Performance Modelling of Flexible Rural Road Pavements in Myanmar

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Abstract

The study aims to determine the factors influencing rural road pavement conditions in Myanmar to improve maintenance and extend pavement lifespan. This paper calculates the visual pavement condition index (VCI) using guidelines for the visual assessment of road pavement and develops a performance model for flexible rural pavements using regression analysis. Visual inspections indicated that ravelling, potholes, edge drops, and bleeding were the most common distresses, highlighting the need for targeted maintenance, especially for severe distress problems. The findings indicate that the positive correlation between pavement condition and construction quality can be statistically explained by the multiple linear regression model. In contrast, pavement condition was negatively affected by factors such as ravelling, edge drop, bleeding, potholes, and pavement age. This study helps authorities allocate resources to reduce poverty and achieve Myanmar's development objectives. Rural road networks may benefit from evidence-based pavement management, enhancing socioeconomic development and community well-being.

Keywords: *Flexible Pavement, Visual Pavement Condition Index, Rural Road, Regression Analysis*

I. Introduction

In Myanmar, rural areas have a more significant proportion of the settled population than urban areas, and most people in rural areas require an acceptable socio-economic standard of living. However, the government is facing various challenges in achieving its goals of reducing rural poverty and promoting national development. The rural road sector is essential in solving the above challenges because roads are the fundamental infrastructure for rural growth. Establishing rural roads facilitates efficient communication between urban and rural areas through rural road networks. As rural roads provide direct connections between the agricultural and production sectors, this is essential for the social and economic development in rural areas. Even while rural road networks are important, planning and development of these networks in Myanmar have required more methodical and scientific techniques, which has resulted in infrastructure that is vulnerable to, especially during unfavourable weather conditions like the rainy season [1]. Moreover, poor quality control during construction, inadequate maintenance afterwards, and limited budgets contribute to faster road deterioration [2].

Therefore, regular inspections are vital for investigating current conditions and obtaining valuable data for pavement condition surveys. Predicting pavement performance is also essential for developing timely maintenance strategies to prevent future deterioration, as delays in repair could significantly increase costs [3]. Pavement managers rely on pavement performance modelling as a crucial tool when making decisions, including setting priorities and allocating funds for maintenance work [4].

In Myanmar, the Department of Rural Road Development (DRRD) is currently in charge of building and maintaining rural roads. DRRD initiated Long-Term Pavement Performance (LTPP) monitoring initiatives to strengthen rural road infrastructure, supported by technical assistance from Research for Community Access Partnership (ReCAP). These initiatives use evaluation and monitoring procedures to build a reliable rural road network in Myanmar. In order to support these initiatives, Raters' Guidelines for the Visual Assessment of Road Pavements were used to collect the pavement condition, thus enabling comprehensive evaluation and monitoring of rural road infrastructure [5].

However, in Myanmar, very few studies have been carried out for the performance of flexible rural roads with existing guidelines. It highlights a significant research gap. In light of this consideration, this paper aims to identify parameters related to pavement performance on rural roads and to conduct the prediction of performance models for flexible pavements on roads in rural areas using visual inspection data and regression analysis. This study aims to provide helpful information that will help improve maintenance strategies and make rural road infrastructure in Myanmar more durable. Ultimately, this will help reach the main goals of reducing poverty and promoting national development. Then, four components will be examined in this study: the literature review, the methodology study, the result and discussion, and the summary and conclusion.

II. LITERATURE REVIEW

A variety of prediction models have been created to pavement management systems to forecast the performance of flexible pavements. The models make noteworthy contributions by explaining the deterioration of pavement and the required upkeep.

Sung-Hee Kim and Nakseok Kim (2006) [6] established asphalt pavement function models of prediction for highways by using PACES data and rating systems. By employing fundamental and multi factor regression studies, they determined that the linear regression model is efficient in cases where the PACES Ratings exceed 70. On the other hand, the multiple linear regression model showed better results under varying Average Annual Daily Traffic (AADT) conditions, highlighting the significance of adding traffic variability into predictive modelling.

Makendran et al. (2023) [7] evaluated various forms of distress, such as roughness, flaking, and craters, to develop multilinear regression analysis-based models for predicting distress. Their model's coefficient of estimation was 0.8, meaning that the Pavement Condition Index (PCI) prediction deviation was accounted for in 80% of the cases. This highlights the effectiveness of multilinear regression in capturing the multifaceted and varied characteristics of the progression of pavement distress.

