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Highway and Life Cycle Costing as Decision-Making Support System Model

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Abstract

Objective: This paper presents the measurable variables in Malaysia Green Highway Index (MyGHI). **Methods/Statistical Analysis:** Mean result were determined showed respondents level of agreement towards LCC component and Green Highway Index (GHI) measureable criteria. **Findings:** This paper also highlights the expected findings which lead to identifying important factors in developing real-time decision making application using LCC. The outcome of the paper will inspire the Malaysian highway builders to respond to green highway development and make LCC as a tool of decision making. **Applications/Improvements:** Thus the later, correlation between MyGHI measurable variables and LCC can be carried out to determine the significant elements that influence the decision-making to achieve targeted score of MyGHI.

Keywords: Decision Making Application, Eco-Efficiency, Life Cycle Cost

1. Introduction

The construction industry has a significant impact on the environment, economy, and society[1]. For instance, surface transportation systems are one of the biggest contributors to greenhouse gas emissions, for which they are responsible for 38% of all CO2 emissions[2]. Increased awareness of the enormous ecological footprint of the infrastructure environment has substantially increased the importance and popularity of various green initiatives as a possible solution to remediate the damages incurred on the planet [3,4]. Many of these initiatives focus on enhancing biodiversity, improving air and water quality, reducing solid waste generation, and conserving natural resources of buildings[5-7].

Therefore, to change into green or sustainable, is one pressing issue coming from both internal and external drivers for construction and engineering companies[8]. To assess how green or sustainable the highway is, several green rating systems, protocols, guidelines and standards have been developed in the past that respond to the need to evaluate and benchmark levels of building achievement in the green revolution[1,8-11].

The first green infrastructures related manual as informed by [9] called Leadership in Energy and Environmental Design (LEED) was established in 1998 by US Green Building Council (USGBC). LEED adopted a checklist approach which emphasized on sustainability development. While for Green Highway it has been cited the Greenroads was the first Green Highway rating system that has been established[12]. It is a voluntary third-party rating system for road projects that aim to recognize and reward projects that are expected to maintain the natural environment of the ecosystem, environmental, economic and social[13].

In 2008, New York State Department of Transportation established GreenLITES which are Green Leadership in Transportation Environmental Sustainability[14]. It is a transportation specific checklist with 4 levels of certification. A year later, University of Washington produced Green road assessment model. On 2010, three Green Highway assessment tools have been established. Recycled Materials Resource Centre and University of Wisconsin-Madison, Portland (Oregon) Bureau of Transportation, and Illinois Department of Transportation have formed Building Environmentally and Economically Sustainable

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Transportation Infrastructure Highways (BE2ST-in-Highways), Sustainable Transportation Access Rating System (STARS) and Liveable and Sustainable Transportation Rating System and Guide (I-LAST) respectively[9].

On 2011, Federal Highway Administration produced FHWA Infrastructure Voluntary Evaluation Sustainability Tool (IN-VEST), Institute for Sustainable Infrastructure Ranking System and Harvard Zofnass Program for Sustainable Infrastructure have establish Envision on 2012[1,15].

Today evaluation of cost mainly focuses on the investment costs with only little regard to future costs. For the highway user the expense of using this infrastructure is a result of the accumulated costs during the highway lifetime. Initiatives that reduce the future costs (e.g. energy savings, improved durability of highway components) often result in larger investment costs, e.g. because of addition of thermal insulation, more durable pavement materials etc. If future costs are not included in the evaluation, these initiatives will not be implemented. Therefore, the total cost of different highway designs should be evaluated based on the Life Cycle Cost (LCC), which includes all expenses and incomes during the lifetime of the construction. In order to obtain total cost, the measureable variable in the stage of life cycle costing should be identified and correlation between them should be established first.

The aim of this study is to develop an automated decision making model for Green Highway life cycle cost. In order to achieve this aim, the early objective of this study is to identify and correlate measurable criteria of green highway index (GHI) and cost components of Life Cycle Cost (LCC).

