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Development of operation and maintenance sustainability index for *penarafan hijau jabatan kerja raya (pHJKR)* green road rating system

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Abstract. The significant impact of infrastructure projects on the environment has created needs to assess its sustainability and responsiveness which indirectly respond to carbon emission reduction. A rating system is widely utilized as a tool to analyze the sustainability of buildings or infrastructures. Malaysia is one of the advanced nations which applies in road green rating system, whereby two rating systems for roads are established; MyGHI for highways and pHJKR (Roads) for non-tolled roads. Preliminary study on pHJKR (Roads) identified that this rating tool assesses road sustainability performance only at planning, design & construction stages. Since the establishment of pHJKR (Roads), no re-assessment has been carried out after the roads begin to operate. Whilst in sustainability resiliency, it is important to sustain its engineering and enhance its performance and services including carbon assessment, under operation and maintenance (O&M) of roads. This paper highlights the methodology of development for assessment criteria and elements during the operation and maintenance phase. The methodology leads to proposed score development which later will be used in association to index indicator for O&M pHJKR (Roads). The data for this study is gathered and analyzed from a comprehensive review of current pHJKR (Roads) with a comparison made to national and cross-nation green road rating index. An expert panel discussion will also be utilized as a method of verification in order to identify suitable sustainability factors during O&M. The outcome of the study will be proposed for the enhancement of pHJKR (Roads) with assessment criteria for operation and maintenance phase and eventually leads to the establishment of multiple life cycle phases for pHJKR (Roads).

1. Introduction

Infrastructure development has a significant impact on a country since it acts as physical assets that provide facilities to connect basic life systems such as transportation, energy, communication, education, and other systems. Roads, dam, sanitation system, water supply, telecommunication structures, bridges, and tunnels are among technical structures which are essential and will always be part of the government's intention for the development and maintenance of social needs. Sustainable infrastructure



solution to environmental and social responsibility will enhance the social acceptance, and furthermore designed for a longer life span and services of the infrastructure itself. Sustainable design of infrastructure that takes into consideration many sustainable factors will contribute to a longer term of operation and maintenance which is however with consequences of the higher initial cost. This is agreeing with the previous study where the high cost of green technologies in a project was found to be the most critical barriers [1]. Although the initial costs of green construction can be higher than conventional projects, it is widely held that longer-term cost savings in operations and maintenance can help recover those costs in return of investment [2].

The Centre for Sustainable Transportation defines a sustainable transportation system as one that allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations; is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and limits emissions and waste within the planet's ability to absorb them [3]. Infrastructure provides the connectivity and supports various fundamental system significant to community living. Conforming to that, a sustainable infrastructure will be the better option to stabilize between social, economic and environment. To understand and implement sustainable infrastructure, an assessment is first necessary [4]. Thus, in ensuring the resilient of sustainable infrastructure, a scale yard must be used as a measurement tool for sustainable assessment. This can be achieved by a rating system which nowadays common to many countries.

Rating systems with consistent guidelines, regulations and statutory requirements that can quantify sustainability were introduced by various public and private entities all over the world. Although several rating systems are widely used to analyse the sustainability of individual buildings, lack of a rating system for assessing the sustainability of infrastructure projects has impeded the widespread adoption of sustainable roads. Considering the significant impacts infrastructure projects and networks have on the environment, the availability of roadway rating system is alarming due to many tools are still under development and revisions [5,6]. Therefore, many agencies especially government agencies that are in charge of public infrastructures have supported and established their rating system that is suitable in use for their organization. This effort is also inclusive to Public Work Department (JKR), Malaysia.

JKR is one of the departments in the Ministry of Public Works of Malaysia which on behalf of the government, is responsible in governance and implementation of road infrastructure works. It has developed JKR Strategic Framework 2016-2020 which outlined 5 strategic themes including Theme No.4 – Leading Sustainability. The strategic result of the theme is to attain Sustainable Infrastructure development [7]. To empower the implementation of sustainable development, JKR Sustainable Development Policy 2016-2020 has outlined 10 areas through 10 working committee chaired by respective Branch Director. One of the committees which is significant to this study is the Committee for Green Road directive by the Director of Road Engineering JKR. This steering committee has established the Public Works Department of Malaysia Green Rating Scheme - pHJKR (Roads). This tool is currently only applied to a new project for Federal road with more than RM50 Million in value and the one-off certification is awarded for planning, design and construction phases with an exception of operation and maintenance activities [8]. From the said criteria, most likely majority of roads were deemed unsuitable for the assessment due to limited project selection criteria. The consequences from the absence of assessment for the majority of road categories will result in the impediment of measurement of sustainability in every hierarchy and phases of road implementation in Malaysia.

