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The Importance of Life Cycle Cost Components for Green Highway and Road Management: A Review

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ABSTRACT

Road infrastructure will face growing pressures and effects from a range of challenges in the future, including changing climatic patterns, restrictions on capacity, population growth, land and capital crises, and rapidly developing techniques that will outweigh the pace of development of new infrastructures. The anticipated shift in road user's travel behaviour will also have a significant influence on highway and road(H&R) construction projects and its transportation aspects. This paper involves the research gap using an objective-oriented approach to create a connection between each cost component of LCC relevant to green highway and road (H&R) criteria and risk likelihood in a structured calculation. The purpose is to suit emerging research questions aforementioned. Therefore, this paper aims to facilitate developing literature for an integrated calculator of green road criteria incurring cost development using the LCC-DSS model. With this aim, the study enables a research gap in line with research questions associated with the integrated calculator that useful in examining risk.

Keywords:
green highway and road (H&R); Life Cycle Cost (LCC); Decision Support System (DSS); cost-effectiveness

1. Introduction

The notion of green technology innovation fosters an enticing green revolution for sustainable environmental and economic enhancement impacting developing nations [1] and in this situation, building a so-called green road with carbon-neutral equipment, in one way, expected to reduce the risk of emissions from fossil fuels and greenhouse gases [2]. For instance, Malaysia took many alternative paving materials and techniques into the building sector, intending to attain green roads [2]. Alongside the significance of green road and highway, transport is another major contributor to the environmental impact, particularly of primary CO^2 emissions contributing to the worldwide warming effect.

Various models, frameworks, and sustainable rating systems have been placed forward, mainly related to sustainable green road and highway growth. However, the need to assess the environmental effects of sustainable green roads has still been undermined [3]. Highways infrastructures contribute 25% of the complete energy expense in any developing nation [4] and have both business and residential consequences [5]. On the positive side, the appeal for the

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implementation of green road and highway management technologies grew at the start of the 21st century and continued to grow over time [6]. Correspondently, green certification by specific green tools certification in regional mechanisms such as in Europe, Asian area, and other developed nations has increased by 80% [5].

According to [7], many parties in the road and highway industry will get the benefit and courtesy by developing sustainable green roads, pathways, and expressways by following developed Green Highway certification. Several green rating schemes, protocols, rules, and norms have been created to assess how green and sustainable roads and highways are in the past, to meet the need to assess the current scenario and address the sustainable aspects for the conservation of the environment in the future.

The effort done are way forward in typical road and highway construction and industry. Similarly, investment in installations is long-lived and necessarily involves threats to road and highway construction longevity, operational and maintenance costs, as well as many other factors affecting the economics of installations. If the cost and time details are substantially risky, an Life Cycle Cost (LCC) appraisal can have little benefit for consumers and policymakers. Therefore, if the LCC models can incorporate a quantitative approach for determining the risk likelihood, this kind of obstacle can be resolved. The most significant improbabilities commonly occur in the earlier stages of a project, even when investment decisions have the most significant effect. However, future cost modeling risks entail similar risks. Likewise, the uncertainties of future capital investment and LCC projections need to be calculated in the post-road or highway variable cost analysis. Therefore, risk assessments offer useful insights into situations that explicitly describe the probability density function [8] and reduce the risk of loss and optimise road or highway construction opportunities. It is risk assessment and final monitoring that is not adequate [9], and formal risk assessment strategies are required to ensure that regularity and standardisation of green road measurable variables are accomplished. Most of these approaches are, however, generally tricky, complicated, and expensive, and therefore the use of these methods is exorbitant for many projects. The lack of understanding and questions regarding adequacy within the ecosystem professions was also recognised as reasons for the slow approach [10].

The present study does so in the context of the green road and highway by developing an integrated calculator as an automated decision-making support system model (DSS) for the green road cost area using LCC in Malaysia. Although the studies mentioned above provided some evidence of evaluating green road and issues related to sustainability in the road construction industry in Malaysia, none of them has exclusively investigated the pattern, dimension, and effect of LCC application with the DSS model towards Malaysian roads and highways. Thus, focus on the green road and highway beneficial and understandable decision-making support systems are necessitated in the Malaysian road and highway scenario. Hence, how to implement the life cycle tools in the decision-making process becomes more critical.

