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Strategic Decision-Making for Rural Pavement Maintenance in Myanmar: A Multi-Criteria Analysis Frame Work

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***Abstract*— The achievement of Myanmar's poverty reduction and economic growth goals depends on the development of rural infrastructure. This study introduces a unique multi-criteria analysis (MCA) methodology for rural pavement network maintenance essential for access to critical services, economic productivity, and rural living standards. Fuzzy Multi-Criteria Decision Making (FMCDM) is a comprehensive system that enhances the sustainability and effectiveness of maintenance measures, optimizes resource allocation, and prioritizes maintenance activities. The proposed approach provides a systematic method for prioritizing maintenance interventions by considering functional distress and the significant influence of pavement roughness on user perception. The framework's applicability was demonstrated using field data from ten rural roads in Myanmar. The study compares the Priority Index (PI) rankings of the Moenethraphu-Kyar Ton Road with the Hlegon-Moenethraphu Road, emphasizing the urgent repair need. This research presents a systematic approach to rural pavement maintenance in Myanmar, contributing to the conversation on infrastructure development in developing countries.**

***Keywords*—Fuzzy Multi-Criteria Decision Making (FMCDM); Priority Index (PI); rural road; Myanamar, maintence**

I. INTRODUCTION

The development of rural infrastructure in Myanmar remains crucial to the nation's broad efforts to overcome poverty as well as achieve sustainable economic growth. Among the fundamental elements of rural infrastructure, the maintenance of rural pavement networks emerges as a strategic imperative, vital for facilitating access to essential services, enhancing economic productivity, and raising the overall standard of living in rural communities [1]. Rural pavement preservation requires strategic decision-making procedures that are aware of several socio-economic, environmental, and technological facts and must be considered for resource allocation to be effective [2, 3].

In light of this, this paper proposes the comprehensive multi-criteria analysis framework for strategic decision-making in rural pavement maintenance in Myanmar. By integrating multiple criteria and stakeholder perspectives, this framework offers a systematic approach to prioritizing maintenance interventions, optimizing resource allocation, and enhancing the sustainability and effectiveness of rural pavement maintenance efforts [4]. This paper aims to offer practical insights and evidence-based suggestions to support the effective management of rural infrastructure in Myanmar, contribute to the formulation of policies, and guide investment decisions through the lens of multi-criteria analysis. The present introduction provides the basic concepts for a comprehensive discussion of the multi-criteria analysis framework and its practical application in rural pavement maintenance contexts in Myanmar. By addressing the complex challenges and opportunities in rural infrastructure management, this paper aims to contribute to the wider discussion on the development of infrastructure and strategic decision-making in emerging economies like Myanmar.

II. OBJECTIVE

This research aims to create and suggest the thorough multi-criteria analysis (MCA) especially designed to direct strategic decision-making procedures in rural pavement repair in the Myanmar environment. The framework seeks to accomplish the following particular objectives:

- To the road pavement sections in order of priority utilizing a Fuzzy Multi-Criteria Decision Making (FMCDM) methodology.
- To maximize resource allocation for rural pavement maintenance by using multiple criteria and stakeholder viewpoints.
- To improve rural pavement repair programs' effectiveness and sustainability.

III. LITERATURE REVIEW

A literature review was undertaken to gain thorough knowledge of pavement performance and modeling techniques. Globally, a great deal of research has been done to create models of roadway performance.

Reddy, B.B., and Veeraragavan, (2002) established a priority ranking method for managing flexible pavement when connecting the network. In this study, a priority ranking module prioritizes road pavement sections by contributing a systematic performance to upgrade and select applicable maintenance plans based on financial constraints [5].

Sathyakumar and Vijayakumar (2004) developed a methodology for using composite facts to access the priority of maintaining roadway pavements. A questionnaire survey for a functional evaluation was carried out following the usage of a survey to obtain expert and user comments in order to ascertain the proportion of distress, which are cracking areas, potholes, and the current serviceability index. [6].