Namir G. Ahmed et al. (2008) [8] aimed to construct a predictive model for PCI in flexible pavements. They identified slippage cracks, potholes, and rutting as common factors influencing pavement condition to achieve this. By integrating these variables, they developed an all-encompassing PCI model that generates an overall full assessment of the pavement's state.

Sasan Adeli et al. (2021) [9] estimated the relationship between PCI and International Roughness Index (IRI) in rural road networks employing a model of regression using linearity. The research established a major emphasis on the importance of various factors, including bleeding, weathering, and low-severity alligator cracking, in their impact on the calculation of PCI. Moreover, they proposed that the constructed model is ideally suited for rural road networks featuring asphalt pavements that do not exhibit the identified defects. This shows the significance of developing models to suit particular pavement conditions and contexts.

These studies highlight many methodologies and variables used to develop performance models for flexible pavements. Each study provides vital information on the causes of pavement deterioration and the maintenance requirements. Therefore, the aim of this study is to create suitable function models for Myanmar's rural roadways, improving the efficiency of pavement management strategies and eventually promoting the sustainable future of rural road infrastructure.

III. METHODOLOGY OF STUDY

The research methodology includes many key steps, including identifying the study area, gathering data, analysing the data, and developing a pavement performance model. Regression analysis is the main technique used in this study to evaluate the performance model of flexible pavements on rural roads.

3.1. Study Area

Ten rural roads, which are with proper pavement history and are constructed under Department of Rural Road Development (DRRD) in Shan State, are selected as the study area. To evaluate and analyse within the section, twenty 25-meter-long subsections were created from each test section. The total length of the test sections was maintained at 0.5 km. The list of selected road sections is reported with Table 1.

Table 1: The list of test sections in ten roads

Road ID	Name of Project Road	Type of Pavement	Length of Road(km)
R1	Taung Ni-Taung Lay Lone Road	Flexible	2.1
R2	Ywar Ngan-Na Palm Gyi Road	Flexible	4.53
R3	Kum Par Ni-Paw Toke Road	Flexible	5.67
R4	BawNing-Tayetpu-Kumparni- Suu Pan Inn Road	Flexible	12.48
R5	Pin Pyint-War Pyar Road	Flexible	11.37
R6	Kanlaung-Zale Road	Flexible	17.36
R7	Nyaung Shwe-Kanu Road	Flexible	6.51
R8	Lwe Ont-Hti Bwar Road	Flexible	7.11
R9	Hlegon-Moenethraphu Road	Flexible	7.8
R10	Moenetharaphu-Kyar Ton Road	Flexible	6.5

3.2. Data Collection

Data Collection was conducted by a pavement condition survey and was collected five times in a three-year period: in July and October 2018, April and August 2019, and January 2020. During each survey, the surfacing assessments, structural assessments, and functional assessments, which were classified according to their nature, degree, and extent, were gathered according to Raters' Guidelines for the Visual Assessment of Road Pavements. Additionally, roughness data was obtained using the free smartphone application "Road Lab Pro." Moreover, traffic data, such as California Bearing Ratio (CBR) and Equivalent Standard Axle (ESA), were also collected in this study.

3.3. Performance Modelling

The Visual Condition Index (VCI) was computed using a predetermined formula that takes into account degree ratings, extent ratings, and weights for each detected defect, based on the gathered distress data. The Visual Condition Index (VCI) is a numerical assessment of the overall state of pavement, ranging from 0 to 100. The VCI formula is:

$$\text{VCI} = 100\,(1- C\sum_{i=1}^{n} F\text{i}) \quad (1)$$

Where:

Fi = Di × Ei × Wi

I = Item number for the visual assessment
N = number of items
Di = Defective rating in terms of degree i
Ei = Defect rating's extent i
Wi = Defective weight i

$$C = 1 \div \sum_{i=1}^{n} F\text{i(max)}$$

Fi (max)= Fi with the rating of Di and Ei at their highest possible values (5)
VCI = Visual Condition Index, rating from 0 to 100 (min to max)

Following this, a data analysis was performed utilizing the VCI index, wherein conditional categories classified pavement conditions as very good, good, moderate, bad, or very poor were established, in accordance with Raters' guideline for visual assessment of road pavements (Draft 1) reported by M Pinard and R Geddes, (2019) [5, 10].

Furthermore, multi linear regression analysis was employed to examine the variables that impact pavement performance, in addition to calculate the Visual Condition Index (VCI) for pavement condition assessment. The VCI was the dependent variable in this study, while other independent factors were taken into account, such as pavement age, volume of commercial vehicles, CBR, construction quality and observed distress types.