2. Methodologies

At beginning, literature review was conducted in order to gather the information about the green highway and life-cycle costing from the journal, books, conference paper, internet and etc. From the literature review, the Energy Efficiency cost elements of Malaysian Green Highway Index (MyGHI) which relevant to the life cycle costing were identified.

After the measurable variables in green highway index had been identified, the research continues with the analyses on the correlation between green highway variables and life cycle costing. Based on the MyGHI manual, literatures, and content analyses method, a preliminary table of EE1 to EE6 illustrate the element cost and each stage of life cycle costing had been developed[14]. Total 181 green highway measureable variables or cost elements had been identified[16,17]. While there are 2 stages of life cycle costing involve which are initial cost and future cost. For initial cost, there are capital; construction cost (installation); and management cost. While for future cost, there are operation; maintenance/ service; replacement; demolition; contingencies cost/ risk and management cost[17]. Then the survey questionnaire was developed using Decision Matrix design. The purpose of the survey questionnaire is to identify the relevant cost item which best suit in the each stage of the life cycle costing and what are the correlation between them. The questionnaire sheets were consisting of two (2) sections as follows:

Section A: Respondents' Profile. This is to know the background of the respondents. It is important to know the experiences and individual preferences who are involved with the highway construction. Section B: Selection of correlation between Green Highway Index (GHI) variables and LCC. There were five categories in the Section B where each category has its own cross-matrix integrated between cost item and LCC. Based on Likert's Scale, respondents were request to indicate no relevance=1, least relevance=2, moderately relevance=3, strongly relevance=4, or very strongly relevance=5, in the appropriate blank box provided alongside each statement.

The questionnaires were distributed to the targeted 16 respondents, which consisted of experts in highway construction industry, especially those who were involved in the M&E section related to development of green highway and life cycle costing[18-20]. The survey was conducted by face-to-face interview with the respondents in order to help them to fill the questionnaire survey form based on their expertise. Then the discussion on the criteria of energy efficiency cost elements and confirm the cost item with the expert also has been done.

The findings from the questionnaire survey were analyzed by using IBM SPSS Statistics[21]. Reliability and correlation analyses were obtained in order to produce significant Energy efficiency cost items which correlated in the life cycle costing. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. However, there is actually no lower limit to the coefficient. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. In[21] provide the following rules of thumb: "_ > .9 – Excellent, _ > .8

– Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor and _ < .5 – Unacceptable”. Inter-item internal consistency of 0.7 and above was chosen.

Average mean index can be obtain in order to determine significant respondents level of agreement for energy efficiency cost elements which mostly affects the life cycle cost components. By referring to[22], the validation of the data used for the questionnaires in this study is as follows as shown at Table 1.

This mean that the variables has average mean Index score ≥ 3.5 can be considered significantly affected in the correlation between the cost item and life cycle costing respectively.

Table 1. Rating scale and classification

Rating	Rating Scale	Classification
1	Very low or extremely ineffective	1.00 < Average mean Index score<,1.50
2	Low or ineffective	1.50 < Average mean Index score<,2.50
3	Medium or moderately in effective	2.50 < Average mean Index score<,3.50
4	High or very effective	3.50 < Average mean Index score<,4.50
5	Very high or extremely effective	4.50 < Average mean Index score < 5.00

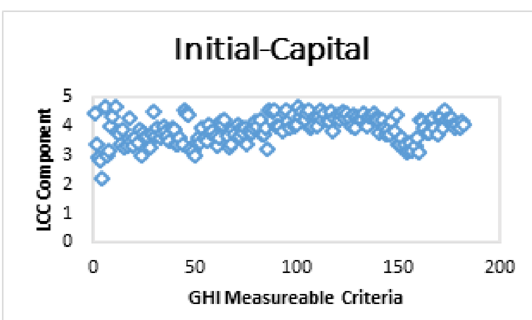

Figure 1. Initial cost-capital.