Initially launched in 2012, the usage of the pHJKR (Roads) assessment was considered a slow achievement. The less encouraging utilization may be due to the unsuitability of project criteria and allocated assessment criteria as well as with the new tools which are non-familiar among the road designer and constructor [8]. Previous road projects were only evaluated based on planning, design and construction stages, and they have not been re-assessed after project defect liability period ends. Therefore, there is a need for availability of assessment intended to road life cycle performance which is on the operation and maintenance phase. Since there is no re-assessment after the roads certified, it is doubtful whether or not the sustainability criteria were maintained when operated by the maintenance

concession companies. To illustrate further unconvincing situation, in referring to a concession maintenance contract, there is no clear indication on the responsibility of concession companies to the compliance of sustainable criteria of the certified roads. Eventually, the certified roads will be operating and function like a normal road, where all the green elements were intentionally or unintentionally dissolved after the refurbishment of a road during operation and maintenance.

On the pilot investigation of the research problem with Public Work Department (JKR), this study reveals that revision of Road Maintenance Contract is imminent where the traditional contract is substituted by Performance Based Contract and will be enforced in near future. It is anticipated that the 5 years contract with a provision of revision in every 2 years will reduce maintenance cost whilst improving the quality of roads. Considering the contract are based on the performance standards complied and not the quantification of work done, it will certainly create opportunities for contractors to increase profit margins if the concessionaires managed to reduce the cost to achieve specified performance standards. Relatively, there will be a lack of control on the type of application, technology, materials, processes, and management of the maintenance works when it is completely the prerogative of concession companies. Therefore, a measurement tool is crucial on operation and maintenance of roads in order to assess and evaluate the sustainable elements compliance thus placing encouragement in pursuing operation cost reduction as a priority. There is a high opportunity for the enhancement of pHJKR (Roads) with assessment criteria for operation and maintenance phase and re-assessment criteria for existing roads.

2. Literature review

Roads and highways are the uppermost infrastructures of the country and they play an essential role in a nation's social and economic development. These infrastructures including roads, bridges, tunnel and other related services are beneficial to the community since they provide connectivity between towns and cities which will enhance the economic and social engagement of societies. Data from Public Work Department (JKR), as reported in 2017, stated that there are 237,022.353km of roads in Malaysia [9]. These roads are inclusive of state and federal roads including highways. According to the World Bank, the total road network in Malaysia covers 20km per 100km² nation's area with 76% of the roads are paved roads. Referring to Table 1.0, it is clearly indicated that federal roads consist of 17,949.731km length and highways contributed 2,000.880km. The data encompass state roads contributes nearly 92% of the total roads in Malaysia with a total length of 217,071.742km. It was reported that the government spends RM4,328,342,800.04 in maintenance cost for the year 2017 [9].

Table 1. Malaysia road statistic year 2017.

Peninsular Malaysia	Sabah & Sarawak	Highway
Federal Road =14,886.841 km	Federal Road =3,062.890 km	=2,000.880km
State Road =165,326.634 km	State Road =51,745.108 km	

*Data from JKR Road Statistic year 2018

Basically, there is almost 240,000 km of roads to be maintained and with the data shows a significant increment every year, it is believed that road operation and maintenance plays an important role in ensuring the performance and longer lifespan of roads. According to data from Road Statistic Report, in the year 2000, the total length of road in Malaysia was only 67,590.46km, while in the year 2017 there are 237,022.353km in total, where it shows a significant increment of more than 300% [9]. The total amount of maintenance cost of state road in the year 2000 was RM841,900,000.00 and this has periodically increased every year in line with the increment of road length to the amount of RM4,328,342,800.04 in the year 2017 with more than 500% increment [9]. These huge amounts of maintenance cost will not only burden the government but also causes a nuisance to the public whenever

refurbishment work is carried out. The maintenance work was assigned to concession companies and contractors who act on behalf of the government to ensure the performance of the roads [10].

The continuous effort of governance on sustainability performance is a doubtful challenge for every agency or organization. Sustainability of a project is determined by assessing the criteria listed; it is more significant than to analyse whether the project is sustainable or not [11]. Therefore, the objective of having a rating system is to act as a sustainable performance indicator of a system. Besides performance indicator which is mostly required by stakeholder, rating system allows designers such as architect and engineers together with contractors to willingly place sustainability as priorities in their planning and execution of a project [12].