IV. RESULTS AND DISCUSSION

For every section of the road, visual condition survey was conducted. Various forms of distress have been observed along the stretches, including rutting, bleeding, longitudinal cracks, potholes, and ravelling. Pavement distresses are classified using the degree and extent classification system, according to guidelines. Numbers on a 0 to 5 scale represent the "degree" of particular distress, which measures its severity throughout the area of the pavement under investigation (0 indicating nonvisible distress, and 5 indicating severe condition). The "extent" of the distress indicates how widespread the distress is through the pavement segment that is being examined. Ravelling, potholes, edge drops and bleeding were found as main distresses in the selected area.

It was observed that the above-mentioned main distresses with higher severity, particularly at degree 3 and extent 3, may require targeted maintenance to prevent further deterioration and safety hazards.

The Visual Conditional Index (VCI) is computed using the results of a survey on visual condition that determines the type, degree, and extent of distress. The pavement condition is determined by the numerical index of whether the performance is failing or perfecting in terms of a rating from 0 to 100.

The pavement thickness layers and the subgrade's CBR value were applied as data on the structural condition of this study in the selected road sections. Maximum dry density of the associated roads and field dry density were used to determine each road section's relative compaction [11]. A function of the percentage reduction in pavement thickness, relative compaction, CBR, and IRI was used to model the construction quality (CQ). The CQ was measured for rural roads and ranged from 0 to 1 rating from low to high. The variety of values that can be utilized to determine the CQ is shown in Table 2 [11].

Table 2: Values used for the quality of construction (CQ)

CBR		**IRI**		**%of reduction design thickness**		**relative compaction**		**Total weight**	**Construction Quality**
Range	**Weight**	**Range**	**Weight**	**Range**	**Weight**	**Range**	**Weight**		
30	5	Below 2.5	5	0-1	5	97-100	5	20	1
15-29	4	2.5-3.69	4	1-2	4	93-96	4	16	0.75
8-14	3	3.7-4.09	3	2-3	3	89-92	3	12	0.5
5-7	2	4.1-5.59	2	3-4	2	85-88	2	8	0.25
3-4	1	above 5.6	1	>4	1	<85	1	4	0

After necessary data are collected, performance modelling was carried out. In this study, regression analysis was used. Mainly simple regression analysis was performed by using SPSS software. Table 3 describes collected pavement condition and traffic data and these data were defined as input data in the model.

Table 3: Additional Data Collection in the study area

Road-ID	Age	ESA (x10 ^{6})	CBR %	CQ	VCI
R1	4.5	1.54	12.45	0.563	39.52
R2	4.5	0.62	11.35	0.500	80.32
R3	2.5	0.42	12.46	0.695	80.45
R4	2.5	1.26	11.48	0.695	85.03
R5	2.5	0.98	11.27	0.500	37.82
R6	2.5	1.11	11.6	0.500	50.12
R7	2.5	0.55	11.6	0.563	83.12
R8	2.5	0.51	15.83	0.625	78.85
R9	2.5	0.61	12.2	0.625	81.93
R10	2.5	0.61	15.05	0.695	81.92

In order to develop a model of performance for Myanmar's flexible rural road pavement, a regression study was employed. The results were very useful because they provided a numerical analysis of the factors that affect the Visual condition Index (VCI) of the pavement state. The model used for regression shows a significant level because the R-square value is 0.738 which expresses that the variation of VCI is roughly 73.8%, explained by the independent components in the model. Table 4 shows the summary of the model.

Table 4: Summary of Regression Model

Model No.	R value	R Square value	Adjusted R Square value	Std. Error of the Estimate
1	.859	.738	.736	8.22912

In table 5, the p value - 0.000 and 0.003 which was less than 0.05, hence the result was significant at 5% level of significance. Therefore, VCI depends on different dimensions like ESA, Ravelling, CQ, Bleeding, Edge Drop, Age and Pothole, as shown in the final MLR Model summary in Table 5.

Table 5: Coefficients of Each Variable

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	76.609	2.350		32.604	.000
	ESA	-15.412	1.507	-.337	-10.229	.000
	Ravelling	-.885	.064	-.285	-13.769	.000
	CQ	41.498	3.490	.346	11.892	.000
	Bleeding	-.680	.083	-.162	-8.201	.000
	Edge drop	-.777	.103	-.155	-7.551	.000
	Age	-1.460	.392	-.090	-3.722	.000
	Pothole	-.579	.191	-.061	-3.026	.003

The final model indicates that the positive coefficient linked to construction quality indicates that better pavement condition results from greater construction quality, which in turn leads to higher VCI values.

ESA, ravelling, edge drop, bleeding, pothole and pavement age are found to be negative impact on a decrease in pavement condition as indicated by VCI.

