CHEMICAL ENGINEERING TRANSACTIONS
VOL. 63, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Jeng Shiun Lim, Wai Shin Ho, Jiří J. Klemeš

ISBN 978-88-95608-61-7; **ISSN** 2283-9216
DOI: 10.3303/CET1863026

Relative Importance Index of Sustainable Design and Construction Activities Criteria for Green Highway

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Highway development and redevelopment inherently contributes to environmental impacts such as stimulation of urban sprawl, loss of open space, and noise and air pollution. Improvement to sustainable highway development is needed, as it will lead to green highway, minimal usage of fuel and greenhouse gas reduction. It is also necessary to have an indicator to reduce greenhouse gases during highway construction. The ideology of 'green' itself shows the connotation towards environment whenever the communities worldwide are concerned. The aim of this paper is to determine the relative importance index analysis in order to rank the criteria to their relative importance. Relative importance index analysis allows identifying most of the important criteria based on participants' replies and it is also an appropriate tool to prioritise indicators rated on Likert-type scales. 22 concessionaires with 140 respondents had been chosen to complete the questionnaires. The data had been analysed through formula of relative index analysis method from previous related studies. The finding showed that site maintenance was ranked first (RII = 0.836), warranty clause is provided in the contract specifications to incorporate construction quality was ranked second (RII = 0.830) and construction personnel training was ranked third (RII = 0.826). It was revealed that the site management which is responsible by the contractors and authorities is the most important factor towards promoting the concept of sustainable development and achieving green highway in Malaysia.

1. Green highway

In earlier decades, sustainable development idea has grown from numerous environmental movements. Sustainable issues have recently been widely discussed especially in the construction industry. Sustainable development is a key issue in order to meet the environmental objectives and fulfil the demand of the large infrastructure projects due to an increasing number of population and urban density. Sahamir et al. (2017) agreed that the implementations of sustainability have become important initiatives discussed and undertaken by both private and public sector especially in construction development. Pollution that causes habitat disturbance, land usage, and climate change are the effects of construction emissions as stated by Griffith and Bhutto (2009). The impacts can be caused by design, construction and management of road, parking and other facilities. Sustainable design can be one of the factors to minimise the impacts of the highway damages/construction to the environment.

Fernández-Sánchez and Rodríguez-López (2010) had stated that it is necessary to have new techniques and tools that will allow the environmental, social an economics commitment to be met in building and civil engineering sector. Bryce (2008) stated that most of the sustainable assessment tools were focused on building construction rather that its infrastructure especially in highway development. Nikumbh and Aher (2017) mentioned that assessment tools would be benchmarking, in identifying areas of success, and in identifying areas of opportunity for improvement for sustainable choices or practices, and according to that certification awarded. Soderlund (2007) had mentioned that there were several developments of sustainable assessment tools for highway development in United States but not in tropical region especially Malaysia. Since Malaysia at this moment does not have any green highway rating system, there is a need of criteria

Please cite this article as: Raja Rafidah Raja Muhammad Rooshdi, Muhd Zaimi Abd Majid, Shaza Rina Sahamir, Noor Akmal Adillah Ismail, 2018, Relative importance index of sustainable design and construction activities criteria for green highway, Chemical Engineering Transactions, 63, 151-156 DOI:10.3303/CET1863026

verification thoroughly. The development of these criteria was primarily 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.

The comparison of several assessment tools had been taken from all over the world such as Greenroads and Green Lites from United States, CEEQUAL from United Kingdom, Australian Green Infrastructure Council (AGIC) and Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) from Australia, and Green Mark from Singapore. Most of the tools had nine (9) to fourteen (14) criteria that were related to sustainable design and construction activities. It had been summarised by Balubaid et al. (2015) that every tool had addressed similar concern towards design and construction activities. The criteria were based on the green highway rating systems, highway project guidelines as well as a few related case studies. According to Rooshdi et al. (2017) most of the criteria for sustainable design and construction activities from those assessments had similar factors such as quality, environment, waste, water, and pollution. All factors were related to each other during designing and constructing stage.

In summary, the preliminary criteria in Table 1 had been taken out from other green highway rating systems. The criteria also considered the location, weather and method of construction to ensure those criteria will be suitable in the Malaysian region.