Currently, numbers of building rating tools are inclusive of sustainable development but there are very limited tools developed to evaluate infrastructure. Among the established rating tools for general infrastructure work are; BCA Green Mark – Singapore, CEEQUAL - UK & Ireland version / Hong Kong Version, Envision – US and Infrastructure Sustainability – Australia. Nevertheless, there are four rating tools that are dedicated to transportation sectors which are; Greenroads – US, GreenLITES – US INVEST -US, STARS -US and Infrastructure Sustainability – Australia [13,14]. While, in Malaysia the available rating tools that are utilized to evaluate sustainability in the country are; Green Building Index – GBI, Green Real Estate – GRE, Sustainability Tools – MyCREST, Penarafan Hijau – pHJKR (Roads) and Malaysia Green Highway Index – MyGHI. However, among the rating tools listed, only Penarafan Hijau – pHJKR (Roads) and Malaysia Green Highway Index – MyGHI focus on roads infrastructure [15]. The Malaysia Green Highway Index (MyGHI) was initiated by the LLM (Malaysia Highway Authority) and designed as a performance baseline standard to measure the level of greenness for current highways in Malaysia [16]. Besides that, the establishment of Penarafan Hijau – pHJKR (Roads) by Public Work Departments (JKR) which consider the sustainable effort for a non-Toll road but only limited to Federal road project which is valued for more than 50 Million [8].

In Malaysia, the development of green highway assessment tools is parallel with the vision of Malaysia Highway Authority (LLM) which is to become world-class in highway development, management, and regulatory affairs. LLM may enhance employees and concessionaire awareness, skills and expertise through the launching of the assessment tool [13]. Furthermore, Balubaid [13] explained that the green highway assessment tool which specifically developed for Malaysia is based on mixed criteria to meet the sustainable purpose with the environment, culture and social needs in the country. In line with Malaysia's national green agenda, Public Works Department of Malaysia Green Rating Scheme (pH JKR) for roads development are trying to demonstrate the sustainable efforts rather than having a satisfying rating scheme. Certainly, it will be intriguing to have an impressive sustainable rating for a project. However, it does not genuinely reflect the impact on the surrounding environment. In consonance with Green Highway Index (MyGHI) developed by LLM, pHJKR (Roads) undoubtedly has the potential to blend the determined criteria and sub-criteria (if not all the criteria) inclusive of the concept to eventually incorporated all elements in a single assessment tools for all road categories in Malaysia.

Table 2 presents a matrix checklist based on the study conducted by previous researchers. The listing rating system for road development is I-LAST, BE2ST-in-HighwaysTM, GreenLITES, Greenroads, INVEST and STARS [5,17–20] which originated from US. These US-based rating tools are dedicated to assessed roads and highways development while the rest of the rating tools available are merely assessing overall infrastructure work. Besides international rating tools, MyGHI and pHJKR (Roads) which are developed in Malaysia specifically for road and highway will also be the basis for cross-review. It will include the type of infrastructure, origin and assessment phases in order to identify the best tool for road assessment that can be utilized up to the operation and maintenance phase.

Table 2. List of rating tools for sustainable transportation.

Origin	I-LAST	BE ² ST-in- Highways TM	Green LITES	Green roads	INVEST	STARS	MyGHI	pHJKR (Roads)
	US	US	US	US	US	US	Malaysia	Malaysia
Type - Highway	√	√	√	√	√	√	√	X
Type - Road	X	X	X	√	X	√	X	√
Planning stage	√	√	√	√	√	√	√	√
Design stage	√	√	√	√	√	√	√	√
Construction stage	√	X	X	√	√	X	√	√
Operation & Maintenance	X	X	√	X	√	X	√	X
CO ² Assessment	X	X	X	X	X	X	D	X

*D-development √-available X-not available

Table 3 is an extension of Table 2 with the comparison on all phases of road project lifecycle, and it shows which tools offer additional function in carbon assessment. Among the rating tools, only 3 tools involve road specific category which are Greenroads, STARS & pHJKR (Roads), while others are developed specifically for the highway. There are 3 tools including GreenLITES, INVEST & MyGHI, which measure sustainability up to operation and maintenance phase. Unfortunately, none of the listed tools is developed to measure and manage non-highway road within operation and maintenance phase. The comparison revealed that since road infrastructure in Malaysia consists of 235,021.473 km in total length compares to the total of 2,000.880km of highways [9], the unavailability of rating tools that measure sustainable roads from planning, design, construction to operation phase is very much needed in sustaining road services performance.

