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Sustainable operation and maintenance criteria for non-toll road green rating system

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Abstract. Green Rating System is utilized as tools to analyze the sustainability of buildings or infrastructures. Improvising green rating system is a continuous effort due to the needs of local implementation of a country. In Malaysia, there are two established rating systems for roads; MyGHI for highways and pHJKR (Roads) for non-tolled roads. Preliminary study on pHJKR (Roads) identified this rating tool assess road sustainability performance only at planning, design & construction stages. This study foresees, it is essential to sustain its engineering and sustainability performance, including carbon assessment under Operation and Maintenance (O&M). Therefore, this paper highlights the relevance and applicability of pHJKR (Roads) in comparison to other establish green road rating tools. The assessment criteria and elements during (O&M) phase are proposed for score development, which extensive research will lead to the establishment of O&M pHJKR (Roads). The data was gathered and analysed from a comprehensive review of current pHJKR (Roads) with a comparison other green road rating index. The expert panel discussion also was utilized to determine suitable sustainability factors. This study, in conclusion providing an opportunity to the enhancement of pHJKR (Roads), which offer a complete cycle of assessment in road project development of road Green Rating System

1. Introduction

1.1. Sustainability

Sustainable infrastructure has gained much acceptance by many infrastructure facilities providers as it is essential for conserving the environment for future generations. It is no secret that development of any infrastructure facilities such as the dams, airports, roads and, ports have a significant impact [definition infrastructure] not just on the environment but to surrounding socio-economic in a country. In the transportation sector, besides the significant impact from vehicle fuel combustion, the development and operation of the roads itself have a high impact to the three-basis element of



sustainable which are the environment, social and economic [1]. While many parties focus on the planning, design and construction phase of a road [2], the importance of operational phase, which includes maintenance of the roads is regularly side-lined. The lifecycle of roads consists of planning, design, construction, operation and maintenance and refurbishment phase [3]. These phases may elongate to 40 years a cycle, where the operation and maintenance phase covers most of the timeline by 35 years with 5 years average for planning, design and construction phase. Therefore, it is wise to consider the operation and maintenance phase as an essential contributor to road sustainability [4].

1.2. Rating system

An assessment to scale yarded sustainability must be used [5] to understand and ensuring road operated sustainably. This objective can be achieved by having a rating system with specific criteria as a measurement tool for an operational road. However, most rating systems are widely utilized to assess the sustainability of vertical development, such as buildings [6, 7]. Although many agencies have established their very own rating system for infrastructure development, particularly in road facilities, it still lacks in the operation and maintenance phase. In Malaysia, there are few rating systems developed to assess sustainable buildings and infrastructure. The most prominent transportation rating tools are Malaysia Green Highway Index (MyGHI) and Penarafan Hijau JKR – pHJKR (Roads). These tools dedicated to assessing highways and non-toll roads in Malaysia. Relatively, both systems were developed for road development; however, pHJKR (Roads) was found lacking in operation and maintenance (O&M) criteria in comparison with MyGHI where it covers all stages of highways development [8]. Oswald and McNeil [9] determined a seven-step process that can be universally applied for the development of sustainability rating systems. The seven steps are listed below;

- Step 1: Define criteria for selected infrastructure under evaluation.
- Step 2: Develop sustainability indicator categories.
- Step 3: Develop sustainability indicators (credits) as the performance measurement for the goal.
- Step 4: Transform indicators into credits by identifying measurements associated with each.
- Step 5: Prioritize credits by assigning weights (level of importance).
- Step 6: Allocate points. The weights can be used as the credit points.
- Step 7: Develop a rating scale or the certification levels of sustainability achieved by the project.

1.3. Roads in Malaysia

In Malaysia, roads are categorized by Federal Road and State Road as non-tolled roads, while Highway is defined as tolled roads. There is more than 230,000 km of roads in Malaysia to date and the majority of the roads are non-tolled roads [10]. With the total length of 217,071.74 km for State road and 17949.73 km for Federal road, while highways in Malaysia consists of 2,000.88 km in total length, it clearly illustrates the disparity between non-tolled roads and highways.

