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Stormwater as a Criterion for Green Highway

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ABSTRACT

Rapid development and illegal logging activities resulting in landslides and flash floods have brought the issue of sustainable stormwater management to the fore. Stormwater management is a process of managing stormwater, reducing the runoff water from the highway, treating and diverting it. This is an important aspect of green highway development. This study aims to identify the sub-criteria of stormwater management towards developing green highway. Survey method was adopted to determine the significance of stormwater for developing green highway. Data obtained from 142 respondents representing concessionaires and relevant authorities was analysed. Results showed that all the sub-criteria are important to be included in the assessment of green highway.

Keywords: Assessment, green highway, sub-criteria, stormwater management

INTRODUCTION

Development of green highway includes designing a highway in such a manner that improves the quality of nation's infrastructure and boosts its growth (Brown, 2003). LLM and UTM (2014) defined green highway as a roadway design based on relatively new concept that incorporates transportation functionality and ecological requirements. Green highway is also synonymous with transportation corridors which use low impact development tools, recycled materials, and locally sourced resources in transit right-of-way to meet

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regulatory requirements for stormwater management and highway design (Weinstein et al., 2008).

Dhakal and Oh (2011), and Gambatese and Rajendran (2005) stated a highway system would have adverse environmental impacts. It would also result in financial inefficiency, natural resource exploitation, and negative social repercussions. The major contributor to environmental problems in the construction sector is stormwater management, demolition debris, and energy consumption (Sharrard et al., 2007). Thus, environmental questions feature prominently in decisions pertaining to in the construction of a highway.

Takaijudin et al., (2010) traced the history of flash floods in Malaysia happen to 1920. In 2014, the worst flood in the nation's history happened in Kelantan, Terengganu and Pahang. Almost 200 thousand people were affected, 21 casualties and 10 missing (Mohamad, 2014). About 500 people lost their homes. MStar online (2015) reported almost RM105 billion losses including property, crops and infrastructure.

In recent years, floods have been caused by illegal logging, drainage system, rivers, topography and erosion (Bernama, 2015). In addition, rapid development creates impervious areas especially in towns such as Kuala Lumpur. Increase in impervious areas reduce green areas that function as natural stormwater. The transition from green to commercial and industrial area has directly affected the ecosystem (Takaijudin et al., 2010).

Thus, stormwater has become critical in the green highway development. It needs to be considered from the planning, construction, maintenance as well as operation phase. So, this study aims to identify the sub-criteria related to stormwater management for green highway development.

Overview of Stormwater

Basically, stormwater is rain or snow that falls on surfaces such as paved street, parking lots, rooftops, sport fields or any developed area. These surfaces are known as impervious areas which means they do not allow water to seep through the surface that will adversely impact on the environment due to the changes in quality and quantity of water flows. These impacts can change the hydrological cycles, natural habitats, geological condition and will pollute water bodies (Soderlund, 2007).

Nowadays, green areas have been redesignated for the purpose of construction and surfaces have been paved (Zakaria et al., 2004). For example, Subang Jaya will see an increase in impervious area from 0 to 40% which will increase the magnitude of runoff discharge about 190% (Zakaria et al., 2004). Increase in paved area will increase the likelihood of floods.

Besides this, roadway construction and maintenance, vehicle travel, and vehicle maintenance, can have an impact on water quality and quantity. It can lead to flooding and erosion, increased concentrations of heavy metals, salts, oil and grease, nutrients

and suspended solids (Green Highway Partnership, 2008).

The Department of Irrigation and Drainage Malaysia reported that the number of rivers capable of catering to the surface runoff has decreased (Zakaria et al., 2004). Managing the surface runoff using the drainage system, will increase discharges to the nearest river system. This problem happens frequently, especially in urban area such as Klang Valley, Penang, Johor Bharu and newly developing areas.

The Importance of Stormwater

The implementation of sustainable stormwater is expected to enhance the environmental quality of life. Water bodies and their greenery act as a natural filter to dust and atmospheric pollution. In a hot climate like Malaysia, the heat from thousands of vehicle engines and air condition make areas even more oppressive and unbearable. Natural water bodies that blend with the surrounding can provide a welcome relief.