Though many products are using life cycle costing as a decision-making tool, its use is still far from being systematic, and the calculation methodologies are based on trial and error methods. Moreover, these products are not using life cycle costing to reach the minimum life cycle cost. Achieving high "green ratings" also acts as a safeguard to minimise the effects of future energy price increases, the impact of which should not be underestimated. It is therefore clear that the current green highway model is not delivering the best value regarding green road and highway index scores due to lack of relationship with green road and highway criteria. Therefore, this research is concerned with identifying the relationship between the LCC component and green road and highway criteria to aid the designers and engineers and decision-makers in selecting their right green strategies.

Road and highways are considered as the backbone of economic acculturation sustained for centuries. To uphold and ascertain the quality of roads, it has evolved toward the green roads because of restoring fast resources degradation. The rising need for green road abandoned the sustainability factors measuring significant factors of the economic aspect. The green road and highway financial aspect provide various opportunities to be considered, and Life Cycle Cost (LCC) is one of them. In addition, LCC would be confirmed by risk concepts, so the relationship between LCC components and risk could be established. The form established and raised the inevitable research questions; firstly, how to correlate measurable criteria of green road and cost components of LCC. Secondly, how the calculation model of green road criteria incurring costs and LCC will presage the output of cost in LCC functionality. Thirdly, can the Decision Support System (DSS) to be utilised on LCC which at the same time designates the risk probability.

This paper involves the research gap using an objective-oriented approach to create a connection between each cost component of LCC relevant to green highway and road (H&R) criteria and risk likelihood in a structured calculation. The purpose is to suit emerging research questions aforementioned. Therefore, this paper aims to facilitate developing literature for an integrated calculator of green road criteria incurring cost development using the LCC-DSS model. With this aim, the study enables a research gap in line with research questions associated with the integrated calculator that useful in examining risk.

2. Methodology

The initial comprehension of this paper is crucial to answering the research problem, research areas, determination of research objectives and scopes. It gives an insight into this paper to avoid deviation from this paper scope. In order to help in furthering the comprehension of this paper, a selective literature review is essential to be conducted [11]. At this stage, the knowledge related to the research topic is critical through reading and discussion of academic resources such as books, published journals, articles, and online publications. At this stage, with a thorough literature review, the previous work of green highway or road and cost components of LCC in Clarivate Analytics, Scopus and Google Scholar were used to synthesised multiple sources of information that were reviewed and provided an insight into the facts of this paper.

3. Literature Review Analysis

3.1 Integrated Matrix Selective Critical Literature Review

In achieving the objective of this paper, it has begun with utilising a focus literature search method for the determination of decision-making criteria in green road and cost components of LCC. There are various criteria's have been critically reviewed based on the formulated research problem identification. The previous work of green road and cost components of LCC was reviewed by addressing literature from primary resources such as books, journals, and conference papers. The secondary data has been analysed to gain in-depth knowledge in the subject area and identify gaps in using LCC cost components related to the green highway and road criteria.

Table 1
Integrated Matrix Selective Critical Literature Review Analysis (SCLRA).

References	Research Area Reported				
	Green Highways And Roads (H&R)	Green H&R Sustainability Rating and Rating Tools	Automation in Green H&R Rating & Rating Tools	Risk analysis In Green H&R Rating & Rating Tools	H&R Life Cycle Costing/Cost Sustainability
[12]	•				•
[2]	•	•			•
[13]					•
[14]					•
[15]	•		•		
[16]					•
[17]					•
[18]					•
[19];[20]					•
[21]	•	•	•		
[22]	•	•			
[23]	•	•	•	•	•
[24]	•	•			
[25]	•				
[26]	•	•			
[27]	•	•			
[28]	•	•			
[29]	•	•			
[30]	•	•			
[31]	•	•			
[32]	•	•			
[33]	•	•			
[34]	•	•			

4. Discussion

In light of the reported literature, Table 2 summarised the research brief. It illustrates the various sustainable green idea of road design is enhanced by investment and maintenance costs [35]. Besides, the current cost assessment focuses primarily on investment expenses with little respect for future costs.