As for today, there is more than 17,000 km of federal roads throughout the nation including Peninsular, Sabah and Sarawak. These roads are categorized to four main categories; main federal roads, Felda federal roads, federal roads to an institution and federal roads to the industrial area. State roads are defined as a road system lies in every state in Malaysia where respective states funded the road maintenance. Generally, the standards applied for state road are similar to federal road standards and quality. Data from Public Work Department (JKR), as reported in 2017, stated that there are 237,022.353 km of roads in Malaysia, including federal road, state road and highways [10].

As reported by JKR Malaysia the increment of road development since the year 2000 (from 67,590 km in 2000 to 237,022 km in 2017) have spawned concerns by road users of its environmental effects from road development particularly during road operation and maintenance. Perhaps, by having a rating system which through its ability and open approach will satisfy the concerns on road development impact to the society, economy, and environment [11]. Therefore, the purpose of the research was to study the very much needed criteria to assess the operation and maintenance of non-toll roads. The finding from the study is criteria to assess the real sustainability of operational road in

order to benchmark the road before it is handed over to maintenance contractors. Successively it will lead to extensive study in proposed criteria for sustainable maintenance activities for the establishment of index indicator O&M pHJKR (Roads).

2. Phase 1 – pilot investigation on penarafan hijau JKR – pHJKR (roads)

Public Work Department (JKR), Malaysia is the responsible agency in governing and implementing road infrastructure throughout Malaysia. Through its latest Strategic Framework developed in 2016, five strategic themes were highlighted, including theme no.4 – Leading Sustainability [12]. It was from this strategic plan, the green road rating system pHJKR (Roads) was vastly promoted, and all projects are encouraged to manage sustainability through the rating system. It has been developed based on the level of the operationalization of existing government development as well as the requirements set for government projects. The objectives of pHJKR (Roads) are; as a measurement tools for the level of sustainability achievement among government development projects, facilitate improvements made from time to time and as encouragement so that development is implemented and operated sustainably. Among the scopes involved are green road technology, improving road user safety, user-friendly facilities, and wildlife conservation. This tool is currently only applied to a new project for a federal road with more than RM50 Million in value, and the one-off certification is awarded for planning, design and construction phases except for operation and maintenance activities [13].

Initially launched in 2012, pHJKR (Roads) has evaluated projects based on planning, design and construction stages only. Large numbers of projects have not assessed using pHJKR (Roads) after their completion due to the unsuitability of criteria for a completed and operational road. To illustrate the further unconvincing situation, most of the federal roads and state roads in Malaysia are handed over to concessionaire maintenance companies where there is no clear indication in their contract for maintenance activities to be carried out sustainably. Therefore, having a rating system that covers the operation and maintenance phase is vital in promoting sustainability in road lifecycle. In line with that, any completed road project must be rated on its sustainability before it can be hand over to concession companies where it will be their responsibility to maintain or gain further improvement in the rating.

In this study, a pilot investigation was conducted to gather information on relevance criteria related to the completed and operational road project. Currently, the criteria developed for the pHJKR (Roads) rating assessment are divided to 7 criteria; SM-Sustainable Site Planning & Management, EW-Environment & Water, AE-Access & Equity, CA-Construction Activities, MR-Material & Resources, PT-Pavement Technologies, and IN-Innovation (figure 1). These criteria satisfy the essential sustainability elements reflected in figure 2, where social contributes the most criteria, followed by environment and economic.

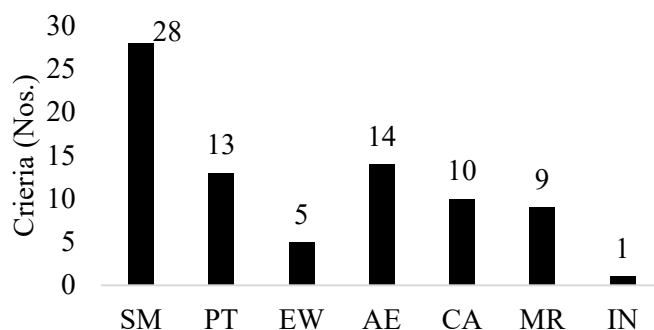


Figure 1. pHJKR (Roads) Category Criteria.

