Score Card Utility Matrix for Prioritization of Asphalt Paved Road Maintenance Projects

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Abstract

Accessibility to social and economic amenities and the provision of a crucial link between production and consumption make transportation infrastructure one of the most crucial factors for a nation's development. This is especially true for landlocked nations like Zambia, which depend on a vast network of both public paved and unsurfaced roads. Poorly maintained roads lead to both macro and micro economic losses, and this study focuses on sustainable prioritization of asphalt-paved road maintenance projects. Regardless of how well-designed or constructed they are, all pavements deteriorate over time because of the combined effects of traffic loads and the environment which could lead to huge costs of repair and rehabilitation if not addressed effectively. Maintenance treatments slow down the degradation process and so extend the pavement life. The choice of which public road to maintain is a challenging decision that governmental agencies must make that can be addressed by taking a multi-criteria decision-making approach. This study answers the question of which public roads to sustainably prioritize for maintenance considering decision-criteria subject to factors that include physical, climate resilience, socio-economic and environment aspects addressing an African's concern. In this study, the authors establish the importance of decision-criteria aspects and develop a score card utility matrix as an objective decision-making tool. In developing this score-card, the authors rely on semi-structured questionnaire guides and Analytic Hierarchy Process (AHP) structured questionnaire approaches in data collection, while adopting a combined AHP and utility matrix approach in developing a score card assessment tool.

Keywords
Decision-Criteria, Pavement, Prioritization, Road Maintenance and Sustainability.

1. Introduction

Accessibility to social and economic amenities and the provision of a crucial link between production and consumption make transportation infrastructure one of the most crucial factors for a nation's development (Bayoumi et al. 2021; Marai et al. 2021; Ng et al. 2019). This is especially true for landlocked nations like Zambia, which depend on a vast network of both public paved and unsurfaced roads (Ng et al. 2019). Poorly maintained roads lead to both macro and micro economic losses, and this study focuses on sustainable prioritization of asphalt-paved road maintenance projects (Adlinge and Gupta 2009; Llopis-Castelló et al. 2020). Regardless of how well-designed or constructed they are, all pavements deteriorate over time as a consequence of the combined effects of traffic loads and the environment which could lead to huge costs of repair and rehabilitation if not addressed effectively. Maintenance treatments slow down the degradation process and so extend the pavement life (Adlinge and Gupta 2009; Pearson 2011).

The choice of which road to prioritize for pavement maintenance is a decision that local and international road authorities must make (Masoumi 2016; Yannis et al. 2020). This problem's complexity can range from being as straightforward as choosing a road based solely on its economic viability to being as complicated as a multi-criteria decision-making problem where the criteria are chosen based on the goal of prioritization or any other influencing factor in establishing influencing decision factors (Lungu et al. 2022).

These multi-criteria might comprise decision parameters relating to pavement deterioration, road safety, cost, economic, social, and environmental considerations (Abu Dabous et al. 2020; Arshad et al. 2021). Sustainability and, more specifically, social and environmental concerns are playing a bigger role in decision-making when it comes to pavement management (Arshad et al. 2021; Pamuković et al. 2021). Aspects that affect how well a road functions also include: rider comfortability and serviceability (Augeri et al. 2019; Ragnoli et al. 2018); road width; and road markings (Mwanaumo and Lungu 2021), for example.

From a review of Literature, and a systematic review study by Lungu et al. (2022), available models fail to address the concerns of Africans including socio-economic and environmental aspects. Further, these models fail to capture emergent concerns related to climate resilience. There is need for a model that holistically takes consideration of physical, climate resilience, socio-economic and environment aspects to better answer the question of which public asphalt paved roads to sustainably prioritize for maintenance.

1.1 Objectives

The primary objective of this study is to develop a project ranking tool, taking a combined Analytic Hierarchy Process (AHP) and utility matrix approach, for the prioritization of which public asphalt paved road to maintain based on establishing which decision-criteria to include, and their level of importance, in addressing sustainability and an African's concern.