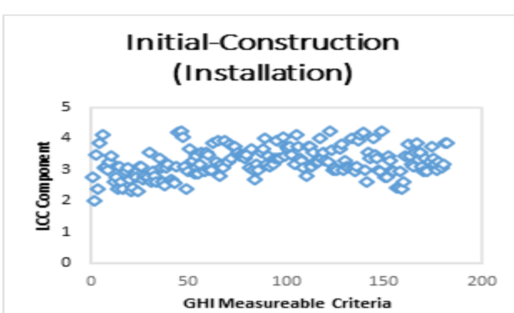

Figure 2. Initial cost-construction (Insta.).

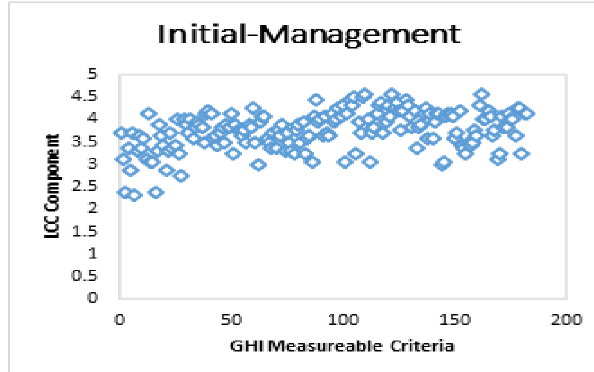

Figure 3. Initial cost-management.

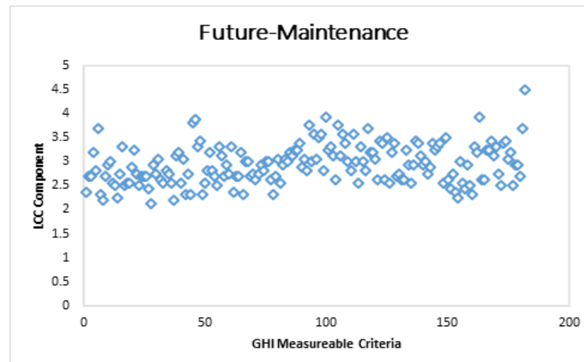

Figure 4. Future cost-maintenance.

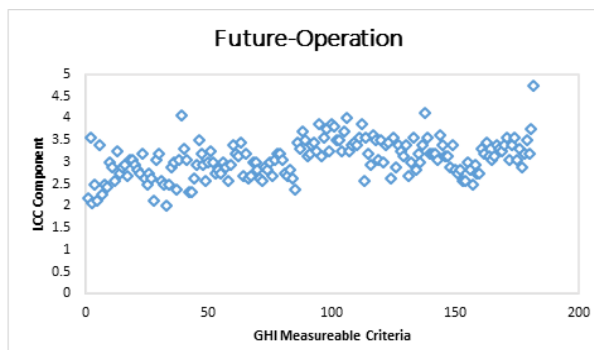

Figure 5. Future cost-operation.

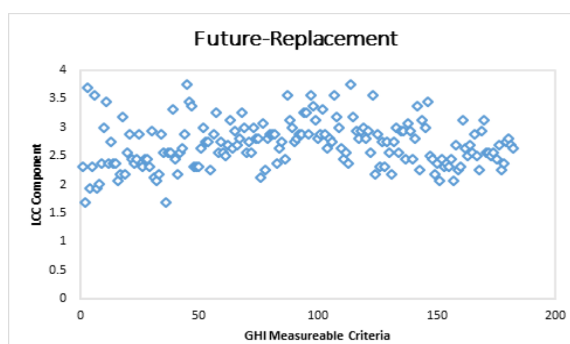

Figure 6. Future cost-replacement.