As a result, rural roads with high ravelling, high potholes, high bleeding will contribute to pavement distress and safety hazards and low CQ will deteriorate more quickly over the years. Moreover, edge drop is one of the important contributing factors, which is the variation in elevation between the shoulder and pavement edge that can be caused by various factors such as the narrow carriage way width, the strength of the subgrade, and the drainage system.

V. SUMMARY AND CONCLUSION

This study presents significant findings regarding the factors that impact the condition of flexible rural road pavements in Myanmar, such as enhancing maintenance approaches and extending the lifespan of pavements. A visual pavement condition survey was conducted in this study. Through visual condition surveys, ravelling, potholes, edge drops, and bleeding were found to be the main distress on all roads. These distresses, especially degree 3 and extent 3, require targeted maintenance to prevent future deterioration and ensure safety of all roads.

MLR model was developed to study the relationship between independent variables (ESA, ravelling, CQ, bleeding, edge drop, age, and pothole) and the dependent variable, VCI. The model has significant explanatory power, with independent variables explaining around 73.8% of the variance in VCI. Better construction quality and pavement condition are positively correlated, according to the investigation, raising VCI values. In contrast, various factors including ravelling, edge drop, bleeding, potholes, and pavement age, have a negative impact on the condition of pavements and contribute to distress and safety hazards. Rural roads with high levels of distress, low construction quality, and severe edge drop are vulnerable to rapid degradation over time. Hence, it is essential for strategic maintenance interventions to prioritize the resolution of these particular concerns to optimize the durability and safety of pavements. By undertaking targeted interventions focusing on improving construction quality and addressing specific distress causes, rural road networks in Myanmar can enhance their performance and resilience against deterioration over time.

This study can help with making policy decisions and allocating resources for rural road infrastructure development and maintenance, contributing to Myanmar's poverty reduction and fulfilling national development objectives. Authorities may preserve and improve the development of reliable rural road networks using systematic and evidence-based pavement management methods, enhancing socio-economic development and rural community well-being.

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REFERENCES

[1]. Md. Musleh Uddin Hasan et al, (2022) "A Methodology for Planning and Prioritisation of Rural Roads in Bangladesh", *Sustainability*, Volume 14, Issue 4, pp. 1-16.

[2]. Sharad.S.Adlinge, Prof.A.K.Gupta, (2013) "Pavement Deterioration and its Causes", *International Journal of Innovative Research & Development,* Volume 2, Issue 4, pp. 9-15.

[3]. Rustam Hafizyar and Mohammad Ali Mosaberpanah, (2018) "Evaluation of Flexible Road Pavement Condition Index and Life Cycle Cost Analysis of Pavement Maintenance: A Case Study in Kabul Afghanistan", *International Journal of Scientific & Engineering Research*, Volume 9, Issue 8, pp. 1909-1919.

[4]. Susan Rose et al, (2010) "Pavement Performance Modelling and Calibration of HDM-4 Deterioration Models for Rural Roads in India", *Journal of the Institution of Engineers (India)*, Volume 91, pp. 3-10.

[5]. M Pinard and R Geddes, (2019) "*Raters' guideline for visual assessment of road pavements, Part B: flexible pavement*", Draft 1.

[6]. Sonny Kim and Nakseok Kim, (2006) "Development of Performance Prediction Models in Flexible Pavement Using Regression Analysis Method", *KSCE Journal of Civil Engineering*, Volume 10, No 2, pp. 91-96.

[7]. Makendran Chandrakasu, (2023) "Performance Prediction Modelling for Flexible Pavement on Low Volume Roads Using Multiple Linear Regression Analysis", *Journal of Applied Mathematics*, Volume 2015, pp. 1-7.

[8]. Namir G. Ahmed et al, (2008) "Development of Pavement Condition Index Model for Flexible Pavement in Baghdad City", *Journal of Engineering*, Volume 14, pp. 2120-2135.

[9]. Sasan Adeli et al, (2021) "Development of a Relationship between Pavement Condition Index and International Roughness Index in Rural Road Network", *Advances in Civil Engineering*, Volume 2021, pp. 1-9.

[10]. Andrew Otto et al, (2020) "The Impact of Drainage on the Performance of Low Volume Sealed Roads", *Sustainability*, Volume 12, Issue 16, pp. 1-15.

[11]. Subitha P et al, (2020) "Development of Pavement Deterioration Prediction Models for Low Volume Roads Using System Dynamics", *Journal of Transportation Engineering, Part B: Pavements*, Volume 146, Issue 3, pp. 1-11.

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