2. Literature Review

This study is grounded on two key concepts including: (a) public asphalt/bituminous paved road maintenance and rehabilitation prioritization; and (b) multi-criteria decision-making (MCDM). Prioritizing which road to repair anchors on the decision theory and criteria, while each road alternative hinges on the maintenance treatment needed.

2.1 Bituminous and asphalt paved public road infrastructure

As contrast to concrete and interlocking paver roads, bituminous or asphalt pavements are the most often built paved roads that are part of public road networks (state owned and everyone has the right to use) in Zambia and many other nations across the world (Mwila 2019; RDA 2014). Asphalt pavement's toughness and durability are widely known. Due to its benefits, it is a preferred option for a variety of pavement applications and the material of choice for the majority of national and link road projects. Yet, it is prone to deterioration, and despite the lengthy lifespan of a correctly installed asphalt pavement, it can be shortened by subpar surface preparation and construction methods, or simply by prolonged exposure to the elements and traffic loads (Marti and Wegman 2017; Wada 2016).

In this study, bituminous pavements relate to bitumen-bound asphalt pavements rather than bitumen-sealed highways (Bijleveld 2015; Garber and Hoel 2009). Hence, in all talks derived from this study, bituminous pavements are equivalent to asphalt pavements. On the other hand, it is inappropriate to use the phrases bitumen and asphalt interchangeably when referring to one another. Bitumen is a binding substance made from petroleum that is either used as a bituminous binder or as a sealant for roads. Yet, asphalt is actually a bituminous-bound substance. A bitumen layer is sprayed, followed by an aggregate layer, to create a bitumen-sealed surface. Repeating this results in a two-coat seal. At a plant, aggregate, bitumen, and sand are heated, dried, and combined to create asphalt. After then, it is spread out across a surface, like an asphalt driveway (Douglas 2015; Garber and Hoel 2009).

2.2 Maintenance of public roads

Regardless whether paved or not, roads deteriorate over time and exposure to the environment. It is natural for a constructed asphalt pavement to deteriorate. It's natural because the materials that make up asphalt deteriorate over time and are influenced by elements like rain, sunlight, and chemicals that come into contact with the pavement surface. Every pavement, no matter how well-designed or constructed, will deteriorate over time due to the combined effects of traffic loading and the environment (Wada 2016; Wang and Gangaram 2014). Pavement typically deteriorates at an increasing rate: initially, there are few defects and the pavement remains in good condition, but as it ages, more defects develop, with each defect making subsequent defects easier to develop (Wada 2016; Wang and Gangaram 2014). We use maintenance and rehabilitation to slow down or stop the deterioration process and in so doing extend the pavement life (Pamuković et al. 2021).

2.3 Multi-criteria decision-making (MCDM)

Prioritization strategies can be as simple as ranking using severity and extent of road pavement condition to more sophisticated approaches such as multi-decision criteria approach (Ewadh et al. 2018; Lungu et al. 2022). Furthermore, to supplement traditional economic and financial concerns, a rising emphasis is being placed on the importance of social and environmental aspects, as well as non-economic policy objectives (Torres-Machi et al. 2014). Road infrastructure policy must take into account collective social goals and local circumstances as major drivers, while arranging those concerns to reduce particularism (Chow et al. 2013; Pujadas et al. 2017). This could explain the diversity in the array of criteria that one could select from in developing a prioritization strategy. Sustainability and, more especially, environmental factors are becoming increasingly important in pavement management decision-making (Abu Dabous et al. 2020). Studies have endeavored to develop frameworks and models based on a number of criteria considerations including incorporating sustainability concerns: social, economic, and environment aspects (Lungu et al. 2022). It goes without saying that when a problem has multiple objectives, making a decision becomes more difficult. Multi-Criteria Decision-Making (MCDM) are theory-based methods for dealing with such difficulties (Mardani et al. 2015). The goal of MCDM is to provide a ranking of possibilities and is both a strategy and a set of theory-based

2.4 Analytic Hierarchy Process (AHP)

One of the most well-known and often used multicriteria procedures is the analytical hierarchy process (AHP). This method integrates the procedures of assessing alternatives and aggregating them to locate the most pertinent ones. The method is used to rank a collection of alternatives or to choose the best option from a group of alternatives. Rankings and selections are made in light of a broad objective that is divided into a number of factors. The approach is applied by determining the importance weights to be assigned to the criteria in defining the ultimate objective.

