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The Importance of Life Cycle Cost (LCC) Components for Emerging Green Costs Incurred in Green Highway Budget Preparation Decision-Making

To cite this article: Muhammad Faiz Abd Rahman *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1067** 012061

The Importance of Life Cycle Cost (LCC) Components for Emerging Green Costs Incurred in Green Highway Budget Preparation Decision-Making

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Abstract. In the journey towards sustainably preserving road infrastructures, financial planning and its asset management are essential to preserve and rejuvenate at its life cycle stages efficiently. There are many methods and efforts to integrate current practices. The road components assets' Life Cycle Cost (LCC) will have an impact in terms of more substantial cost investment since reliable cost information is rarely sufficient. The final budget of various road projects should be calculated based on the Life cycle costing, which covers both costs and revenues for the period of development until post-construction. This paper focuses on the importance of the Life cycle costing components to the green highway project, and it also responds to the sustainability of road infrastructure development literatures reported. This paper also highlights the anticipated results, leading to the identification of crucial models in creating the Life cycle costing decision-making instrument. The findings of this paper have significance in terms of encouraging stakeholders to react to green highway evolution and establish Life cycle costing as a decision-making tool.

1. Introduction

The construction sector has significant environmental, economic, and social consequences. The anticipated shift in road user's travel behaviour will also have a significant influence on highway and road (H&R) construction projects and their transportation aspects. H&R 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 infrastructure. The knowledge of the enormous ecological size of the infrastructure set has significantly improved the significance and popularity of multiple green H&R concepts as a possible solution for remediating the damage to the planet[1].

Many green infrastructure projects aim to improve biodiversity, improve the quality of air and water, reduce waste, together with protecting the infrastructure's natural assets. In order to demonstrate the aims, the first green infrastructure related manual, called Leadership in Energy and Environmental Design (LEED), was established in 1998 by the US Green Building Council (USGBC). Following that, the idea behind green roads lies far beyond road construction without harming the environment as it attempts to create circumstances that would ultimately upgrade global quality [2]. Then, the green road is defined as an effort to construct road infrastructure responsibly while lowering waste and helping to maintain the footprint of the ecology in roadways. Past studies (e.g., [3]; [4]) identified four green H&R procedures engaged in planning, building, designing, and conducting activities with some critical primary factors. The stakeholders engaged in green road and highway issues should, therefore, consider the use of water and energy, the quality of the surroundings, the selection of materials, and the impact on their site [5].

Because of the green H&R and issues related to sustainability in the construction industry, to name a few, past conceptual and empirical studies in the local context include fundamental elements of the green H&R by Ismail [6], a literature review of the green road energy efficiency by Zakaria [7], assessment index tool for the green road by Balubaid [8], assessment framework for pavement material and technology elements for green road index by Bujang [9], road and life cycle costing as DSS model by Rahman [10], awareness of green H&R concept and terminology by Nusa [11], integration model of fuzzy AHP and LCC analysis for evaluating road infrastructure investments by Goh [12] and a review on green economy and development of green H&R by using carbon-neutral materials by Attahiru [13].

There is evidence to suggest that this perhaps true, managing green H&R infrastructures advances sustainable development through accountable project management, programs, and initiatives to attain environmentally friendly H&R and a green economy. However, the execution of green H&R initiatives continues to face several difficulties in terms of project management in approaches used in various H&R infrastructure projects in the construction industry [14]. H&R construction faced prevalent challenges and difficulties in creating a sustainable project management plan that addresses problems, effects, and their solutions. In addition to the green H&R manual and its rating system, the sustainability aspects of each green H&R infrastructure project must be considered. The sustainable green idea of H&R design is enhanced by considering investment and maintenance costs [10]. 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 Life cycle costing, 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 measurable variables at the LCC stage, and the correlation between them should be established [10]. This expected outcome and ability to assist and boost the green H&R Triple Bottom Line (TBL), specifically green technology in the green H&R 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 H&R measurable variable inferring can be improved with integrated risk and LCC tools [15]. Nevertheless, the life cycle costs for H&R projects can be optimised, plus the LCC profile and database can be established by aligning the green H&R cost model with value engineering.