Based on information from the road inventory, the route's functioning state, the potential for tourism, and important connecting principal roads, Sreedevi (2006) created an improvement priority index. This report discusses the research applied to 80 road links, totaling 441 km in length, that connect to tourist attractions in order to make improvements [7].
Gunaratne & Bandara (2001) evaluated the fuzzy multi-criteria decision-making procedure by generating alternatives for various scenarios since it offers an optimal choice in such uncertain settings [8].
These studies provide the basis for the development of a strong framework for rural pavement maintenance, highlighting the significance of systematic prioritization, stakeholder participation, and the incorporation of multiple criteria to improve decision-making processes.

IV. DATA COLLECTION

In order to compile information on pavement condition, ten rural roads with suitable pavement histories were selected. There was a test portion of every road that avoided hairpin curves and steep climbs. Each test portion was subdivided into 20 subsections, each measuring 25 meters, in order to preserve homogeneity throughout the area. The test sections were kept to a total length of 0.5 km. Ten distinct routes were listed in Table 1.

TABLE I. THE LIST OF CHOSEN ROAD SEGMENTS

Road ID	Name of the Project Road	Type of Pavement
R1	Kanlaung-Zale Road	Flexible
R2	Nyaung Shwe-Kanu Road	Flexible
R3	Lwe Ont-Hti Bwar Road	Flexible
R4	Hlegon-Moenethraphu Road	Flexible
R5	Moenetharaphu-Kyar Ton Road	Flexible
R6	Kanlaung-Zale Road	Flexible
R7	Nyaung Shwe-Kanu Road	Flexible
R8	Lwe Ont-Hti Bwar Road	Flexible
R9	Hlegon-Moenethraphu Road	Flexible
R10	Moenetharaphu-Kyar Ton Road	Flexible

There was a separate visual condition study done for each portion of the route. Numerous signs of distress, such as rutting, bleeding, longitudinal cracks, potholes, and raveling, had been noted along the section and were expressed as a percentage of the entire pavement area, and rutting was expressed in millimeters. According to the results of a visual condition survey, the main causes of distress in the chosen area were discovered to be raveling, potholes, edge drops, and bleeding.

V. DATA ANALYSIS, RESULTS AND DISCUSSION

A. Pavement Prioritization through Fuzzy Logic

The fuzzy set theory aims to clarify the uncertainty present in each specific situation [9]. A fuzzy set is recognized as a fuzzy number $\tilde{A}$, and the membership function of the fuzzy set is considered as $\mu_{\tilde{A}}(x): R \rightarrow [0,1]$ represented by the letter "x" as criteria [10, 11]. Triangular fuzzy numbers (TFNs) are fuzzy numbers that correspond to a linear membership function, a commonly used function [2]. TFNs are a particular type of fuzzy numbers, determined by three real numbers (l, m, n), and are pictorially shown in Figure 1 [2].

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{(x-l)}{(m-l)}; & l \le x \le m; \\ \frac{(n-x)}{(n-m)}; & m \le x \le n; \\ 0; & \text{Otherwise;} \end{cases}$$

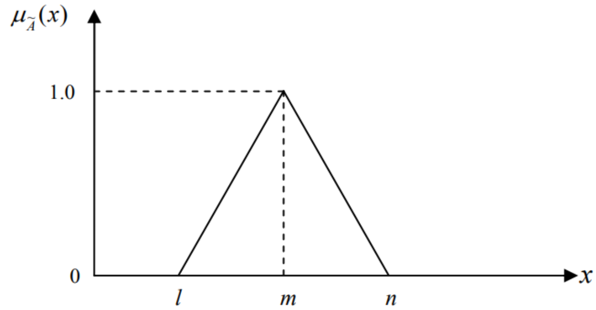

Fig. 1. *Triangular Fuzzy Numbers Membership Function [2]*

When $\tilde{A} = (l, m, n)$ and $\tilde{B} = (p, q, r)$, the following are the general operations [2].