Table 1: Preliminary criteria for sustainable design and construction activities

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

2. Research methodology

This study investigates the expertise involved in highway development in Malaysia. The research was conducted using literature on sustainability research, experts' opinions, questionnaires and a statistical analysis of the survey data. There are a lot of references for the establishment of decision criteria for the evaluation but in Malaysia there are still lack of reference.

The Nominal Group Technique (NGT) devised by Delbecq et al. (1986) had been used to derive the criteria for the sustainable design and construction activities of green highway. The objective of the technique is the exploration of ideas from a team of experts for decision making as mentioned by Adler and Ziglio (1996). Even Delphi and NGT provide same advantages but NGT would draw more attention from the expert team to each idea and increase opportunity for each member to assure that his ideas are part of the group's frame of reference (Delbecq et al., 1986).

The questionnaires had been developed based on the criteria carried from literature review and expert discussion. The questionnaires were then distributed to the respondents in order to get the agreement level for each criterion. Questionnaires were used in this research to gather information. Several steps were taken to complete the questionnaires for this research including finding objectives of the survey, determining sampling group, designing the questionnaire, administering the questionnaire and interpreting the result. The questionnaire was divided into two sections: Section A for demographic and Section B for main criteria. The questionnaires contained nine (9) main criteria, twenty-one (21) sub-criteria, and twenty-nine (29) elements description collected from the literature and it was reviewed by expertise during pre-expert discussion stage. The main criteria had been divided into sustainable design and construction activities. It had been coded as SD1 and SD2 for sustainable design and CA1, CA2, CA3, CA4, CA5, CA6, and CA7 for construction activities. Experts responded to the survey to ensure the number and description of each criterion is suitable with highway design and development in Malaysia.

The questionnaires were distributed to several respondents to ensure they completed it manually. These questionnaires were distributed to the respondents who are experts in the highway construction industry. 140 respondents, from 22 concessionaires and consulting companies were approached to provide their feedback and justification for the data analysis. The questionnaires were distributed by hand and the informal interview were also held during the survey. The informal interviews were conducted to understand the content of questionnaires and to avoid the discrepancies among the respondents. The setting of data collection is in Kuala Lumpur, Selangor, and Johor area.

3. Data Analysis

The feedback from the respondents had been analysed using Microsoft Excel application. Based on the content of the questionnaires, the analysis was divided into two sections: demographic and relative importance index analysis.

Relative index analysis was selected in this study to rank the criteria according to their relative importance. The following formula is used to determine the relative index

$$RI = \sum \frac{w}{A \times N} \tag{1}$$

where w is the weighting as assigned by each respondent on a scale of one to five with one implying the least and five the highest. A is the highest weight and N is the total number of the sample.

Based on the ranking (R) of relative indices (RI), the weighted average for the two groups will be determined. According to Akadiri (2011), five important levels are transformed from RI values: high (H) ($0.8 \leq RI \leq 1$), high-medium (H–M) ($0.6 \leq RI \leq 0.8$), medium (M) ($0.4 \leq RI \leq 0.6$), medium-low (M-L) ($0.2 \leq RI \leq 0.4$) and low (L) ($0 \leq RI \leq 0.2$).

3.1 Demographic analysis

Based on the 140 questionnaires that had been distributed, 110 of respondents were employee of a concession, 20 were from consultant, six were from government agency and other four respondents do not answer this question. 105 respondents have bachelor degree as their highest education level, 23 have other education level, 10 have master, one has philosophy doctorate and one respondent does not answer this question.

From 140 questionnaires, 38 respondents have more than 15 years; another 38 have between 10 to 15 years of working experience, 36 have 5 to 10 years of working experience, 27 have less than 5 years and one respondent does not answer this question. As of 140 questionnaires, 48 respondents have less than 5 years involvement in highway development, 36 have between 5 to 10 years of involvement, 29 have been involved for 10 to 15 years, 21 have been involved for more than 15 years while six respondents do not answer this

question. From 140 questionnaires distributed, 67 of respondents are aware of the green development, 65 respondents have heard about it, three respondents have no knowledge about the green development, three respondents do not answer this question and only one respondent is an expert in green development.
From the level of awareness of green development, more than half of the respondents which are 79 have never involved in the green development. 49 respondents are involved less than 5 years, eight respondents have been involved between 5 to 10 years, three respondents do not answer this question and one respondent have been involved more than 10 years in the green development. Since they more than 10 years of working experience with highway development, they were very concerned about green development in highway industry.