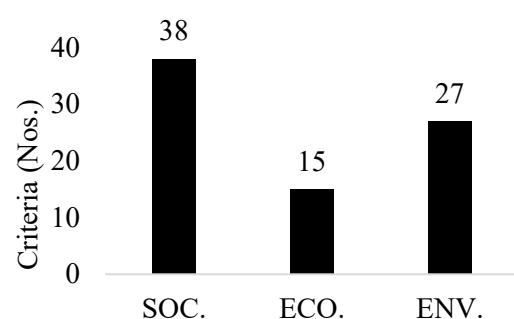


Figure 2. Criteria by Sustainable Triple Bottom Line.

The criteria are tailor-made to evaluate any project at planning, design and construction phase. Referring to information gathered during the investigation, for year 2017-2018, there is 12 assessment

performed by adopting pHJKR (Roads) criteria (figure 3). 6 assessment performed for pre-assessment stages, 6 assessment for design stage and 15 projects in the planning stage are still pending for assessment. Results from the assessment are described in figure 4 & figure 5.

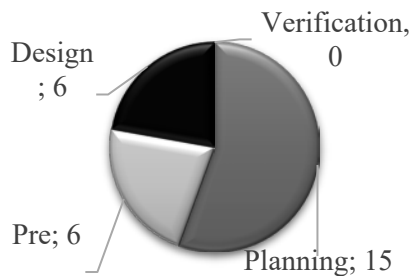


Figure 3. Total assessment.

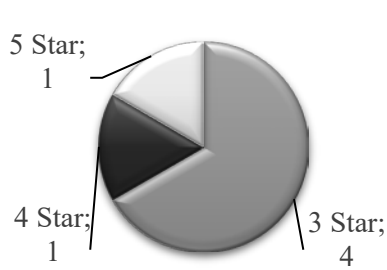


Figure 4. Pre-assessment.

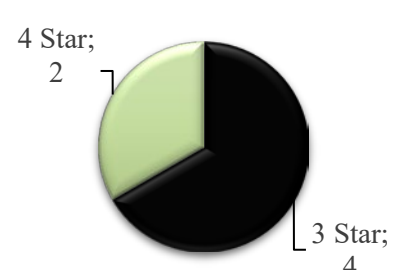


Figure 5. Design assessment.

Once the construction of the project completed and operational, numerous criteria were found incompatible to assessed during this stage. Consequently, the projects are rated below average on a sustainable scale. This information is significantly important as the project will be handed over to maintenance concessionaire where they will be required to maintain its sustainability level during the maintenance period. There are 11 districts throughout Malaysia involved in the pilot study involving 21 roads projects. Projects selected for the study valued from RM800,000.00 to RM280,000,000.00. Although pHJKR (Roads) only evaluates project valued more than 50Million, this study attempted to investigate the possibility of projects below the value achieving any certification level by adopting existing criteria in pHJKR (Roads). In the same way, projects under state road were also studied as well as the federal road to assimilate all road category in the pHJKR (Roads) assessment. In reference to the project category investigated for the pilot study, 66.7% of the projects valued less than 50 Million and 47.6% projects in the state road category. Based on the assessment conducted, only 4 projects achieved a minimum rating as Potential Certification (40%-49% points) and 17 projects achieved below than the lowest rating. The 4 projects achieving minimum rating are in the category of more than 50 Million and federal road. These results show that pHJKR (Roads) criteria are designed to evaluate a project, particularly in the specified categories.