Two fuzzy numbers are added,

$$(l, m, n) \oplus (p, q, r) = (l + p, m + q, n + r) \quad (1)$$

Two fuzzy numbers are subtracted,

$$(l, m, n)\ \Theta\ (p, q, r) = (l - r, m - q, n - p) \quad (2)$$

Any fuzzy integer multiplied by a real number "k",

$$k \otimes (l, m, n) = (kl, km, kn) \quad (3)$$

B. Prioritization Process

The strategies suggested by different scholars have been used to prioritize the possibilities for pavement sections [10]. The following steps provide an explanation of the prioritization process.

(a) A straightforward normalization, as illustrated below, is used to normalize data gathered in the field on a range from 0 to 100, representing the highest value of that series [2]. Then, the normalized value is equal to the actual value divided by the maximum value in that series [2]. Table 2 presents a synopsis of normalizing data. Ten groups were

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created using the normalized distress levels, arranged in ascending order with a uniform spacing of l0. Each group was then rated between 1 and 10 and 91 and 100, respectively, and shown in Table 3.

(b) Triangular Fuzzy Numbers (TFN), which are displayed in Table 4, are the linguistic variables given for describing the impact of roughness and severity of distress parameters.

(c) Raveling, bleeding, potholes, and edge drops are characteristics that differentiate the three severity degrees of distress: low, medium, and high, and the study used actual IRI values collected from the chosen road segments to classify roughness into three severity levels, which are low, medium, and high, with Raters' guideline for visual assessment of road pavements (Draft 1) reported by M. Pinard and R. Geddes, (2019) [12], and the degrees of distress are stated in Table 5. The relationship between various degrees of roughness and distress is displayed in Table 6.

(d) The impacts of roughness and severity of distress in terms of linguistic qualities stated in Table 6 were converted into fuzzy integers using the TFNs given in Table 4 and arranged in a weight matrix (W_j) as shown in Table 7.

TABLE II. NORMALIZED DATA ON PAVEMENT CONDITION FOR A CHOSEN SEGMENT

Road ID	LRA	MRA	HRA	LBA	MBA	HBA	LPO	MPO	HPO	LED	MED	HED	LRO	MRO	HRO
R1	82	4	50	97	22	0	33	17	100	74	7	0	0	0	97
R2	95	2	0	100	7	0	95	67	0	98	27	0	0	0	83
R3	39	24	100	0	0	0	20	20	0	53	7	0	100	0	0
R4	74	20	0	0	0	0	37	0	0	82	0	0	91	0	0
R5	12	100	7	5	100	0	9	50	100	39	100	0	0	0	99
R6	12	29	20	0	10	0	35	100	0	33	6	80	0	0	82
R7	56	100	50	12	56	75	60	50	0	74	40	100	91	0	0
R8	10	3	64	0	44	100	45	0	0	72	80	0	0	0	81
R9	10	0	0	6	7	0	17	0	0	58	16	33	94	0	0
R10	56	4	10	10	20	50	83	0	0	79	8	10	98	0	0

TABLE III. RATING MATRIX FOR ROUGHNESS AND DISTRESS PARAMETERS

Road ID	LRA	MRA	HRA	LBA	MBA	HBA	LPO	MPO	HPO	LED	MED	HED	LRO	MRO	HRO
R1	9	1	5	7	0	0	4	2	10	8	1	0	0	0	10
R2	10	1	0	10	1	0	10	7	0	10	3	0	0	0	9
R3	3	3	10	0	0	0	2	2	0	6	1	0	10	0	0
R4	8	2	0	0	2	0	9	2	0	8	0	0	10	0	0
R5	2	10	1	1	10	0	1	5	10	4	10	0	0	0	10
R6	2	3	2	0	1	0	4	10	0	4	1	8	0	0	9
R7	5	10	5	2	5	8	6	5	0	7	4	10	10	0	0
R8	2	1	7	0	5	10	5	0	0	8	8	0	0	0	9
R9	2	0	0	1	2	9	7	2	0	8	2	4	10	0	0
R10	5	1	1	1	2	4	9	0	0	8	1	1	10	0	0