Given the above critical literature review, a particular guideline for this green H&R, such as a standard or a policy, must be created to allow road user's to move towards sustainability in the environment by offering a healthy, modern, and green transport system to the country. Consequently, the green H&R concept has been incorporated into the construction industry, initially to draw on the concept of sustainable development and aimed at reducing the environmental impact produced by construction activities throughout the life cycle of the H&R project [16].

Together with this, the dynamics of the local green H&R include four general aspects. First, road designers continue to lack insight into how life cycle costing can be effectively implemented in road design and implementation. Life cycle costing is still a challenging issue as it relates to sustainability, and green concept cost is still lacking. This has led to uncertainty of return on investment and has led to a reluctance among construction industry players to invest [17]. Second, the lack of breadth and depth of information about the LCC profile in H&R planning for design or planner engineers and needs of the green H&R to be implemented to conserve resources. Third, there is a limited study done in the area of TBL, specifically the financial factor analyses of green H&R costs. Fourth, in developing countries, pricing in the roadbuilding industry is not adequately studied and, if examined, pricing strategies between client and contractor are not systematic.

Furthermore, the recent distressing financial news, the declining economy, continuing credit market turmoil, and the rapid deterioration in property markets have a significant negative impact on H&R infrastructure investors, and they might assume that the green H&R trend is over or at least on hold [12]. However, the importance and awareness of such non-traditional costs are growing, with many companies and individuals concerned about greenhouse gas emissions and climate change. If in the future, a tax is imposed on energy consumption, a more energy-efficient road will incur a lesser impact. The uncertainty of return on investment has led to the reluctancy of the construction industry to invest in the green road construction sector. Therefore, the need for additional and facilitating tools is required to assist investor's perception of green H&R cost-benefit.

According to [18], green costs are incurred when green materials and the cost of green commodities are to be used. This paper reviews the related literature pertaining to the aforementioned green H&R research area and uses questionnaire survey results to bring a sense of the importance of Life cycle costing application for green H&R budget preparation decision making. In summary, the results shown will contribute to the application of Life cycle costing contributing to the growing literatures on green H&R especially in the green cost area.

2. Methodology

In achieving the objective of this paper, it further utilises a focus literature search method for the determination of LCC components related with decision-making criteria for green H&R[19]. The previous work on green H&R and LCC was reviewed by addressing literature to gain in-depth knowledge of the subject area and identify gaps in using LCC components related to the green H&R criteria as green cost constructs. The construct is then used to develop the questionnaire items.

There are two stages of the LCC component involved, which are the initial cost and future cost. For the initial costs, there are capital, construction costs (installation) and management costs. As for future costs, there are operation, maintenance/service, replacement, demolition, contingency costs/risk and management costs [10]. With these two costs, the survey questionnaire was developed using the Integration Matrix design. The purpose of the survey questionnaire is to identify the relevant green H&R cost items which fit with each component of the LCC and what the relationship between them.

According to [20], the best response scale is one that can be accurately understood, distinguishes between respondent perceptions, can be easily interpreted, and has minimal reply bias. The five-point Likert-type scales are used for all the questions selected for this study. Likert scaling presents a simple and straightforward method for respondents to rate items. According to [21] and [22], this method presumes that the scales are ordinal, while the attitude towards each scale carries equal weight, and is generally easy to construct and adaptable to a variety of items in forming an index. In this study, the responses available to these items were no relevance=1, least relevance=2, moderately relevance=3, strongly relevance=4, and very strongly relevance=5. These responses were asked of respondents in relation to the LCC component in the EE criteria as a green H&R cost item. Based on the questionnaire data collected through survey distribution with 68 engineering technical backgrounds respondents, Friedman's test is used to evaluate the ranking of LCC components for green H&R Energy Efficiency (EE) criteria in the development of Life cycle costing calculation model. Engineering technical backgrounds were chosen to answer the questionnaire because they have cost competency to suit the type of question being asked. In order to determine sample size, power analysis using the G*Power program by [23] was performed. Recent discoveries by [24] suggest that researchers should select sample size through power analysis. Based on [25], two numbers of LCC components were identified, which are initial and future costs, and are used as predictors in the questionnaire. Hence, G*Power shows that the sample size required is 68 (effect size = 0.15, α = 0.05, power = 0.80).