Authors have the chance to create hierarchical structures with specified or established criteria by utilizing this approach. Presenting a model with a distinct focus on the decision-criteria and sub-criteria, as well as the weights assigned to each based on their relative relevance, is the result. Its disadvantage is that when producing precise values from spoken assessments, it leaves out the subjectivity of human judgments.

In research published in 2022, Lungu et al. thoroughly examined models created for allocating asphalt road repair priorities. The study's conclusions showed that, regardless of the social environment or whether specified or established criteria were used, these studies restricted their hierarchical aims to factors related to physical, traffic, and strategic relevance. Suthanaya (2017) makes an effort to incorporate social and accessibility factors, although the author only considers socio-cultural factors when making accessible decisions. Roads having economic, agricultural, and developmental significance, for example, or other facilities associated to them, may be significant impact variables included in this decision-criteria component. From the studied literature, it can be concluded in general that created models miss key sustainability factors that are relevant to African concerns.

3. Methods

In establishing which decision-criteria to include, and their level of importance, in addressing sustainability and an African's concern, this paper firstly takes advantage of a systematic review study by Lungu et al. (2022), and semi-structured in-depth interviews to predetermine which criteria to assess. This study takes a purposive and snow ball sampling approach in selecting respondents with expertise and knowledge relevant to this subject matter with a saturation reached with 20 respondents. These criteria are illustrated in Figure 1 in data collection section.
This study draws derivatives from the Analytic Hierarchy Process (AHP) and Multi-Attribute Utility Theory (MAUT). The authors adopt the AHP methodology in determining assigned weights, also referred to as priority vectors, of each established attribute. In adopting the AHP methodology, the authors take three steps in establishing these priority vectors: stratifying the hierarchy, comparative judgement of each attribute using pair-wise comparison, and calculating the weight of each attribute.

The authors establish relative importance between any set of two attributes, predetermined, with the objective of answering the question: "Which of the two attributes is more important and what is the weight of its dominance in comparison?". This comparison is based with respect to the higher level of attributes established based on the following hierarchy: (a) Level 1 (Goal): decision-criteria relevant to sustainable prioritize road for maintenance in an African societal context; (b) Level 2: criteria (C1, C2…Cn); and (c) Level 3: secondary or sub-criteria (S1, S2…Sn).

The authors measure the relative weight importance based on pairwise comparison, using a 9-point sliding scale as illustrated in Table 1 for an example between criterion C1 and other criteria (C2, C3…Ci).

Table 1. Comparative judgement table for data collection

1=Equal; 3=Moderate; 5=Strong; 7=Very Strong; and 9=Extreme										
Criterion $\mathbf{C_1}$	9	7	5	3	1	3	5	7	9	Criterion $\mathbf{C_2}$
Criterion $\mathbf{C_1}$	9	7	5	3	1	3	5	7	9	Criterion $\mathbf{C_3}$
. . Criterion $\mathbf{C_1}$										. . Criterion **Cn**

The outcome of any comparative judgement in this study is a comparative matrix and if let **A** denote the matrix, aij (i^th^ row, j^th^ column=1… n) denote the scale of relative importance of attribute i to j, and aji=1/aij denote the values for inverse comparison, then the results of all pair-wise comparisons can be summarized as an n-by-n reciprocal matrix **A**=[aij], where aii=1 for all i=1…n. The purpose of the pair-wise comparison is to determine the (a) priority vector **W**=[W1 W2 .. Wn] for each set of sub-criteria with respect their level 2 criteria; and (b) priority vector **W**=[W1 W2 .. Wn] for each criterion established under level 2 hierarchy. These priority vectors are based on the comparative n x n matrix developed, **A**=[aij].