The entire cost of various road or highway designs should be assessed based on the life cycle cost (LCC), which involves all costs and revenues over the lifetime of the building. In order to achieve total costs, all elements should first be identified as the measurable variable at the LCC stage, and the correlation between them should be established [35]. This expected outcome and ability able to assist and boost the green road Triple Bottom Line (TBL), specifically green technology of green road investment area and the correlation amongst its LCC components, can be known. Besides, the LCC components error control can be applied using correlation studies, and the green road measurable variable inferring can be improved with integrated risk and LCC tools [36]. Nevertheless, the LCC value for road and highway projects can be optimised, plus the LCC profile and library can be established by aligning the road and green highway cost model with value engineering.

Furthermore, it is essential to remember that green road and highway technology is presently at the most advanced stage than ever before, and as the world's supply of non-renewable resources becomes scarce and costly, green technology remains to increase its importance. For road and highway users, the cost of using this infrastructure is a consequence of the accumulated cost during the lifetime of the road and highway. Initiatives reducing future cost (e.g., power efficiency, increased road component durability) often lead to higher investment costs (e.g., adding heat insulation, more resilient paving materials). If future costs are not included in the assessment, these projects are not endorsed accordingly.

Table 2
Summarised Research Brief outline.

References	Research Addressed
A Quantitative Analysis of Sustainability and Green Transportation Initiatives in Highway Design and Maintenance [12]	The research explained modified maintenance cost analysis to be considered in highway design and maintenance to incorporate green highway and sustainability concepts. Initial cost without maintenance and maintenance of a life cycle cost was calculated using a genetic algorithm to optimise highway alignments design cost. The results portrayed that the Initial cost with maintenance perspectives was lower than without maintenance consideration. Hence, new green highways and roads can be formulated to integrate both cost and sustainability aspects in order to achieve cost sustainability.
A review on green economy and development of green roads and highways using carbon neutral materials [2]	This research reviewed green economy insight for highways and road sustainability development. Detail criteria of green highways and roads on carbon-neutral credit ratings are also discussed constructively. However, improvement can be suggested with an actual application through automation—for instance, the development of web-based applications.
Evaluation of pavement life cycle cost analysis: Review and analysis [13]	The author recognised the needs of life cycle costing been considered during highways and roads project throughout all phases involved, such as planning and design. Economic attributes in life cycle costing were discussed in detail. This research also showed that improvement could be made by making life cycle applications more user-friendly and easier-to-use features available.
Life-Cycle Cost Analyses for Road Barriers [14]	The research clarified the use of activity-based life cycle costing as a new approach in calculating road barriers life cycle costing. The author briefed cost-efficiency can be achieved during road project planning and design process by applying the method. Nevertheless, it was still insufficient to just relying on the current offered manual method.
'Rage against the machine'? The opportunities and risks concerning the automation of urban green infrastructure [15]	This research studied the gap in the automation of urban green infrastructures (UGI), such as exploration of the digital application of highway verges and GPS-tagged site identification in green highways and roads (H&R). Nevertheless, these uptrends in automation can be applied in green highway rating and green highway rating tools.
Life cycle costing as a bottom line for the life cycle sustainability assessment in the solar energy sector: A review [16]	This research assesses and reviews life cycle cost importance and relationship in many fields, including highways, where solar energy has a significant impact on cost sustainability. The impact can be justified using life cycle cost integration in sustainability valuation.
Critical review and methodological issues in integrated life-cycle analysis on road networks [17]	The research demonstrated state of the art on life cycle cost and life cycle assessment integration that can improve the real-world application of life-cycle analysis in H&R network projects.
Automated Sequence Selection and Cost Calculation for Maintenance and Rehabilitation in Highway Life-Cycle Cost Analysis (LCCA) [18]	This research showed reinforced Realcost software used in the California Department of Transportation (Caltrans). The software has been retrofitted with analytical capability for cost assessment, refining work zone traffic analysis, and creating an automation module for maintenance and rehabilitation (M&R) sequencing.
Integration Model of Fuzzy AHP and Life-Cycle Cost Analysis for Evaluating Highway Infrastructure Investments [19];[20]	The author studied an integration model of Fuzzy AHP and life cycle cost that can aid decision making in cost sustainability related to highway construction projects.