Table 3. Applicability according to CO² assessment, and operation and maintenance phase.

Type of infrastructure	Highway			Road specific scheme		
	MyGHI	Green LITES	INVEST	Green roads	STARS	pHJKR
CO ² Assessment	D	X	X	X	X	X
Operation & Maintenance	√	√	√	X	X	X
Construction stage	√	√	√	√	√	√
Design stage	√	√	√	√	√	√
Planning stage	√	√	√	√	√	√

*D-development √-available X-not available

Besides, except for MyGHI (in development stage), neither GreenLITES nor INVEST had ventured into CO₂ assessment in their respective operation and maintenance criteria. The development of transportation infrastructure such as roads also contributes to greenhouse gas emissions (GHG) and it is

also responsible for the emission of CO₂. According to AASHTO, transportation is one of the largest contributors to environmental impacts, especially harmful CO₂ emissions that would result in global warming. According to the National Energy Balance reported in 2013, transport sector energy's consumption has led to a staggering increase in carbon dioxide (CO₂) emissions, as much as 184.9% over the last 40 years and it has elevated Malaysia to rank third after Indonesia and Philippines in terms of CO₂ emission from the transport sector in ASEAN countries [15]. In conjunction with the Green Technology Master Plan Malaysia 2017-2030, GHG emissions released into the atmosphere by the operation of any organization needed to be monitored and controlled to ensure the responsiveness to sustainable development.

As a signatory nation to the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), under Paris Agreement signed in 2015, Malaysia has pledged to reduce its Greenhouse Gas (GHG) emission intensity of Gross Domestic Product (GDP) up to 45% by 2030. [15]. While in managing climate change, Malaysia has initiated a programme called MYCarbon – National Corporate GHG Reporting Programme for Malaysia in August 2013 aimed for an advanced GHG reporting and management by organizations in Malaysia, particularly those in the private sectors. However, it is noticeable that the astonishing economic growth and trade performance of Malaysia was accompanied by emissions that have caused deterioration in environmental quality. CO₂ emissions have reached a worrisome level in which they have increased the deterioration level in environmental quality by roughly two-fold from 129.5 metric tonnes in 2000 to 236.1 metric tonnes in 2014 (CEIC database) [21].

Evidently, the lifecycle of roads including construction, operation, and maintenance phases are responsible for the carbon dioxide (CO₂) and other greenhouse gas (GHG) emission and need to be delicately tackled due to its sensitivity towards enterprise and economic factors. Unquestionably the scope of routine maintenance for roads will contribute to fair amount of GHG emission. In response to that, it is genuinely important for criteria and elements for carbon emission of road maintenance to be included as part of a sustainable assessment and eventually reported as estimated quantity of GHG emitted per unit of activity.

Operation and maintenance play an important 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 (up to 50mm from ground), Maintenance of Road Furniture, Maintenance of Bridges and Culverts, Drainage, Landscaping, Routine Inspection for Roads, PPM, Emergency Works [10]. Optimum operation of buildings and infrastructure requires maximizing the availability and safety at minimum cost. It is essential to define cost-efficient operation policies, among which maintenance plays a significant role [22].

3. Research development and methodology

The objective of this research is to establish pHJKR (Roads) operation and maintenance green rating criteria and index which then later can be established for all hierarchy of un-tolled roads in Malaysia during design, construction, operation, and maintenance phase. It is essentially directive to a measurement of carbon footprint in the operation and maintenance activities. The research essentially covers five key areas of development:

- Investigation of the governance and effectiveness by assessing sustainability criteria for existing operational roads.
- Determination of sustainable assessment criteria in operation and maintenance for road maintenance works.
- Identification of source and measurement of carbon emission in road maintenance work activities.
- Development of the operation and maintenance sustainability index for pHJKR (Roads) rating system.
- Establishment of the Operation and Maintenance Manual on sustainability index for pHJKR (Roads) rating system.

The first step of the methodology is a comprehensive review of existing pHJKR (Roads) with a comparison between national and cross-nation green road rating index. Established rating tools will be studied to understand the concept pertaining to sustainable parameters in a road and current best practice as well as method that might be applied to local rating tools. The determination of rating tools reliability will be conducted by reviewing and assessing the newly completed project, existing non-green certified road in operation and certified green road in operation using pHJKR (Roads) as a tool.

