analysed using the factor analysis procedures. It was found that, 6 criteria and 31 sub-criteria were related to the Sustainable Design and Construction Activity elements of green highways for tropical climates. The criteria were, Pollution Prevention (11 sub-criteria); Life Cycle (4 sub-criteria), Noise Mitigation (3 sub-criteria), Infrastructure Planning (4 sub-criteria), Design Innovation (2 sub-criteria), and Quality Management (7 sub-criteria). 2 items, namely, the Involvement Plan and Plan for Erosion and Sedimentation, were removed from the list. These criteria and sub-criteria were intended for the element of the Sustainable Design and Construction Activity that could be used in assessing green highways for tropical climates.

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