Sustainability assessment of roadway projects under uncertainty using Green Proforma: An index-based approach [21]	This research has examined the uncertainty of highway projects' best management practice (BMP) sustainability indicators in *Greenroad*™ using Fuzzy Synthetic Evaluation to enable an expert opinion to be incorporated in the rating tools. Hence, improvement has been proposed using an Excel-based tool that enables the integration of expert opinion with sustainability rating tools.
Sustainability rating tools for highway projects: the nature and outcomes of use [22]	The author reviewed all projects that undergo rating processes, drawing from third party-verified rating tools *Ceequal, Envision, Greenroads*, and IS. Significant gaps and future studies requirements were highlighted in order to improve the practicality of these rating tools while assessing the sustainability level of valued infrastructure assets.
Building Environmentally and Economically Sustainable Transportation Infrastructure: Green Highway Rating System [23]	This research provided a comprehensive explanation about how a green highway rating named BE2ST-in-Highways with the integration of triple bottom line (TBL) consists of economic, environmental and social aspects. The methodology used by authors could enable many sustainable and green highway initiatives to be used by practitioners, especially for industry players.
Energy efficiency criteria for green highways in Malaysia [24]	The study revealed the chosen energy efficiency criteria in Green Highway studies selected from the literature. Factor analysis was carried out to finalise the list of the elements. There are included in the Green Highway Index manual developed for Malaysian Green Highway Index. Other Green Highway Index or Rating tools were reviewed to ensure the criteria used are relevant.
Green Road Design Concept [25]	The author conveys a unique definition of the green road where all ecological aspects were taken into consideration in every phase of road projects. Sustainability and green technology become clear objectives or treated as need statements for every decision taken. In order to make road or highway projects green, every single engineering aspect will be set as a "low-input, low energy consumption, low pollution, high production" mode.
Assessment index tool for green highway in Malaysia [26]	The research reported the green highway rating system developed for the Malaysian highway environment. It consists of five categories, which are Sustainable Design and Construction Activities, Energy Efficiency, Environmental and Water Management, Material and Technology, Social and Safety.
Fundamental Elements of Malaysia Green Highway [27]	The research highlighted fundamental elements of green highway sustainable measures available from the past research conducted by various scholars. Then, confirmatory studies had been conducted to verify the significance level of every measure.
Sustainable design and construction elements in green highway [28]	The research depicted the sustainable design and construction elements in green highway studies chosen from reviewed literature. Then, factor analysis was applied to selected elements to determine the screened list. The elements included in the Green Highway Index manual developed for Malaysian Green Highway Index. Other Green Highway Index or Rating tools were reviewed to ensure the criteria used are relevant.
Weightage Factor for Criteria of Design and Construction for Green Highway [29]	The authors described the sustainable design and construction elements in green highway studies chosen from reviewed literature. After that, factor analysis was applied to selected elements to determine the filtered list. Finally, points are given for each element based on weightage determined. The elements included in the Green Highway Index manual developed for Malaysian Green Highway Index. Other Green Highway Index or Rating tools were reviewed to ensure the criteria used are relevant.
Relative importance index of sustainable design and construction activities criteria for green highway [30]	This section of the research illustrated the ranking of sustainable design and construction based on their relative importance. Relative index analysis was conducted to rank the criteria. At the end of the study, the importance level among criteria was stated.
Sustainable Waste Management for Green Highway Initiatives [31]	This research presented a sustainable waste management plan derived from past researches. Listed indicators were ranked based on the average index and relative importance analysis. Then, the correlation between indicators was determined, and this research was expected to contribute a direction for Malaysia Highway Authority for Malaysia green highway index establishment and implementation.

Pavement Material and Technology Elements in Green Highway Rating Systems-A Conspectus [32]	In order to choose suitable elements for material and technology elements in Green Highway Index, the research has used a comparative approach by considering all elements of pavement material and technology practices in existing green highway rating systems. Those are GreenLITES, Greenroads, I-LAST, GreenPave. Envision and INVEST. Finally, the author reported recycled materials and pavement reuse were the most practical elements used while WMA and Bioengineering techniques were the least popular elements used.
Assessment framework for pavement material and technology elements in green highway index [33]	The authors have identified essential factors while assessing pavement material and technology elements in Malaysia green highway index. Two pilot tests conducted found that there was still a lack of efforts to practice green highway measures in pavement material and technology, especially in Malaysia. The measures were grouped into four categories, which are ecological protection, industrial properties, innovation and erosion reduction.
Pavement Technology Elements in Green Highway [34]	The study examined weighted analysis on developing relevance elements of pavement technology to achieve the aims of the green highway design. Erosion protection was the most weighted elements agreed to conclude in the study. It is followed by cool and permeable pavement.