TABLE IV. TRIANGULAR FUZZY NUMBERS (TFN) FOR LINGUISTIC VARIABLES

Triangular variable for linguistics	Fuzzy Numbers (TFN)		
Very Low (VL)	0	0	0.3
Low (L)	0.1	0.3	0.5
Medium (M)	0.3	0.5	0.7
High (H)	0.5	0.7	0.9
Very High (VH)	0.7	1	1

TABLE V. STATEMENT OF THE DEGREES OF PAVEMENT DISTRESS

Sr. No	Distress Types	Severity Levels	Description/ Statement
1	Raveling	Low	Loss of individual stones that is apparent upon closer examination.
		Medium	Noticeable stone loss in small areas.
		High	Widespread stone loss over a large area affecting all layers.
2	Bleeding	Low	Surfacing has a small amount of extra binder.
		Medium	Surfacing has a rich extra binder and a sleek appearance.
		High	Surfacing with a high binder content gives the pavement surface an oily appearance. A layer of excess binder covering every stone in the wheel areas. When it's summertime, the surface is sticky, and the binder may pick up wheel prints.
3	Potholes	Low	Diameter is < 250 mm.
		Medium	Diameter is > 250 mm and depth is > 60 mm.
		High	Diameter is > 500 mm and depth is > 75mm or serious defects.
4	Edge Drops	Low	<50mm
		Medium	≈ 75mm
		High	>100mm
5	IRI	Low	< 3.5 m/km
		Medium	3.5 – 4.5 m/km
		High	> 4.5 m/km

TABLE VI. THE IMPACT OF ROUGHNESS AND DISTRESS

Intensity of Various Distress		Linguistic Variable Assigned
Low Raveling	(LRa)	Low
Medium Raveling	(MRa)	Medium
High Raveling	(HRa)	High
Low Bleeding	(LB)	Low
Medium Bleeding	(MB)	Low
High Bleeding	(HB)	Medium
Low Pothole	(LP)	Medium

TABLE VII. FUZZY ASSESSMENT VALUES PI FOR ROAD SEGMENTS

Criteria		Fuzzy Weight		
Low Raveling	(LRa)	0.1	0.3	0.5
Medium Raveling	(MRa)	0.3	0.5	0.7
High Raveling	(HRa)	0.5	0.7	0.9
Low Bleeding	(LB)	0.1	0.3	0.5
Medium Bleeding	(MB)	0.1	0.3	0.5
High Bleeding	(HB)	0.3	0.5	0.7
Low Pothole	(LP)	0.3	0.5	0.7
Medium Pothole	(MP)	0.5	0.7	0.9
High Pothole	(HP)	0.7	1	1
Low Edge Failure	(LE)	0	0	0.3
Medium Edge Failure	(ME)	0.1	0.3	0.5
High Edge Failure	(HE)	0.3	0.5	0.7
Low Roughness	(LRo)	0.1	0.3	0.5
Medium Roughness	(MRo)	0.3	0.5	0.7
High Roughness	(HRo)	0.5	0.7	0.9

(e) The weight matrix (W_j) and rating matrix (R_{ij}) were multiplied to obtain the fuzzy evaluation value (P_i), which was then added together for each stretch and displayed in Table 8. The following is the mathematical expression for the process [2]:

$$\tilde{P}i = \sum_{j=1}^{M} Rij \otimes \tilde{W}j \quad (4)$$

TABLE VIII. FUZZY WEIGHT MATRIX FOR DIFFERENT PARAMETERS

Road ID	Fuzzy Evaluation Value (P_i)		
R1	18.7	29.5	39.7
R2	13.7	23.9	37.1
R3	8.9	15.1	23.1
R4	6.3	12.9	21.9
R5	20.6	33.6	44.8
R6	15.4	23.4	32.6
R7	17.8	31.8	47.9
R8	14.3	23.7	35.5
R9	8.7	16.5	26.7
R10	6.9	13.9	23.3

(f) In order to determine each stretch's relative preference, the difference between each combination of fuzzy values has been calculated. To determine the extent of preference, the fuzzy preference relation matrix has been constructed and is displayed in Table 9.