These comparison judgments, also known as collaborative judgments, are gathered from collaborative respondents for this study. The two most popular group decision-making techniques for collaborative judgments are aggregating individual judgments (AIJ) and aggregating individual priorities (AIP). In the first, a judgment matrix is created for the group using the geometric mean of each individual judgment, and the AHP technique is used to determine the global and local priorities. In AIP, group priorities are determined using the geometric mean after local priorities for each person are calculated first (Escobar and Moreno-Jiménez 2007; Ossadnik et al. 2016).

In this study these collaborative judgements are drawn from the initial 20 respondents included in this study and the authors adopt the AIP as the aggregation method for these individual judgements and the geometric mean method in determining the priority vectors. These methods are selected based on this study consisting respondents belonging to different organizations and thus not implying a synergistic aggregation of individual preferences as is the case in using AIJ by the geometric mean. Using the AIP also allows the authors to observe the variation of each expert respondent.

Therefore, in this study from the collection of 20 expert individuals for collaborative judgement on **m** attributes, the priority vector (say **W=[W$_{\mathbf{Lk}}$]** for every **L**-th individual and **k**-th attribute) when normalized satisfy Equation 1.

$$\sum_{k=1}^{m} W_{Lk} = 1\,, for\ L = 1{,}2 \dots N\ (Equation\ 1)$$

In using the AIP, the authors obtain the final priority vector with the geometric mean **g**=[g_k] using Equation 2. However, the authors use an additional normalization when components of the final priority vector do not sum equal to one.

$$Aggregated\ geometric\ mean\ g_k\ for\ L\ experts$$

$$= \sqrt[N]{\prod_{L=1}^{N} g_i^L} \; , for\ i - th\ row\ (Equation\ 2)$$

This final priority vector is drawn from the calculated individual priority vectors for each **L**-th individual from the n x n comparison matrix **A**=(aij) taking the following steps:

(a) Step 1: where the authors firstly calculate the geometric means for each i-th row following Equation 3.

$$Individual\ geometric\ mean\ g_i\ for\ L - th\ individual$$
$$= \sqrt[n]{\prod_{i,j=a}^{n} a_{ij}^L} \; , for\ i - th\ row\ and\ j - th\ column\ and\ L = 1,,2 \dots 20\ (Equation\ 3)$$

(b) Step 2: summation of the geometric means for i=1,2….n as shown in Equation 4.

$$\sum_{i=1}^{n} g_i^L \; , for\ i = 1,2 \dots n\ and\ L = 1,2 \dots . N\ (Equation\ 4)$$

(c) Step 3: normalization of the geometric means to obtain the priority vector for **L**-th individual as shown in Equation 5, with the condition that the sum of the priority vector equal to one must hold.

$$Priority\ vector\ W_L\ for\ L - th\ individual = \left[g_i^L \Big/ \sum_{i=1}^{n} g_i^L \right], for\ i = 1,2 \dots n\ \ and\ L = 1,2 \dots . N\ (Equation\ 5)$$

4. Data Collection

The authors illustrate in Figure 1 that this study established seven criteria and for each criterion established specific sub-criteria, all recognized with respect to the goal of the hierarchy developed for this study. The authors complete pair-wise comparisons following the hierarchy levels illustrated in this figure and which are further subjected to data analysis to develop relative weight matrices. The number of pair-wise comparisons are calculated as n(n-1)/2 for each level of comparison. These pairwise comparisons are drawn from 20 respondents following saturation of judgements after 20 responses and the authors present data analysis based on this aggregated sampled data.