5. Conclusions

The issues, as mentioned earlier, show the construction of this paper. In summary, the significance of the green road and highway criteria and life cycle cost components is critical to quantify in order to desirably assess the cost-effectiveness of green road or highway across separate variables when assessing alternatives between two options. The alternative can assist and analyse the trade-offs between different variables, such as environmental effects, geographical characteristics, and unique energy efficiency characteristics. This matter leads to the choice and design of instruments and a framework to conduct a future study on life cycle cost in the green road and highway fields.

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References
[1] Kenis, Anneleen, and Matthias Lievens. "Greening the economy or economizing the green project? When environmental concerns are turned into a means to save the market." *Review of Radical Political Economics* 48, no. 2 (2016): 217-234. https://doi.org/10.1177/0486613415591803
[2] Attahiru, Yusuf Babangida, Md Maniruzzaman A. Aziz, Khairul Anuar Kassim, Shamsuddin Shahid, Wan Azelee Wan Abu Bakar, Thanwa Filza NSashruddin, Farahiyah Abdul Rahman, and Mohd Imran Ahamed. "A review on green economy and development of green roads and highways using carbon neutral materials." *Renewable and Sustainable Energy Reviews* 101 (2019): 600-613. https://doi.org/10.1016/j.rser.2018.11.036
[3] Nusa, Fatin Najwa Mohd, Shahrin Nasir, and Intan Rohani Endut. "Awareness of green highway concept and terminology: a perspective of on-site personnel in Malaysian highway construction industry." *Advances in Transportation and Logistics Research* 1 (2018): 475-487.
[4] Lollino, Giorgio, Daniele Giordan, Kurosch Thuro, Carlos Carranza-Torres, Faquan Wu, Paul Marinos, and Carlos Delgado, eds. *Engineering Geology for Society and Territory-Volume 6: Applied Geology for Major Engineering Projects*. Springer, 2014. https://doi.org/10.1007/978-3-319-09060-3
[5] Wu, Xueying, Wenyi Zhao, and Tianshan Ma. "Improving the impact of green construction management on the quality of highway engineering projects." *Sustainability* 11, no. 7 (2019): 1895. https://doi.org/10.3390/su11071895