Then, this paper employed Friedman's test for finding differences in treatments across multiple attempts of LCC components. Friedman's test is a non-parametric test, which means the test does not assume the data comes from a particular distribution (like the normal distribution). It is used in place of the ANOVA test when the researcher does not know the distribution of the data. All the inputs received from respondents were analysed by employing a software program called IBM Statistical Package for Social Science (SPSS).

3. Results

Keywords of green 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, and H&R Life Cycle Costing/Cost Sustainability indicated findings mentioned in Table 1 from various research. These terms have been identified as keywords used frequently within the selective critical literature review analysis and.

Table 1. Integrated Matrix Selective Critical Literature Review Analysis (SCLRA) of Green Highway and Road (H&R)

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
[26]	●				●
[13]	●	●			●
[27]					●
[28]					●
[29]	●		●		
[30]					●
[31]					●
[32]					●
[33];[34]					●
[35]	●	●	●		
[36]	●	●			
[37]	●	●	●	●	●
[7]	●	●			
[38]	●				
[39]	●	●			
[6]	●	●			
[40]	●	●			
[41]	●	●			
[42]	●	●			
[43]	●	●			

[44]	●	●
[9]	●	●
[45]	●	●

The above Table 1 integrated matrix also confers that there is a significant deficit of automation in green H&R assessment tools and risk analysis. However, Life cycle costing issues are also falling behind in integration within green H&R rating tools for better performance. This shows that there is a need for additional facilitating tools integrating Life cycle costing into budget preparation decision-making to assist investors perceptual experience and lower perceptions of green H&R costs. The benefit of LCC will evidently benefit the H&R projects in fetching more interest from investors, builders, developers, owners, and occupants to the next level of quality in the built environment industry.

Table 2. Energy Efficiency LCC Cost Components Result.

Stage	Life Cycle Cost Components	Mean Ranks
Initial Cost	Capital Cost	7.36
	Construction/Installation Cost	6.50
	Management Cost	6.84
Future Cost	Operation Cost	5.17
	Maintenance/Service Cost	5.32
	Replacement Cost	4.47
	Demolition Cost	2.84
	Contingency/Risk Cost	3.36
	Management Cost	3.15

Data acquired from the survey in Table 2 demonstrates the mean rank of the LCC cost components of the green road EE variables used to build the LCC decision-making instrument. Friedman's test is significant at $\chi 2(8, N = 68) = 204.637$, $p < .05$. Pairs ranking contributed to significant Friedman's test are Capital-Construction (z = -3.269, p=.001), Capital-Operation. (z = -5.334, p=.000), Capital-Maintenance (z = -3.453, p=.001), Capital-Replacement (z = -5.944, p=.000), Capital-Demolition (z = -6.244, p=.000), Capital-Contingency/Risks (z = -5.896, p=.000), Capital-Future management (z = -5.990, p=.000), Operation-Construction (z = -4.333, p=.000), Replacement-Construction (z = -5.808, p=.000), Demolition- Construction (z = -6.289, p=.001), Contingency/Risk-Construction (z = -5.931, p=.000), Future Management-Construction (z = -5.490, p=.000), Operation-Management (z = -4.951, p=.000), Management-Replacement (z = -5.495, p=.000), Management-Demolition (z = -6.228, p=.000), Management-Contingency/Risks (z = -5.901, p=.000), Management-Future Management (z = -6.418, p=.000), Operation-Replacement (z = -4.540, p=.000), Operation-Demolition (z = -6.299, p=.000), Operation-Contingency/Risks (z = -4.797, p=.000), Operation-Future Management (z = -3.598, p=.000), Maintenance-Demolition (z = -4.257, p=.000), Maintenance-Contingency/Risks (z = -3.591, p=.000), Maintenance-Future Management (z = -3.451, p=.001), Replacement-Demolition (z = -5.519, p=.001), Replacement- Contingency/Risks (z = -4.021, p=.000) where these pairs were significant at $p < .0014$.