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TABLE IX. THE MATRIX OF FUZZY PREFERENCE RELATIONS

Road ID	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	0.50	0.75	1.64	1.81	0.35	0.85	0.39	0.78	1.37	1.67
R2	0.32	0.50	1.09	1.23	0.22	0.55	0.26	0.52	0.93	1.13
R3	0.03	0.13	0.50	0.65	0.01	0.12	0.03	0.13	0.41	1.38
R4	0.01	0.09	0.37	0.50	0.00	0.08	0.02	0.09	0.31	0.44
R5	0.69	0.95	1.93	2.09	0.50	1.09	0.53	0.99	1.63	1.94
R6	0.25	0.45	1.16	1.33	0.16	0.50	0.20	0.47	0.95	1.21
R7	0.62	0.83	1.54	1.67	0.47	0.93	0.50	0.86	1.34	1.56
R8	0.30	0.48	1.11	1.26	0.20	0.53	0.24	0.50	0.93	1.16
R9	0.08	0.20	0.60	0.74	0.04	0.20	0.07	0.20	0.50	0.66
R10	0.03	0.12	0.43	0.56	0.01	0.11	0.03	0.11	0.36	0.50

(g) The following mathematical formula is used to determine the Priority Index (PI) for each pavement length based on the matrix of the fuzzy preference relation [2, 13].

$$(PI)i = \sum_{j=1}^{n} (eij - 0.5) \tag{5}$$

(h) Based on the PI, each stretch has been ranked and is displayed in Table 10. The previously stated processes demonstrate how many criteria and spans are involved in the process of prioritization, which makes it quite complex and time-consuming. In Table 10, R4 has the lowest PI of -3.096 and the lowest priority, whereas R5 has the greatest PI of 7.340 and the highest priority.

TABLE X. THE PAVEMENT STRETCHES: RANKING ORDER

Road ID	Priority Index	Rank Based PI
R1	5.110	3
R2	1.736	4
R3	-1.622	7
R4	-3.096	10
R5	7.340	1
R6	1.696	6
R7	5.322	2
R8	1.707	5
R9	-1.716	8
R10	-2.738	9

VI. CONCLUSION

Managing infrastructure maintenance on road networks is a complicated multi-criteria decision-making problem. A systematic method must consider various essential factors in the decision-making process, as road surfaces naturally deteriorate over time due to weather conditions and high traffic volumes. Inspections are essential to identifying various types of damage, which facilitates identifying appropriate maintenance methods to ensure the road remains in optimum condition and functional for an extended period.

An initial evaluation is carried out to determine the most crucial road faults, an essential initial stage of a productive maintenance management system, facilitating informed decision-making for upcoming maintenance procedures.

Using information gathered from the field, the suggested fuzzy multi-criteria decision-making strategy is demonstrated. This robust method can be expanded to prioritize any given road network. Priority is assigned to the road link with the highest priority index (PI), and vice versa. In this study, Hlegon-Moenethraphu Road requires immediate attention and maintenance as it has the lowest PI of -3.096 and the lowest priority, while Moenetharaphu-Kyar Ton Road, having likely undergone recent maintenance efforts, offers a superior driving experience due to its high PI of 7.340 and the highest priority. This method provides an accessible and systematic method for managing and prioritizing the maintenance of rural pavements. It ensures that resources are allocated optimally and improves the overall state of the road network.

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