Irrigation by far is the largest water consumer using about 69% of water available for human used, followed by industry at 23% of available water. Thus, only 8% remain for all other domestic uses (Zakaria et al., 2004). In line with growing population in Malaysia, drinking water demand is growing quickly and taken increasing part of total water resources. Since the existing water resources would not increase, therefore, there will be a competition between irrigation and domestic usage in the future. Therefore, stormwater runoff from impermeable surfaces in city should be considered as a valuable resource and used after treatment for less demanding cases. In general, new methods for multiple water reuse, harvesting and safe storage of rainwater should be explored.

Malaysia cannot avoid water shortage problem. After 1998 crisis, when Kuala Lumpur and Selangor faced water scarcity, the government realised the importance of sustainable water management (Abdullah, 2000). Unpredictable weather will cause climate change and global warming. Signs of climate change due to global warming could be seen through some disasters and also symptoms that hit several areas in in the country such as rising sea levels, haze, floods and lack of water resources. Reuse of water should take place.

Sub-criteria of Stormwater from Current Rating System

Based on the guideline and rating system available, the sub-criteria related to stormwater has been studied and listed in Table 1. Table 1 shows the sub-criteria from several green highway rating systems that are related to stormwater.

Greenroad rating system has sub-criteria of stormwater which are stormwater management, runoff treatment, permeable area, and innovative stormwater technology (Weinstein et al., 2008). Stormwater management aims to increase the impact of stormwater management solutions. For runoff treatment, it needs to meet enhanced

runoff treatment criteria. By preserving and enlarging the permeable area, it helps in providing natural infiltration of runoff.

GreenLites also have sub-criteria related to stormwater. There are stormwater management, runoff treatment and reduce runoff. For stormwater management, it monitors the volume of runoff and maintains water quality. Reducing the runoff will prevent pollution according to guideline given by the authority.

WISE have four sub-criteria related to stormwater in order to develop green highway: reducing the stormwater runoff; treating the runoff; divert the runoff; and improve the water quality (Bryce, 2008). Treating the runoff includes the attempt to reuse the water for different purpose. The water can be used for watering plant, washing cars and others. The other way is by diverting the runoff water to areas that can infiltrate through ground water table. To improve water quality, WISE prevents the runoff water from being polluted.

The greenroad manual has three sub-criteria related to water management. There is runoff flow control, runoff quality and stormwater cost analysis (Muench, et al., 2011). For runoff flow control, it aims to reduce the runoff quantity and minimise off site stormwater control. For runoff quality, the stormwater runoff is treated to a higher level of quality and for other uses. According to the greenroad manual, stormwater cost analysis must be conducted for every element of stormwater to uncover all related costs involved in the management of stormwater and to serve as a guideline in the future.

The BE2ST provides the cycle of green highway development based on water consumption. Its target is to reduce at least 10% of water consumption (Recycle Material & Resource Centre, 2010) from the construction, maintenance right up to operation of the highway. However,, BE2ST only focuses on water consumption. It does not look at stormwater.

I-Last focuses on impervious area, stormwater treatment and protects water quality (Illinois Department of Transportation, 2010). In order to allow the stormwater runoff infiltrate naturally, reducing impervious areas is important. In addition, I-Last also treat the stormwater runoff to be used for other purposes. It protects water quality of stormwater.

MyGHI have two criteria for stormwater, stormwater runoff quantity and stormwater runoff quality (LLM & UTM, 2014). Stormwater runoff quantity has several sub criteria which consists of runoff flow control; disaster cost analysis; and network drainage system. Runoff flow is controlled by water flow dissipation management, reduction of runoff quantity, detention or retention, critical volume of water and reduction of impervious area. Life cycle cost analysis was conducted. While stormwater runoff quality consists of water pollution reduction and runoff treatment, water pollution reduction by detection and elimination of non-stormwater discharge, ensures proper discharge of non stormwater discharge and

which follows the local authority standards for prevention of water pollution. Runoff treatment will minimise pollutants, erosion and sedimentation.