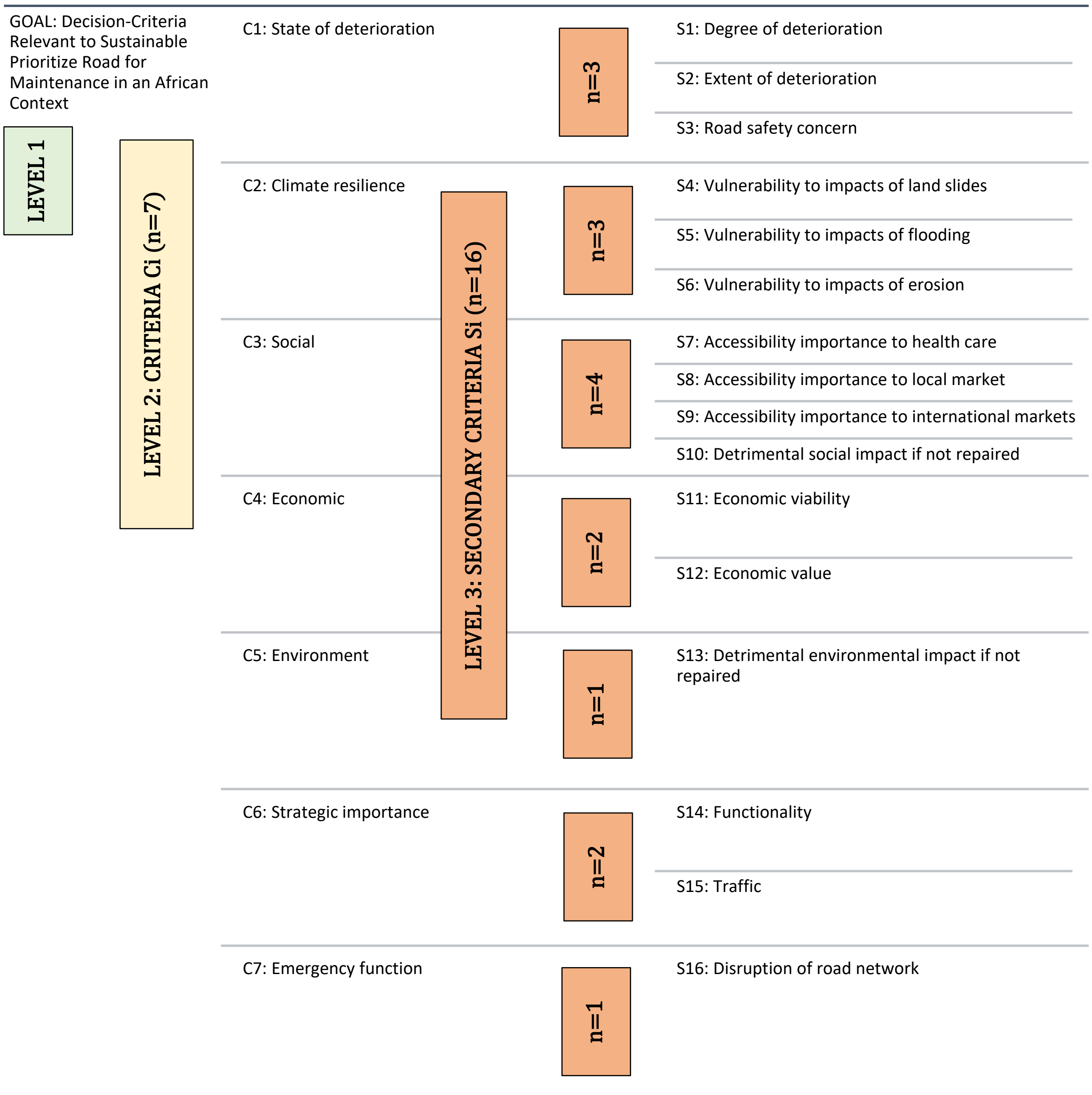

Figure 1. Hierarchy framework established from data collection and assigned unique attribute identifiers

5. Results and Discussion

5.1 Numerical Results

This study collects individual expert judgements from 20 respondents to draw pair-wise comparisons from each set of established sub-criteria with respect to their specific criterion. By using Equations 3-5, the authors analyze each i-th row priority vector for individual judgements. Further analysis takes the authors to apply geometric mean method in aggregating these N=20 individual judgements to obtain an aggregated geometric mean g which wen normalized yields a priority vector for each i-th row as presented in Tables 2-6.