Moreover, referring to the study conducted, most of the projects lack in scores for criteria involving the planning and design phase where information was not disseminated to the construction and maintenance team. These were the result of the project team member's education, awareness, and knowledge in regard to sustainable [14, 15]. Considering the fragmented work transition and contrasting scope of work between planners, designers and project team, numerous criteria appears to be irrelevant to assess in the operation phase. Despite the project selection criteria, the study discovers pHJKR (Roads) can be adapted to all category of roads regardless its value, type of road and phase but requires a modification to ensure relevance criteria for the operational road are used effectively in the assessment [16]. According to the results, the development of criteria to assess completed and operational project based on information available during the stage is necessary.

3. Phase 2 – review on transportation green rating tools

Suitable criteria required for green assessment was developed by observing and associating established rating system with existing pHJKR (Roads). Comprehensive content analysis from numerous rating system were reviewed as guide and models to create relevant criteria and credits. Gathering a summary of criteria and its weightage from other rating system is significant to distinguish compatible criteria for a non-tolled road in Malaysia. Assessment criteria from established transportation green road rating system [11] (table 1); I-LAST, BE2ST-in-HighwaysTM, GreenLITES, Greenroads, INVEST, STARS, and MyGHI are benchmarked to constitute the relevance and applicability of pHJKR (Roads). An exception to MyGHI which originated from Malaysia, other rating system

reviewed are based in the United States and committed to assessing green development of highways and roads. MyGHI as an ally rating system with pHJKR (Roads) in Malaysia spotlighted on green highway development as their focus.

Table 1. Criteria weightage comparison of various transportation green rating tools.

	I-LAST	BE ² ST-in-Highways TM	Green LITES	Green roads	INVEST	STARS	MyGHI	pHJKR (Roads)
Planning & Design	21%	5%	X	20%	9%	X	16%	35%
Environmental	17%	10%	20%	10%	9%	6%	13%	4%
Water	9%	10%	7%	6%	X	6%	12%	3%
Material	21%	22%	7%	10%	3%	X	8%	10%
Pavement	X	X	15%	X	8%	X	3%	16%
Construction activities	6%	X	X	18%	X	X	7%	13%
Access & Community	11%	X	X	10%	6%	32%	10%	13%
Safety	6%	10%	2%	7%	11%	19%	10%	5%
Energy	5%	22%	12%	13%	11%	6%	20%	1%
Maintenance activities	X	X	35%	X	43%	X	X	X
Innovation	1%	X	2%	7%	X	X	2%	1%
Economic & Cost	X	21%	X	X	X	32%	X	X

Table 2. Criteria mean score comparison from various transportation green rating tools vs pHJKR.

Criteria	N	Min	Max	Mean	pHJKR	Remarks
Planning & Design	8	0%	35%	13%	35%	Above average
Energy	8	1%	22%	11%	1%	Below average
Environmental	8	4%	20%	11%	4%	Below average
Access & Community	8	0%	32%	10%	13%	Above average
Material	8	0%	22%	10%	10%	Above average
Maintenance activities	8	0%	43%	9%	0%	Below average
Safety	8	2%	19%	8%	5%	Below average
Water	8	0%	12%	6%	3%	Below average
Construction activities	8	0%	18%	5%	13%	Above average
Pavement	8	0%	16%	5%	16%	Above average
Economic & Cost	8	0%	32%	4%	0%	Below average
Innovation	8	0%	7%	1%	1%	Above average

Table 2 describes the results from the cross review on average weightage from other rating system compares to pHJKR (Roads) criteria weightage by mean scoring. Research has found that Planning & Design, Energy, Environmental, Access & Community, and Material are the most listed criteria by other rating systems where the mean score are >10%. It is noted from the results, pHJKR (Roads) achieved mean score (>10%) for Planning & Design, Access & Community, Material, Construction Activities, and Pavement. From the result and summary, the ability of pHJKR (Roads) to have assessment criteria which is consistent with other established rating system has proven its relevance.

While as stated in table 3, with all the related rating tools listed, it is noted that only Greenroads, STARS & pHJKR (Roads) involve specifically to road projects while GreenLITES, INVEST & MyGHI developed for the highway project. Since this study focus on the operational non-toll road, therefore 3 rating tools (GreenLITES, INVEST & MyGHI) relevance to operation and maintenance phase were studied and benchmarked to establish criteria for operational phase for pHJKR (Roads).