3.2 Relative importance index analysis

Reliability test were conducted in the beginning of the section analysis to check the reliability of data before they were analysed. The reliability coefficient normally ranges between 0 and 1. The closer a is to 1 the greater the internal consistency reliability of the criteria in the scale. The Cronbach's Alpha is 0.922 with 29 variables. There is high internal consistency for the data set which the Cronbach's Alpha is more than 0.7 (Hair et.al, 1998).
Relative index analysis was used to rank the criteria according to their relative importance. Table 2 shows the ranking results for each category by using the relative index analysis in Eq(1).
Based on these ranking results, 13 criteria were highlighted to have high important levels in sustainable design and construction industry with a RI value between 0.801 and 0.836. These 13 criteria are reduced urban heat island effect, visual enhancement, provided site maintenance plan, warranty clause, environmental training, quality management system, reduced usage of fossil fuel at Hot Mix Asphalt (HMA), usage of emission reduction, usage of alternative fuel, efficient method of temporary erosion and sediment control, erosion and sedimentation as well as control plan, usage of water tracking system, and last but not least usage of water pollution control measure on site. It is categorised into 2 rankings:

1. Sustainable design; and
2. Construction activities.

As stated in Table 2, the highest ranking for sustainable design is sub-criteria SD2_f: design to reduce urban heat island effect (0.804). The ranking followed by SD2_e: design to utilise visual enhancement (0.803) and SD2_d: design to adjust highway features using design flexibility (0.794). The last or 7th criteria rank under this category is design to reduce the area of undeveloped land (0.737). All the criteria for sustainable design had fallen under high-medium importance level. It can be concluded that the importance of remaining the natural environment during designing the highways which can benefit by end users.
The ranking for construction activities had the same result as the overall ranking. As stated in Table 2, the highest ranking for construction activities is CA7_1: providing site maintenance plan to maintain environmental quality and aesthetics of the roadway project during use is the highest overall ranking (0.836). It shows that most of the respondents are taking awareness and responsibilities to ensure the environment remains clean and healthy during construction activities. Second-ranking was followed by CA6_c: providing warranty clause in the contract specifications to incorporate construction quality into the use of warranties onto finished product (0.830). The third-ranking is CA6_b: providing construction personnel with the certified knowledge to identify environmental issues and best practice methods to minimise environmental impact (0.826). These highest three criteria mentioned show the importance of criteria chosen for sustainable design and construction activities. The lowest or 22nd criteria rank under this category is provide construction and demolition waste management plan (CWMP) during roadway construction.
The overall result shows that construction activities had the highest ranking rather than sustainable design. As per Table 2, in the overall criteria ranking, no. 1 until no. 8 are under construction activities. Therefore, the highest ranking for overall criteria is CA7_1: providing site maintenance plan to maintain environmental quality and aesthetics of the roadway project during use is the highest overall ranking (0.836). Second-ranking was followed by CA6_c: providing warranty clause in the contract specifications to incorporate construction quality into the use of warranties onto finished product (0.830). The third-ranking is CA6_b: providing construction personnel with the certified knowledge to identify environmental issues and best practice methods to minimise environmental impact (0.826). It can be concluded that the activities during the construction stages should implement the more sustainable concept. Even, the lowest criteria rank under construction activities category is provide construction and demolition waste management plan (CWMP) during roadway construction but,the lowest ranking from the overall result is design to reduce the area of undeveloped land and provide construction and demolition waste management plan (CWMP) during roadway construction with same relative index result (0.737). Both criteria were agreed by the respondents as the most not important criteria for sustainable concept in green highway either during design and construction stages. It is an interesting remark

where none of the criteria fall under the medium and lower importance level. This clearly shows the importance of sustainability criteria during designing and constructing of the highway. Note that all criteria were rated with high or high-medium importance levels.