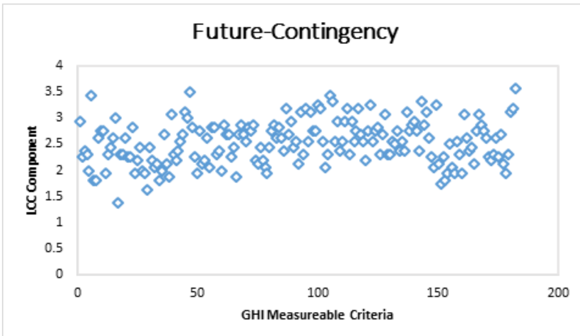

Figure 7. Future cost-contingency.

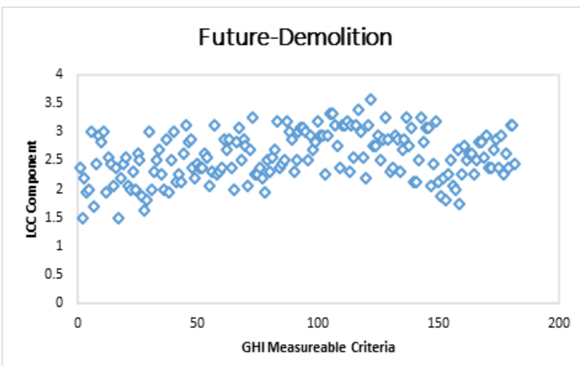

Figure 8. Future cost-demolition.

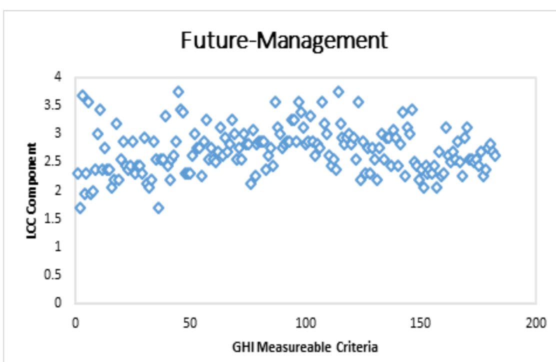

Figure 9. Future cost-management.

3. Experimental Results

Total of 16 survey questionnaire papers had been distributed to the respondents. Figure 1 to 9 illustrated mean result showed respondents level of agreement where level of agreement more than 3 shown strong agreements. Finally, research could be extended towards doing correlation analyses between cost item and life cycle costing based on 95% level of significance and correlation coefficient greater or equal to 0.50 which have average relationships[20].

4. Conclusion

This paper had presented the measurable variables in Malaysia Green Highway Index (MyGHI). Additionally, mean result were determined showed respondents level of agreement towards LCC component and Green Highway Index (GHI) measureable criteria. The conclusions are given as follows:

i. Respondents had shown their acceptance level in considering the importance of LCC component in Green Highway Index (GHI) measureable criteria.
ii. Initial cost had shown significant level of agreement when compared to the most of future cost.

From extensive literature review, several measurable variables (cost items) of energy efficiency in Green Highway index have been identified to have significant contribution towards the establishment of Malaysia Green Highway Assessment within the stage of life cycle costing. Various dialogues and discussions were conducted to analyze these variables, expand the ideas and describe in details every variables in line with life cycle costing requirement. After literature studies and various discussions, a table of measurable variables (cost item) of energy efficiency in Green Highway index can be formulated.

There are 2 stage of Life cycle costing involve which are initial cost and future cost. For initial cost, there are capital; construction cost (installation); and management cost. While for future cost, there are operation; maintenance/ service; replacement; demolition; contingencies cost/ risk and management cost.

Correlation between green highway index variables and LCC can be developed through empirical path initiated by elements extraction from literature review, questionnaire survey, data analyses using IBM SPSS Statistics 22, and will be followed by expert discussions. Since the Malaysia Green Highway Index (MyGHI) had been established, hence the development of Green Highway measurable variables is critical in developing the future expansion of Malaysia Green Highway Index.