Table 3. Applicability according to the operation and maintenance phase.

Type	Highway					Road specific scheme		
Rating tools / Phase	I-LAST	BE ² ST-in-Highways	MyGHI	Green LITES	INVEST	Green roads	STARS	pHJKR (Roads)
Origin	US	US	Malaysia	US	US	US	US	Malaysia
O&M	X	X	√	√	√	X	X	X
Construction	√	X	√	√	√	√	√	√
Design	√	√	√	√	√	√	√	√
Planning	√	√	√	√	√	√	√	√

Admittedly, all the tools listed are meant for sustainable highway measurement, but table 4 indicated based on the criteria studied; clearly, there is some resemblance between a highway and non-toll road criteria. MyGHI is applying generic criteria for all phases including planning, design, construction and operation and maintenance for its assessment. GreenLITES have dedicated criteria for sustainable maintenance activities where it is acknowledged in point scoring. INVEST focus on the internal operation as well as maintenance and operation criteria in favor of assembling points. All categories and credits from the rating system were reviewed in order to determine appropriate criteria for application in the operation and maintenance phase.

Table 4. Criteria in rating tools for operation and maintenance phase.

MyGHI	GreenLITES	INVEST
Sustainable Design and Construction Activities	Bridges	Internal Sustainability Plan
Environment & Water Management	Pavement	Electrical Energy Efficiency and Use
Social and Safety	Drainage	Vehicle Fuel Efficiency and Use
Material Technology	Signals and Lighting	Reduce, Reuse and Recycle
Energy Efficiency	Snow and Ice	Safety Management
	Facilities and Rest Areas	Environmental Commitments Tracking System
	Roadside Environment and Signs	Pavement Management System
	Innovative/Unlisted Activities	Bridge Management System
		Maintenance Management System
		Highway Infrastructure Preservation and Maintenance
		Traffic Control Infrastructure Maintenance
		Road Weather Management Program
		Transportation Management and Operations
		Work Zone Traffic Control

4. Phase 3 – expert discussion

Once the existing green road rating system has been reviewed, industry experts were interviewed during a pre-expert discussion to identify criteria related in the operational road. Based on the reviewed criteria used in rating system in table 4, incorporated with criteria from pHJKR (Roads) pilot case study, a list of criteria relevance with operational road were listed. A total of 42 road expert as in table 5 from varies background such as District Engineer, Road Engineer, Maintenance Engineer, Project Site Personnel and Road Maintenance Managers were asked to rate the importance of each criterion and its applicability to operational road assessment. The level of agreement for each criteria was independently measured by the expert's professional point of view using Likert scale (1: Strongly Disagree 2: Disagree 3: Moderate 4: Agree 5: Strongly Agree) [17]. It was assumed that all criteria with the level of agreement more than 3, are considered as relevant, and as a result, 176 criteria from the expert's opinion were listed for further expert assessment in focus group discussion session where

they will be given questionnaires survey form and eventually to finalize the green criteria for an operational road.

Table 5. Road experts interviewed for the green criteria in the operational road.

Designation	Frequency	Percent
District Engineer	5	12%
Road Engineer	11	26%
Maintenance Engineer	2	5%
Project Site Personnel	21	50%
Road Maintenance Manager	3	7%
Total	42	100%

A focus group discussion in workshop format will be conducted by assembling experts from a different background related but not limited to roads development. Besides possessing ample years of experience in roads and transportation development, experts will be invited by their involvement in various phases of road lifecycle mainly planning, design, construction, operation and maintenance phase. All the experts will act as respondents and will be requested to rank their level of agreement by ticking the appropriate checklist in the questionnaires survey form provided in the workshop. Any written suggestion from experts will also be encouraged to gather any additional information. The result from the focus group discussion will then collected and analysed to define criteria recognized by the convention in the workshop. Insignificant criteria will be eliminated and dismissed from the rating system.