Table 1
Sub-criteria of stormwater

Sub-criteria	Greenroad Rating (2007)	GreenLites (2008)	WISE (2008)	Greenroad manual (2010)	BE2ST (2010)	I-Last (2012)	MyGHI (2014)
Stormwater management	/	/	/			/	
Runoff treatment	/	/					/
Permeable area	/					/	
Innovative stormwater technology	/						
Reduce runoff		/	/				
Divert runoff water			/				
Improve water quality			/			/	
Runoff flow control				/			
Runoff quality				/			
Stormwater cost analysis				/			/
Reduce water consumption					/		
Runoff flow control							/
Disaster cost analysis							/
Network drainage system							/
Water pollution reduction							/

METHODS

Through literature review and comparing current green highway rating systems, the study managed to identify the appropriate stormwater sub-criteria for green highway development in Malaysia. The questionnaire survey was distributed to Concession Companies and authorities. Concession companies included LATAR and LKSA highway. Whereas the authorities included Jabatan Kerja Raya, Lembaga Lebuhraya Malaysia and Kementerian Kerja Raya Malaysia. A total of 142 respondents participated in this study to justify the sub-criteria of stormwater for green highway. The proposed sub-criteria of stormwater is outlined in Table 2.

Data was analysed using correlation. Correlation analysis is used to prove the strength of the correlation or relationship between variables. For this study, a test was carried out between 11 sub-criteria regarding stormwater as listed in Table 1. Before the correlation analysis was done, normality test had been carried out using Kolmogorov-Smirnov and Shapiro-Wilks test. Kolmogorov-Smirnov and Shapiro-Wilks test are the set of normality tests to

Table 2
Propose sub-criteria of stormwater

Criteria	Sub- criteria	Indicator
Stormwater	Stormwater management	A
	Innovative stormwater technology	B
	Runoff flow control	C
	Runoff quality	D
	Runoff quantity	E
	Runoff treatment	F
	Water bodies protection	G
	Stormwater cost analysis	H
	Infiltration	I
	Water conservation	J
	Network drainage	K

identify the distribution of normal data (as cited in Chua, 2006b). Determination of normality distribution data will indicate the appropriate correlation test. The result of the normality test shows all the variables have significance value $p<0.05$. It shows, the distribution of data is not normal. According to Chua (2006a) normal distribution data is when both Kolmogorov-Smirnov and Shapiro-Wilks test is not significant at $p>0.05$. Chua (2006a) suggested Spearman's Rho test for correlation in the event data is not normal.

Spearman Rho test was conducted to examine the correlation between the variables. The strength of the relationship is identified in Table 3. Strength of the correlation tests can be done within all the variables listed in Table 1. Table 3 shows the correlation analysis between variables of stormwater.

Table 3
Strength of the correlation coefficient (Chua, 2006a)

Correlation Coefficient	Strength of relationship
0.91 to 1.00 or -0.91 to -1.00	Very High
0.71 to 0.90 or -0.71 to -0.91	High
0.51 to 0.70 or -0.51 to -0.70	Moderate
0.31 to 0.50 or -0.31 to -0.50	Low
0.01 to 0.30 or -0.01 to -0.30	Very Low
0.00	No Correlation

From the correlation using Spearman's Rho test, the results in Table 4 shows significant among the variables ($r > 0.50$, $p < 0.10$). Correlations between variables A with B ($r = 0.758$), A with C ($r = 0.725$), B with E ($r = 0.714$), C with D ($r = 0.835$), C with E ($r = 0.883$), C with F ($r = 0.866$), C with H ($r = 0.719$), C with I ($r = 0.753$), D with E ($r = 0.843$), D with F ($r = 0.791$), D with G ($r = 0.732$), D with H ($r = 0.746$), D with

I (r = 0.782), E with F (r = 0.860), E with H (r = 0.750), E with I (r = 0.770), F with G (r = 0.718), F with H (r = 0.757), F with I (r = 0.786), G with H (r = 0.739), G with I (r = 0.715) and H with I (r = 0.814) are high strength. Whereas the others are moderate strength of relationship correlation. Overall, all the variables have high and moderate significant correlation. This explains all the factors are important and need each other in order to be included in the criteria of stormwater.