[6] Amiril, Assa, Abdul Hadi Nawawi, Roshana Takim, and Siti Nur Farhana Ab Latif. "Transportation infrastructure project sustainability factors and performance." *Procedia-Social and Behavioral Sciences* 153 (2014): 90-98. https://doi.org/10.1016/j.sbspro.2014.10.044
[7] My Green Highway Index [Internet]. [cited 2020 Jul 16]. Available from: http://myghi.llm.gov.my/index.php
[8] Oduyemi, Olufolahan, and Michael Okoroh. "Building performance modelling for sustainable building design." *International Journal of Sustainable Built Environment* 5, no. 2 (2016): 461-469. https://doi.org/10.1016/j.ijsbe.2016.05.004
[9] Suter II, Glenn W. *Ecological risk assessment*. CRC press, 2016. https://doi.org/10.1201/9781420012569
[10] Nguyen, Hong-Trang, Martin Skitmore, Matthew Gray, Xiaoling Zhang, and Ayokunle Olubunmi Olanipekun. "Will green building development take off? An exploratory study of barriers to green building in Vietnam." *Resources, Conservation and Recycling* 127 (2017): 8-20. https://doi.org/10.1016/j.resconrec.2017.08.012
[11] Khan, Jam Shahzaib, Rozana Zakaria, Eeydzah Aminudin, A. I. N. Abidin, A. M. Mahyuddin, and Rosli Ahmad. "Embedded life cycle costing elements in green building rating tool." *Civil Engineering Journal* 5, no. 4 (2019): 1-9. https://doi.org/10.28991/cej-2019-03091284
[12] Jha, Manoj K., Hellon G. Ogallo, and Oludare Owolabi. "A quantitative analysis of sustainability and green transportation initiatives in highway design and maintenance." *Procedia-Social and Behavioral Sciences* 111 (2014): 1185-1194. https://doi.org/10.1016/j.sbspro.2014.01.153
[13] Babashamsi, Peyman, Nur Izzi Md Yusoff, Halil Ceylan, Nor Ghani Md Nor, and Hashem Salarzadeh Jenatabadi. "Evaluation of pavement life cycle cost analysis: Review and analysis." *International Journal of Pavement Research and Technology* 9, no. 4 (2016): 241-254. https://doi.org/10.1016/j.ijprt.2016.08.004
[14] Karim, Hawzheen, Rolf Magnusson, and Kenneth Natanaelsson. "Life-cycle cost analyses for road barriers." *Journal of transportation engineering* 138, no. 7 (2012): 830-851. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000391
[15] Gulsrud, Natalie Marie, Christopher M. Raymond, Rebecca L. Rutt, Anton Stahl Olafsson, Tobias Plieninger, Mattias Sandberg, Thomas H. Beery, and K. Ingemar Jönsson. "'Rage against the machine'? The opportunities and risks concerning the automation of urban green infrastructure." *Landscape and Urban Planning* 180 (2018): 85-92. https://doi.org/10.1016/j.landurbplan.2018.08.012
[16] Naves, Alex Ximenes, Camila Barreneche, A. Inés Fernández, Luisa F. Cabeza, Assed N. Haddad, and Dieter Boer. "Life cycle costing as a bottom line for the life cycle sustainability assessment in the solar energy sector: A review." *Solar Energy* 192 (2019): 238-262. https://doi.org/10.1016/j.solener.2018.04.011
[17] Hasan, Umair, Andrew Whyte, and Hamad Al Jassmi. "Critical review and methodological issues in integrated life-cycle analysis on road networks." *Journal of Cleaner Production* 206 (2019): 541-558. https://doi.org/10.1016/j.jclepro.2018.09.148
[18] Kim, Changmo, Eul-Bum Lee, John T. Harvey, Amy Fong, and Ray Lott. "Automated sequence selection and cost calculation for maintenance and rehabilitation in highway Life-Cycle Cost Analysis (LCCA)." *International Journal of Transportation Science and Technology* 4, no. 1 (2015): 61-76. https://doi.org/10.1260/2046-0430.4.1.61
[19] Goh, Kai Chen, Hui Hwang Goh, and Heap-Yih Chong. "Integration model of fuzzy AHP and life-cycle cost analysis for evaluating highway infrastructure investments." *Journal of Infrastructure Systems* 25, no. 1 (2019): 04018045. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000473
[20] Goh, Kai Chen, and Jay Yang. "Managing cost implications for highway infrastructure sustainability." *International Journal of Environmental Science and Technology* 11, no. 8 (2014): 2271-2280. https://doi.org/10.1007/s13762-014-0572-5
[21] Umer, Adil, Kasun Hewage, Husnain Haider, and Rehan Sadiq. "Sustainability assessment of roadway projects under uncertainty using Green Proforma: An index-based approach." *International Journal of Sustainable Built Environment* 5, no. 2 (2016): 604-619. https://doi.org/10.1016/j.ijsbe.2016.06.002
[22] Griffiths, Kerry, Carol Boyle, and Theunis FP Henning. "Sustainability rating tools for highway projects: the nature and outcomes of use." *Infrastructure Asset Management* 5, no. 2 (2018): 35-44. https://doi.org/10.1680/jinam.17.00017
[23] Lee, Jincheol, Tuncer B. Edil, Craig H. Benson, and James M. Tinjum. "Building environmentally and economically sustainable transportation infrastructure: green highway rating system." *Journal of Construction Engineering and Management* 139, no. 12 (2013): A4013006. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000742
[24] Zakaria, Rozana, Foo Kian Seng, Muhd Zaimi Abd Majid, Rosli Mohamad Zin, Mohd Rosli Hainin, Othman Che Puan, Haryati Yaacob et al. "Energy efficiency criteria for green highways in Malaysia." *Jurnal Teknologi* 65, no. 3 (2013). https://doi.org/10.11113/jt.v65.2152
[25] Su, Zhi Zhong, Dong Yi Zhang, and Shuai Zhang. "Green Road Design Concept." In *Advanced Materials Research*, vol. 726, pp. 3573-3579. Trans Tech Publications Ltd, 2013. https://doi.org/10.4028/www.scientific.net/AMR.726-731.3573