The results in Table 2 present the priority vector **W** as $[0.2679\ \ 0.2679\ \ 0.4641]^T$ indicating that road safety concern takes a higher priority compared to the other attributes with respect to the criterion state of deterioration. This raises worry as Road safety concern is an aspect that is eluded by most models by other scholars when prioritizing which road to repair (Lungu et al. 2022).

Table 2. Geometric means and priority vectors for sub-criteria S1 to S3 with respect to the criterion-state of deterioration (C1) for N=20 individual experts

		g	Normalized g	Priority vector W
S1	Degree of deterioration	0.25820	0.267949192	**0.2679**
S2	Extent of deterioration	0.25820	0.267949192	**0.2679**
S3	Road safety concern	0.44721	0.464101615	**0.4641**
	∑	0.96361	1.00000	1.00000

In an attempt to include climate change aspects in prioritization of which road to repair, the authors explore the relative importance of vulnerability to impacts of landslides, flooding and erosion. Vulnerability to the impacts of flooding was determined as the most important factor with the other sub-criteria to a lesser extent. This is presented in Table 3 and by the priority vector **W** = $[0.1487\ \ 0.53490\ \ 0.3123]^T$.

Table 3. Geometric means and priority vectors for sub-criteria S4 to S6 with respect to the criterion-climate resilience (C2) for N=20 individual experts

		g	Normalized g	Priority vector W
S4	Vulnerability to impacts of landslides	0.19911	0.148705437	**0.1487**
S5	Vulnerability to impacts of flooding	0.72174	0.539034121	**0.5390**
S6	Vulnerability to impacts of erosion	0.41810	0.312260442	**0.3123**
	∑	1.33895	1.00000	1.00000

Accessibility to health care is established as more than 50% of priority importance with respect to social aspects when considering which road to repair, as presented in Table 4. Detrimental social impact if not repaired is also a much important aspect compared to the other sub-criteria and this can be explained by the strong linkages from socio-economic and socio-environmental rolling effects due to social disbenefits incurred if the road is not repaired. The priority vector W from this table is presented by the matrix $[0.5680\ \ 0.1438\ \ 0.0731]^T$.

This study establishes that the economic value a road adds and economic viability in repairing the road are equally important in prioritization of a road for maintenance. Following that there are only two criteria compared with respect to the economic aspects, they are assigned 50% priority vectors as represented in Table 5 and as W = $[0.5000\ \ 0.5000]^T$.

Table 4. Geometric means and priority vectors for sub-criteria S7 to S10 with respect to the criterion-social (C3) for N=20 individual experts

		g	Normalized g	Priority vector W
S7	Accessibility importance to health care	0.5680	0.567950287	**0.5680**
S8	Accessibility importance to local market	0.1438	0.143849632	**0.1438**
S9	Accessibility importance to international markets	0.0731	0.073094709	**0.0731**
S10	Detrimental social impact if not repaired	0.2151	0.215105372	**0.2151**
	∑	1.0000	1.0000	1.0000

Results indicate that the maintenance of a road is more justifiable by the traffic volume it carries (Table 6) and is almost twice as important as the functionality of the road. This is presented by the priority vector capturing these two sub-criteria with respect to the criterion strategic importance and denoted as $[0.3660 \;\; 0.6340]^T$.