Table 4
Correlation analysis between variable of stormwater

Variables	Correlation coefficient	Strength of relationship	P Value	Variables	Correlation coefficient	Strength of relationship	P Value
A – B	0.758**	High	0.000	D – F	0.791**	High	0.000
A – C	0.725**	High	0.000	D – G	0.732**	High	0.000
A – D	0.678**	Moderate	0.000	D – H	0.746**	High	0.000
A – E	0.685**	Moderate	0.000	D – I	0.782**	High	0.000
A – F	0.700**	Moderate	0.000	D – J	0.567**	Moderate	0.000
A – G	0.540**	Moderate	0.000	D – K	0.533**	Moderate	0.000
A – H	0.627**	Moderate	0.000	E – F	0.860**	High	0.000
A – I	0.658**	Moderate	0.000	E – G	0.698**	Moderate	0.000
A – J	0.517**	Moderate	0.000	E – H	0.750**	High	0.000
A – K	0.580**	Moderate	0.000	E – I	0.770**	High	0.000
B – C	0.663**	Moderate	0.000	E – J	0.554**	Moderate	0.000
B – D	0.594**	Moderate	0.000	E – K	0.580**	Moderate	0.000
B – E	0.714**	High	0.000	F – G	0.718**	High	0.000
B – F	0.677**	Moderate	0.000	F – H	0.757**	High	0.000
B – G	0.587**	Moderate	0.000	F – I	0.786**	High	0.000
B – H	0.700**	Moderate	0.000	F – J	0.588**	Moderate	0.000
B – I	0.652**	Moderate	0.000	F – K	0.620**	Moderate	0.000
B – J	0.553**	Moderate	0.000	G – H	0.739**	High	0.000
B – K	0.591**	Moderate	0.000	G – I	0.715**	High	0.000
C – D	0.835**	High	0.000	G – J	0.638**	Moderate	0.000
C – E	0.883**	High	0.000	G – K	0.509**	Moderate	0.000
C – F	0.866**	High	0.000	H – I	0.814**	High	0.000
C – G	0.648**	Moderate	0.000	H – J	0.607**	Moderate	0.000
C – H	0.719**	High	0.000	H – K	0.648**	Moderate	0.000
C – I	0.753**	High	0.000	I – J	0.549**	Moderate	0.000
C – J	0.518**	Moderate	0.000	I – K	0.596**	Moderate	0.000
C – K	0.592**	Moderate	0.000	**. Correlation is significant at the 0.01 level			
D – E	0.843**	High	0.000	(2-tailed)			

RESULTS

Table 5 shows the sub-criteria of stormwater according to mean. The highest is stormwater management with a mean of 3.94. This is followed by network drainage (3.92), water conservation (3.88), water bodies protection (3.87), runoff flow control (3.84), runoff quality and runoff treatment (3.82), innovative stormwater technology (3.80), runoff quantity and infiltration (3.75) and last stormwater cost analysis (3.70). This study only discussed the 3 highest ranking.

Stormwater management has the highest rank. It prevents and reduces pollutants by treating the source (Soderlund, et al., 2008). The management of stormwater has to be carefully planned from the planning phase. Good management will minimise or eliminate natural disaster happen that will adversely affect the environment. Besides that, it also can reduce the likelihood of floods.

Network drainage is an important criterion because a good drainage system will avoid or eliminate floods happen. Before developing a new area, a well-planned idea of drainage system (LLM & UTM, 2014) has to be clearly gazetted. In addition, the authorities also need to ensure the drainage system must be in good condition all the time. They need to ensure there is no illegal discharge into drainage ditch that will result to poor water flow. Flooding is the worst consequence if water quantity increases especially during heavy rain.

Water conservation is in ranked number 3. The function of water conservation is to minimise the shortage of water supply and the cost as well as saving the environment (CWCB, 2005; Zakaria et al., 2004). The stormwater must be well treated and conserved to prevent water pollution. The water also can be used for other purpose.

Table 5
Ranking of the sub-criteria of stormwater

Sub-criteria	Mean	Std. Deviation	N	Ranking
Stormwater Management	3.94	.874	142	1
Network Drainage	3.92	.794	142	2
Water Conservation	3.88	.803	142	3
Water Bodies Protection	3.87	.789	142	4
Runoff Flow Control	3.84	.769	142	5
Runoff Quality	3.82	.727	142	6
Runoff Treatment	3.82	.813	142	6
Innovative Stormwater Technology	3.80	.765	142	8
Runoff Quantity	3.75	.764	142	9
Infiltration	3.75	.827	142	9
Stormwater Cost Analysis	3.70	.832	142	11

CONCLUSION

Stormwater is an important criterion for environmental protection. The sub-criteria identified in this study are stormwater management, innovative stormwater technology, runoff flow control, runoff quantity, runoff quality, runoff treatment, water bodies protection, stormwater cost analysis, infiltration, water conservation, and network drainage. These sub-criteria have moderate and high strength of correlation between each other. The three important sub-criteria are stormwater management, network drainage, and water conservation. This study only highlighted the sub-criteria of stormwater as one of the important criteria in green highway. These sub-criteria of green highway will contribute to the main research in development of green highway assessment system.

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