Table 2: The ranking results for each category for sustainable design

ID	Sub criteria	Relative index	Ranking by category	Overall ranking	Importance level
Sustainable design					
SD2_f	Design to reduce urban heat island effect	0.804	1	9	H
SD2_e	Design to utilise visual enhancement	0.803	2	10	H
SD2_d	Design to adjust highway features using design flexibility	0.794	3	14	H-M
SD2_c	Design to avoid impact to socio economic resources	0.790	4	15	H-M
SD2_b	Design to avoid impacts to environmental resources	0.779	5	20	H-M
SD2_a	Design to provide buffer between highway and high-quality area	0.753	6	24	H-M
SD1_align	Design to reduce the area of undeveloped land	0.737	7	29	H-M
Construction activities					
CA7_1	Provide Site Maintenance Plan to maintain environmental quality and aesthetics of the roadway project during use.	0.836	1	1	H
CA6_c	Provide warranty clause in the contract specifications to incorporate construction quality into the use of warranties onto finished product.	0.830	2	2	H
CA6_b	Provide construction personnel with the certified knowledge to identify environmental issues and best practice methods to minimise environmental impact.	0.826	3	3	H
CA6_a	Provide Quality Management System to improve construction quality by using a contractor that has a formal quality management process.	0.824	4	4	H
CA5_c	Reduce fossil fuel use at the hot mix asphalt (HMA) plant.	0.821	5	5	H
CA5_b	Apply emission reduction technologies to the construction equipment's.	0.820	6	6	H
CA5_a	Reduce fossil fuel used in construction equipment by using alternative fuel as a replacement for fossil fuel.	0.819	7	7	H
CA4_e	Use efficient method of temporary erosion and sediment control.	0.814	8	8	H
CA4_d	Provide Erosion and Sedimentation Control Plan.	0.803	9	11	H
CA4_b	Use water tracking system to develop data of monitoring and controlling water consumption in construction.	0.801	10	12	H
CA4_c	Use appropriate water pollution control measures on-site.	0.801	11	13	H
CA4_a	Use efficient method of water conservation.	0.787	12	16	H-M
CA3_c	Use alternative construction methods with low-noise or quieter equipment's /machineries /plants.	0.786	13	17	H-M
CA3_d	Operate stationary equipment (air compressor, generator etc.) from noise sensitive receptor.	0.786	14	18	H-M
CA3_b	Use proper noise mitigation techniques on-site to control the average noise level.	0.780	15	19	H-M
CA3_a	Provide Noise Mitigation Plan (NMP) during construction for the prime contractor.	0.779	16	21	H-M
CA2_b	Reduce vehicle emission to reduce air pollution during construction.	0.766	17	22	H-M
CA2_a	Use construction equipment's that reduce emissions of localised air pollutants.	0.761	18	23	H-M
CA1_c	Use appropriate approach for waste disposal on-site.	0.747	19	25	H-M
CA1_d	Provide Site Recycling Plan as part of the CWMP during construction.	0.747	20	26	H-M
CA1_b	Use efficient method of waste minimisation from its sources on-site.	0.744	21	27	H-M
CA1_a	Provide Construction and Demolition Waste Management Plan (CWMP) during roadway construction.	0.737	22	28	H-M

4. Conclusions

This paper described the development of a set of assessment criteria for sustainable design and construction activities of green highway. A total of 29 criteria were identified based on a thorough literature review and discussion with selected expertise in highway development projects. Relative index analysis was used because to determine the relative ranking of the criteria and its transformed from all the numerical scores of the identified criteria. These ranking enabled the researcher to cross-compare the relative importance of the criteria as perceived by respondents. Ranking analysis revealed that all criteria were highlighted at “high” or “high-medium” important levels in sustainable design and construction activities for green highway. A total of 13 criteria were highlighted at the “high” important level which are: provided site maintenance plan, warranty clause and environmental training among the workers. Based on the overall criteria ranking most of the criteria are under construction activities thus it shows the respondents agreed that the sustainable criteria should be implemented during the construction stages. The result from this study can be used by the contractors and local authorities in implementing the sustainable infrastructure development.

Acknowledgments

The authors gratefully acknowledge the support for this research from Universiti Teknologi MARA (research grant 600-IRMI/DANA 5/3/LESTARI (0153/2016).

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