Table 5. Geometric means and priority vectors for sub-criteria S11 and S12 with respect to the criterion-economic (C4) for N=20 individual experts

		g	Normalized g	Priority vector W
S11	Economic viability	0.5000	0.5000	**0.5000**
S12	Economic value	0.5000	0.5000	**0.5000**
	∑	1.0000	1.0000	1.0000

This study further analyses the individual judgements for the established criteria C1 to C7 with respect to the first level hierarchy (goal). The goal of this hierarchy is denoted as: decision-criteria relevant to sustainable prioritize road for maintenance in an African context. Table 7 presents the established priority vectors for each criterion indicating that state of deterioration is to a lesser extent important than emergency function, strategic importance, and socio-economic aspects. This is more worrisome to models that have a bias in predetermining that state of deterioration on its own or other physical aspects are more important exclusively in prioritization of which road to repair (Lungu et al. 2022).

Table 6. Geometric means and priority vectors for sub-criteria S14 and S15 with respect to the criterion-strategic importance (C6) for N=20 individual experts

		g	Normalized g	Priority vector W
S14	Functionality	1.0000	0.366025404	**0.3660**
S15	Traffic	1.7321	0.633974596	**0.6340**
	∑	2.7321	1.0000	1.0000

Priority vector matrix W for S13 with respect to the criterion environment (C5) and S16 with respect to the criterion emergency function (C7) are both equal to [1], following that they are the only sub-criterion to make a judgement from with respect to their higher-level criterion.

Table 7. Geometric means and priority vectors for criteria C1 to C7 with respect to the level 1 hierarchy (goal) for N=20 individual experts

		g	Normalized g	Priority vector W
C1	State of deterioration	0.08930	0.099369515	**0.0994**
C2	Climate Resilience	0.07270	0.080902984	**0.0809**
C3	Social	0.13519	0.150431414	**0.1504**
C4	Economic	0.13902	0.154701445	**0.1547**
C5	Environment	0.05614	0.062474506	**0.0625**
C6	Strategic importance	0.18351	0.204198782	**0.2042**
C7	Emergency function	0.22280	0.247921355	**0.2479**
	∑	0.89866	1.00000	1.0000

In developing the utility matrix score card, this study establishes the rating classification of each sub-criteria as the descriptive contexts associated to the crisp value ratings **hi** as: 0=Low to none; 5=Moderate; and 9=Extreme. This study postulates that each qualitative description is subjective to the decision-makers standards and operating procedures followed or established in reference to local and international guidelines adopted following review of literature from a study by Lungu et al. (2022).

Further, the authors develop a matrix score card **Hi** algorithm for sub-criteria based on these utility rating crisp values **hi**, assigned to developed qualitative stratification for each recognized sub-criteria, and priority vectors **W** established for each sub-criterion with respect to its level 2 criterion (Equation 6).

$$H_i = \sum_{i=a}^{n} h_i x W_i \quad (Equation\ 6)$$

Finally, the algorithm for the determining the utility score to assign to a project alternative is developed based on the utility score **Hi** and the priority vector **W** established for each criterion with respect to the level 1 hierarchy (goal), as illustrated in Equation 7.

$$Utility\ score\ for\ road\ alternative\ needing\ repair\ = \sum_{i=a}^{n} H_i x W_i \quad (Equation\ 7)$$

Therefore, in this study this analysis yields the utility score for road alternative needing repair to be represented as:

$$Utility\ score\ for\ road\ alternative\ needing\ repair = Sum\ \boldsymbol{Matrix}\ (\boldsymbol{Score})$$
$$where:$$

$$\boldsymbol{Matrix}\ (\boldsymbol{Score}) = \begin{bmatrix} Score1 \\ Score2 \\ Score3 \\ Score4 \\ Score5 \\ Score6 \\ Score7 \end{bmatrix} = \begin{bmatrix} 0.0994 \\ 0.0809 \\ 0.1504 \\ 0.1547 \\ 0.0625 \\ 0.2042 \\ 0.2479 \end{bmatrix} x \begin{bmatrix} (h1x0.2679 + h2x0.2679 + h3x0.4641) \\ (h4x0.1487 + h5x0.5390 + h6x0.3123) \\ (h7x0.5680 + h8x0.1438 + h9x0.0731 + h10x0.2151) \\ (h11x0.5000 + h12x0.5000) \\ (h13x1) \\ (h14x0.3660 + h15x0.6340) \\ (h16x1) \end{bmatrix}$$

5.3 Proposed Improvements

The authors propose improving the model by taking advantage of including fuzzy logic in building crisp values for the comparative judgements. This follows the important role Fuzzy logic plays in handling possible uncertainties of the subjective datasets used in this study. (Moazami et al. 2011) take a fuzzy-AHP approach in developing their model but limit their decision-criteria to pavement condition and strategic importance aspects.