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6. References

1. Lee J, Edil TB, Benson CH, Tinjum JM. Building environmentally and economically sustainable transportation infrastructure: green highway rating system. Journal of Construction Engineering and Management. 2013; 139(12):604–19. Crossref
2. Tatari O, Kucukvar M. Cost premium prediction of certified green buildings: A neural network approach. Building and Environment. 2011; 46(5):1081–86. Crossref
3. Benedict MA, McMahon ET. Green infrastructure: Linking landscapes and communities. Island Press: Washington-Covelo-London, 2006; 288 pp.
4. Sustainability science. Available from: https://en.wikipedia.org/wiki/Sustainability_science. Date Accessed:17/10/2016.
5. Goh KC, Yang J. The importance of environmental issues and costs in Life Cycle Cost Analysis (LCCA) for highway projects. The 11th International Conference on Asphalt Pavement. 2010. p. 228–35.
6. Jha MK, Shariat S, Abdullah J, Devkota B. Maximizing resource effectiveness of highway infrastructure maintenance inspection and scheduling for efficient city logistics operations. Procedia Social and Behavioral Sciences. 2012; 39:831–44. Crossref
7. Selih J, Kne A, Srdic A, Zura M. Multiple-criteria decision support system in highway infrastructure management. Transport. 2008; 23(4):299–305. Crossref
8. Huang RY, Yeh CH. Development of an assessment framework for green highway construction. Journal of the Chinese Institute of Engineers. 2008; 31(4):573–85. Crossref
9. Nguyen T, Toroghi SH, Jacobs F. Automated Green Building Rating System for Building Designs. Journal of Architectural Engineering. 2015; 22(4).
10. Yudelson J. Marketing Green Building Services: Strategies for Success: Architectural Press. 2008; 282pp.
11. Yudelson J. What Is a Green Building? Sustainable Retail Development. Risk Analysis and Simulation Add-In for Microsoft Excel ®, 2013, Palisade Corporation. 2010; 41–65.
12. Sarsam SI. Sustainable and green roadway rating system. International Journal of Scientific Research in Environmental Sciences. 2015; 3(3):1–99. Crossref
13. Rooshdi RRRM, Rahman NA, Baki NZU, Majid MZA, Ismail F. An Evaluation of Sustainable Design and Construction Criteria for Green Highway. Procedia Environmental Sciences. 2014; 20:180–6. Crossref
14. Zakaria R, Seng FK, Majid MZA, Zin RM, Hainin MR, Puan OC, Hamzah N. Energy Efficiency Criteria for Green Highways in Malaysia. Jurnal Teknologi. 2013; 65(3):91–5. Crossref
15. Nusa FNM, Endut IR, Takim R, Ishak SZ. Green Highway for Malaysia: A Literature Review. Journal of Civil Engineering and Architecture. 2015; 9(1):64–71.
16. Bull JW. Life Cycle Costing for Construction: Taylor & Francis. 2003.
17. Life cycle costing for engineers. Available from: http://www.bvsde.paho.org/bvsaia/fulltext/costing.pdf. Date Accessed: 2009.
18. Arnold GK. Book Reviews: Statistical Analysis in Psychology and Education George Ferguson and Yoshio Takane New York: McGraw-Hill, 1989. x+ 587 pp. Journal of Educational and Behavioral Statistics. 1991; 16(2):145–9. Crossref, Crossref
19. Ferguson GA, Takane Y. Statistical analysis in psychology and education .6th (edn)., McGraw-Hill Education: New York. 1989.
20. Piaw CY. Kaedah dan statistik penyelidikan. Asas statistik penyelidikan. Malaysia: McGraw-Hill SdnBhd. 2006. PMid:16252078
21. Gliem JA, Gliem RR. Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. 2003.
22. Majid M, McCaffer R. Assessment of Work Performance of Maintenance Contractors in Saudi Arabia. Journal of Management Engineering. 1997; 13(5):91. Crossref