For carbon emission, observation and record review, they will be conducted by collecting the direct and indirect emission released from road maintenance activities. Besides, the in-situ audit will also be conducted in determining the type of equipment and machinery used in the maintenance operation together with its effective hours of usage under typical operations. All this information will be used in developing criteria and elements by identifying operation which contributes most emission.

Second step of methodology is through descriptive and empirical study via interviews and questionnaires as survey instrument distributed to an expert group discussion where industry experts from JKR Malaysia road expert professional, regional roads concession companies, road users and experts in carbon footprints will be asked to rate the importance of each criterion and their applicability to operation and maintenance phase of road. After defining the criteria and elements which will be considered in sustainable operation and maintenance index, a weighting operation by mean of a questionnaire survey to determine the level of agreement will be performed in another expert group discussion to allocate points for each of the criteria requirement across the system. All the collected data will then be utilized for statistical analysis of factor analysis with weightage score to develop the operation and maintenance index for pHJKR (Roads).

This study will focus on the operation and maintenance of federal roads and state roads in Malaysia where maintenance contracts were awarded to concession companies based on regional segmentation. Referring to roads in Peninsular Malaysia, concessionaires are branched into four regions which are Northern, Central, Southern and Eastern region. The full process involved in establishing the tools is shown in Figure 1.

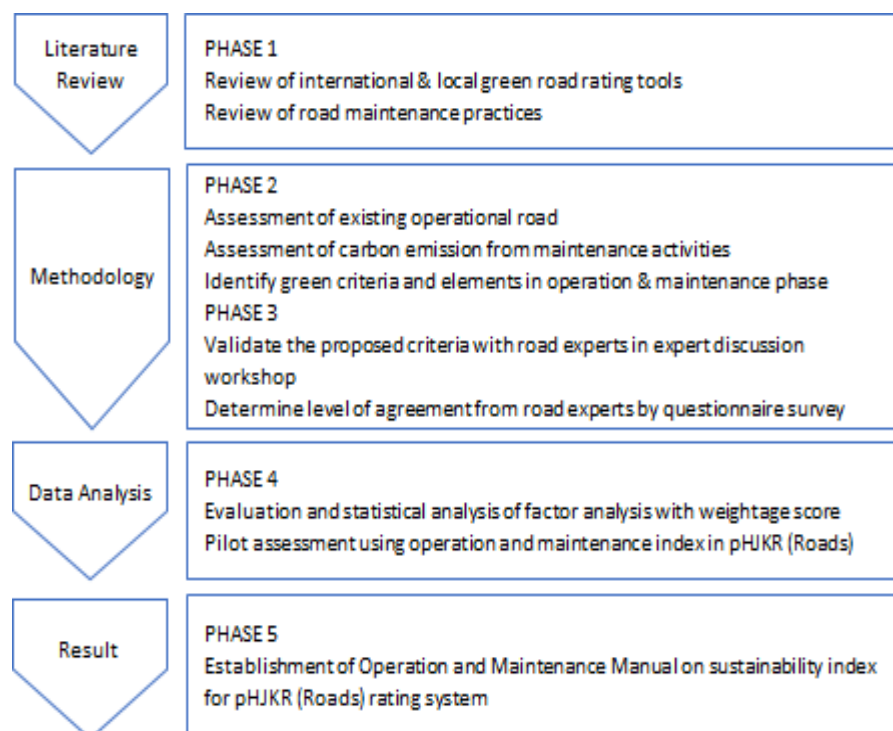


Figure 1. Research framework.

4. 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. The certified green road will not be able to sustain its sustainable criteria if the implementation of operation and maintenance of roads do not compliment the green effort and sustainable criteria. 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 designed specifically for only Federal Road assessment. Consistent with the sustainable goals for development in Malaysia, 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. Road concession companies should be bounded with green practice during operation & maintenance phase as well as abiding by the local Environmental Act. This will enhance the application of sustainability to the green certified roads in the operational phase. Revision to the road maintenance concessionaire's contract in ensuring sustainable approach in daily operations and sustainable as part of the company's performance is significantly important. Utilizing pHJKR (Roads) as certification for concession companies in sustainable operation and maintenance will enable it to act as performance indicator among concessionaires.

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. But due to its great length that stretched up to 240,000km 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 & 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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