6. Conclusion

Studies by other scholars either limit their models to expert choice project selection scenarios tied to a study area or develop models that fail to address concerns of an African including important sustainability aspects. The model developed in this paper does not take a predetermined bias in limiting decision criteria to aspects such as pavement condition, functionality and traffic as do most models as indicated in a study by Lungu et al. (2022).

The primary contribution of this study is the ability of the authors to establish which decision-criteria to include, and their level of importance, in addressing sustainability and an African's concern. This study postulates that state of deterioration, climate resilience, social, economic, environment, strategic importance, and emergency function are the most important factors to consider. Furthermore, that state of deterioration is to a lesser extent important than emergency function, strategic importance, and socio-economic aspects. This paper also established sub-criteria with respect to each criterion and their relative level of importance.

Following the methodology adopted and these key findings, the authors recommend the development of a fuzzy AHP model and to perform variance and statistical analysis as a separate in-depth study to allow for model adjustments.

This study develops an algorithm score utility matrix as a project ranking tool for the prioritization of which public asphalt paved road to maintain, based on these characterized criteria and their respective sub-criteria following the established relative weights of importance from aggregated comparative judgements.

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Biographies

Kelvin Lungu is a University Lecturer and researcher at the University of Zambia. He holds a Masters in Civil Engineering from Stellenbosch University-Universiteit Stellenbosch and is currently pursuant of a PhD in Construction Management from the University of Zambia's School of Engineering. Kelvin is a strong pioneer of climate change adaptation and resilience through attaching himself in projects and research related to these subject matters and others including infrastructure development, public health and flood disaster management. Under these subject matters, he is also partisan to both local and international non-governmental organization efforts in implementing projects in Zambia aimed at attaining Sustainable Development Goals (SDGs). As a researcher, and related to the subject matter of climate change and disaster management, he has most recently: co-authored a paper published by CRC press in a book titled 'Building Smart, Resilient and Sustainable Infrastructure in Developing Countries'; while also co-authoring, a paper titled 'Government institutional emergent issues and gaps in disaster management mechanisms for WASH: a case study of Zambia's Kanyama peri-urban area' published by IWA publishing.

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Chabota Kaliba is a Director in a Zambian Civil Engineering Consulting Firm, and is a Lecturer and researcher from the University of Zambia. He is an expert in construction management with over 10 years' experience in planning, design and construction of engineering infrastructure. He has research experience varying from construction management to highway engineering, as well as climate resilience studies for roads in Zambia. He holds a PhD. In Construction Management from the University of Zambia, MEng. in Construction Management from said University while also a MPhil., from University of Stellenbosh in South Africa. Kaliba is the past Chairperson for the Civil and Structural Engineering Section of the Engineering Institution of Zambia, and is a recognized Fellow under said institution. He is a member of a number of committees including the Steering Committee for Development of Standards for Roads in Zambia, and the Ethics and Disciplinary Committee of the Engineering Institution of Zambia. Kaliba has published several peer reviewed papers, and supervised and examined both Masters and PhD. students while most recently (2022) co-authoring a book chapter 'Building Smart, Resilient and Sustainable Infrastructure in Developing Countries'-published by CRC press.

Pumza Mpundu is a Transport Infrastructure Engineer at the Road Development Agency (RDA). He is a Chevening scholar currently pursuing a Master of Science in Transport Infrastructure: Design and Construction from the University of Leeds in the United Kingdom. He holds a Masters in Business Administration from the University of

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