5. Phase 4 – factor score calculation

Results from the questionnaire survey forms will be analysed using data management tool Statistical Package for Social Science or SPSS software [18] in order to perform the frequency analysis and factor analysis. Factor analysis, which is part of SPSS application, will be utilized for further data reduction in order to reduce large numbers of criteria for green operation and maintenance rating system. The multivariate technique, such as factor analysis is an assumption of response variables to be influenced by multiple factors [19]. The analysis will also generate mean and factor loading for each element. The descriptive analysis Kaiser-Meyer Olkin (KMO) will be proposed for data suitability check-in Factor Analysis. The higher values of KMO (range from 0-1) will indicate further suitability of the data. Factor Score is used to evaluate elements or criteria listed for green rating and helps to determine which variable has more weight than another. Calculation of Factor Score, FS can be made by multiplying the mean scores, with the Factor Loading, FL; $FS = \text{mean} \times FL$

6. Phase 5 – weightage factor calculation

Weightage factor is a value of importance that demarcates criteria from each other. The purpose of assigning weightage factor is to help us separate the work by priority. Results from Factor Score calculation will be exploited for Weightage factor calculation. Computation of Weightage factor will produce a weightage for assessment criteria and will be prioritized according to the value. The weightage will represent the scoring for each criteria in the green assessment. Calculation of Weightage score (WS) can be made by dividing Factor Score with Total Factor Score for every criteria, $WF = FS / \sum FS$. [20].

7. Phase 6 – carbon assessment observation and record

Operation and maintenance portray an essential role in enhancing the sustainability of existing infrastructure and asset before completing its design life. Among activities involved in operation and maintenance of roads are Pavement, Maintenance of Road Shoulder, Grass Cutting, Maintenance of Road Furniture, Maintenance of Bridges and Culverts, Drainage, Landscaping, Routine Inspection for Roads, PPM, and Emergency Works [21]. In addition, observation and record review will be

conducted by collecting the direct and indirect emission released from maintenance activities. Besides, the in-situ audit also will be conducted for determination of the type of equipment and machinery used in the maintenance operation together with its effective hours of usage under normal operations. The information will be used to establish criteria for carbon assessment, which later will be utilized for carbon reduction strategy plan. The establishment and confirmation of carbon emission from maintenance activities and score point will be discussed during the 2nd expert discussion.

8. Phase 7– applicability and validation through a pilot study

An explanatory manual to demonstrate functions of the newly developed rating system will be strategized to help user navigates the assessment criteria and indicators. The applicability of the green assessment will be put into an experimental field study to evaluate and verify the acceptance [2]. Various types of project, regardless of its value, type of road and implementation phase, will be adopted for a pilot study.

9. Conclusion

Sustainable application in operation and maintenance phase for roads require vital consideration in ensuring the road continue to operate as intended in the design. Existing pHJKR criteria and sub-criteria is still at early implementation and may not be suitable for all types of the road based on its current selection criteria where it is explicitly designed for only Federal Road assessment. Consistent with the sustainable goals for development in Malaysia, the possibility to assess all hierarchy or types of roads will not only ensure the sustainability but furthermore expectation for a longer lifespan of roads can be materialized and lower the maintenance cost.

The CO₂ emission from maintenance activity may not have a significant impact on the environment if it is viewed from the perspective of the type of maintenance activity. However, due to its enormous length that stretched up to 240,000 km and with every single stretch need to be maintained, without a doubt, the maintenance activity will have a high impact on the environment. Establishment of carbon inventory for road operation and maintenance as baseline carbon emission will not only feature in the assessment criteria, but it is essential for future carbon reduction strategies-and considerably lower the operation cost of road maintenance. Besides that, it will offer integrated big data from roads that report to MyCarbon GHG Programme.

Therefore, with the development of rating tools which correspond to criteria for all types of road, phases and maintenance activity, it is expected that the sustainability of road development will be holistically accomplished. This study will later lead to the enhancement of pHJKR (Roads) with assessment criteria for operation and maintenance phase and re-assessment criteria for existing roads.

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