[26] Balubaid, Saeed, Mastura Bujang, Wan Nur Aifa, Foo Kian Seng, Raja Rafidah Raja Muhammad Rooshdi, Norhaliza Hamzah, Yazlin Salfiza Mohd Yazid et al. "Assessment index tool for green highway in Malaysia." *Jurnal Teknologi* 77, no. 16 (2015). https://doi.org/10.11113/jt.v77.6405

[27] Mohd Affendi, Ismail, Zakaria Rozana, Balarabbe Abubakar Sani, Kian Seng Foo, Mazlan Ain Naadia, Yazid Yazlin Salfiza, Mohamad Zin Rosli et al. "Fundamental Elements of Malaysia Green Highway." In *Applied Mechanics and Materials*, vol. 284, pp. 1194-1197. Trans Tech Publications Ltd, 2013. https://doi.org/10.4028/www.scientific.net/AMM.284-287.1194

[28] Rooshdi, Raja Rafidah Raja Muhd, Muhd Zaimi Abd Majid, and Shaza Rina Sahamir. "SUSTAINABLE DESIGN AND CONSTRUCTION ELEMENTS IN GREEN HIGHWAY." *Jurnal Teknologi* 77, no. 16 (2015). https://doi.org/10.11113/jt.v77.6407

[29] Rooshdi, R. R. R. M., M. Z. A. Majid, and S. R. Sahamir. "Weightage factor for criteria of design and construction for green highway." *Chemical Engineering Transactions* 56 (2017): 355-360.

[30] Rooshdi, Raja Rafidah Raja Muhammad, Muhd Zaimi Abd Majid, Shaza Rina Sahamir, and Noor Akmal Adillah Ismail. "Relative importance index of sustainable design and construction activities criteria for green highway." *Chemical Engineering Transactions* 63 (2018): 151-156.

[31] Husin, Nur Illiana, Asmalia Che Ahmad, Abdul Muhaimin Ab Wahid, and Syahrul Nizam Kamaruzzaman. "Sustainable Waste Management for Green Highway Initiatives." In *MATEC Web of Conferences*, vol. 66, p. 00059. EDP Sciences, 2016. https://doi.org/10.1051/matecconf/20166600059

[32] Bujang, Mastura, Mohd Rosli Hainin, Mohammadreza Yadollahi, Muhd Zaimi Abd Majid, Rosli Mohamad Zin, and Wan NurAifa Wan Azahar. "Pavement material and technology elements in green highway rating systems-A conspectus." *Jurnal Teknologi* 70, no. 7 (2014). https://doi.org/10.11113/jt.v70.3593

[33] Bujang, Mastura, Mohd Rosli Hainin, Muhd Zaimi Abd Majid, Mohd Khairul Idham Mohd Satar, and Wan Nur Aifa Wan Azahar. "Assessment framework for pavement material and technology elements in green highway index." *Journal of Cleaner Production* 174 (2018): 1240-1246. https://doi.org/10.1016/j.jclepro.2017.11.002

[34] Aifa, W. N., M. R. Hainin, MZ Abd Majid, R. MohamadZin, H. Yaacob, R. Zakaria, and M. Bujang. "Pavement technology elements in green highway." *Jurnal Teknologi* 73, no. 4 (2015). https://doi.org/10.11113/jt.v73.4284

[35] Rahman, M., and Rozana Zakaria. "Highway and Life Cycle Costing as Decision-Making Support System Model." *Advanced Science Letters* 24, no. 6 (2018): 3989-3992. https://doi.org/10.1166/asl.2018.11527

[36] Ilg, Patrick, Christoph Scope, Stefan Muench, and Edeltraud Guenther. "Uncertainty in life cycle costing for long-range infrastructure. Part I: leveling the playing field to address uncertainties." *The international journal of life cycle assessment* 22, no. 2 (2017): 277-292. https://doi.org/10.1007/s11367-016-1154-1