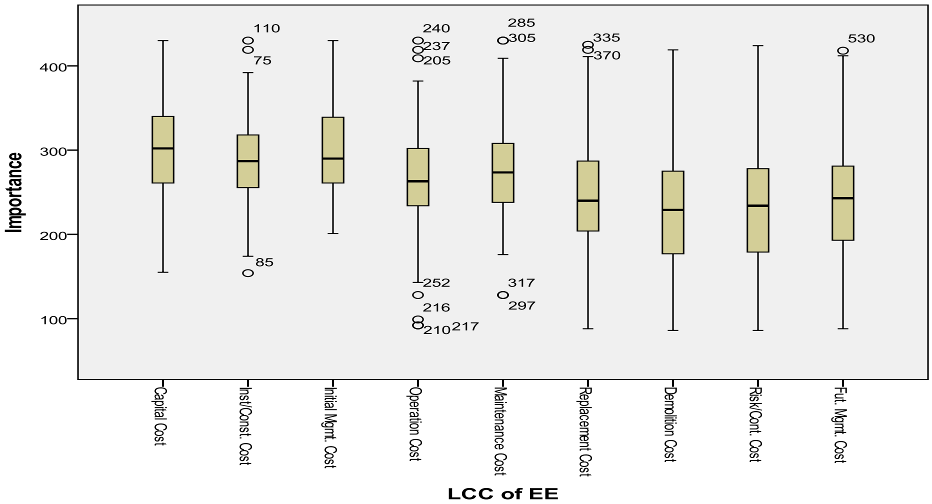

Figure 1. Energy Efficiency LCC profile boxplot result.

Figure 1 indicates that the capital cost had the highest median ordinal score compared to the other pairs. As a result, the capital cost was placed at the highest level, as it is in line with previous studies that demonstrated the capital cost of the project is the highest factor determining the success of H&R projects. In order to successfully apply the green dimension to H&R development, it is therefore vital and urgent that the Life cycle costing analysis be carried out in the budget evaluation, as each aspect may have a significant impact on the overall budget of green H&R projects.

4. Conclusions

It is noteworthy that various research on green H&R does not weight LCC significantly. Nor do those studies involve Life cycle costing in its research. So, the importance of the LCC components and their application to green H&R project budget development has been addressed in this paper. The table of green highway energy efficiency criteria of LCC components was formulated, as presented in Table 1 and Figure 1. The results of the table will be used to identify the cost uncertainty of the green H&R variable, which has made a significant contribution to the development of the LCC decision-making tool for the emerging green H&R project. In conclusion, this study analyses the associated literature pertaining to the growing green H&R research field and utilises questionnaire survey findings, which may offer a feeling of the relevance of Life cycle costing application for green H&R budget preparation decision making. In summary, the results provided will conduce to the application of Life cycle costing contributing to the expanding literatures on green H&R notably in the green cost sector.

5. Acknowledgment

The authors would like to thank Malaysian Ministry of Higher Education for funding this study under the grant FRGS, cost center no:Q.J130000.2551.21H52), GreenPROMPT research team members and Department of Construction Management, together with the opportunity to conduct the research.

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