Pavement Maintenance and Management System for Sangli District

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Abstract: **India is one of the fastest-growing economies in the world and has the second-largest road network globally. The road network is a crucial component of the transportation sector, making it the right time to develop and implement a road maintenance management system. Currently, the measurement of pavement distress is carried out through physical inspections alone. If the cost of maintenance exceeds the cost of road reconstruction, it becomes an uneconomical option. Therefore, there is a need for an economically viable solution. This study focuses on assessing the quantity and severity of pavement distress to evaluate the condition of the road network in the Sangli district. By analysing the distress data, a priority list for maintenance activities within the selected road network is established, along with the development of a maintenance management system. An economic analysis is conducted to compare the costs of maintenance versus reconstruction, providing a clear differentiation between the two. The road maintenance management system aims to ensure that maintenance is carried out at the appropriate time, optimizing the overall management of the road network.**

Keywords: **Distress measurment, Distress severity, Pavement condition index, Sangli district.**

I.   INTRODUCTION

Road transportation plays a critical role in India's overall transportation sector. With the second-largest road network in the world, a significant portion of this network consists of rural roads. The country's high population growth rate has led to an increase in the number of road users. Since India gained independence, road traffic, both in terms of goods and passenger movement, has grown rapidly and significantly.

To ensure safe travel, maintaining a well-functioning road network is essential. The cost of reconstructing roads is considerably higher than performing maintenance, which is why maintenance is generally preferred in developing nations. As such, there is a need to adopt a systematic approach to determine the maintenance and rehabilitation requirements of pavements. Additionally, efforts should be directed at developing an efficient road maintenance management system (RMMS) to enhance the existing road infrastructure. In this context, creating a Pavement Maintenance Management System (PMMS) would offer valuable insights and data to facilitate consistent, cost-effective decision-making regarding the preservation of highway networks.

A Pavement Management System serves as a key tool in making management decisions. It forecasts future pavement deterioration caused by traffic, weather conditions, and other factors, providing maintenance and repair recommendations based on the type and age of pavement sections. This project aims to develop a Pavement Management System that incorporates elements such as inventory planning, pavement inspection, condition assessment, condition prediction, condition analysis, and work planning. Ultimately, the goal is to establish a comprehensive PMMS that project planners can use to guide the design and execution of road maintenance projects.

II. OBJECTIVES

- To collect both primary and secondary data and perform a detailed analysis of pavements conditions to access the current state of the pavements.

- To Compute the distress severity and develop an effective pavement maintenance and management system.

III. LITERATURE REVIEW

Afaf Mahmoud, Hassan Y. Ahmed, Ayman M. Othman," Deterioration of egyptian desert roads in al-minea district"

In this paper author done work on development on a deterioration model for roads in Egyptian desert's road. For the preparation of the model collect the data regarding to progressive deterioration stages of road surface. He took 10 road segments for the study each segment had length 500 meters. For all 10 segments current pavement condition index calculated and plotted against the time for each road, and he developed a deterioration prediction model for Egyptian desert roads.

Yogesh U.Shaha, S.S. Jainb, Devesh Tiwaric, M.K.Jaind, "Development of overall pavement condition index for urban road network"

In this paper, author describes the evaluation of pavement performance done using pavement condition indicators and pavement condition indicator basic component of the pavement management system. The pavement maintenance management strategy decided over pavement condition index, present serviceability index, roughness index. In this paper, author did work on development of overall combined index for the Noida urban road network.

Ary Setyawana, Jolis Nainggolanb, Arif Budiarto, "Predicting the remaining service life of road using pavement condition index"

In this paper author described that there are various distress which causes the damage to pavement surface so the remaining service life of existing pavement is unpredictable. The aim of this paper is to evaluate the condition of the pavement and damages to calculate the remaining service life of pavement. The pavement condition calculated according to ASTM procedure and deflection data ,air, temperature , surface temperature, ground water level measured with the help of falling weight deflectometer and the correlation between PCI value and remaining service life calculate into Microsoft excel program.

 Bharath Boyapati, R. Prasanna Kumar," Prioritisation of pavement maintenance based on pavement condition index"

The main objective of this research is a calculation of pavement condition index (PCI) by using field data collection and analyses this data to give priority to maintenance work on the pavement. Data regarding to patches, potholes, rutting, cracks, etc. collected for selected sections to measure the severity of distress. Corrected to deduct values are obtained by assigning importance to distress severity and pavement condition index is calculated.

Hakan Sahina, and Paul Narcisoa, and Narain Hariharan," Developing a five-year maintenance and rehabilitation (m&r) plan for hma and concrete pavement networks"

In this paper, the author describes steps involved in developing a multi-year pavement maintenance and rehabilitation (M&R) plan. These include: condition assessment, network inventory, identification of pavement sections requiring M&R, needs analysis; and impact analysis. In this research Texas university campus road network taken as a case study consist of 13.95 miles of roadway. The pavement condition index is calculated by the help of ASTM D-6433-07 and identified the road sections which required M & R. and cost effective M &R plan prioritized. Impact analysis used to determine impact of reduced budget.

Khaled M. Nassar, Hordur G. Gunnarsson, Mohamed Y. Hegab," Using weibull analysis for evaluation of cost and schedule performance"

In the construction industry large amount of money lost because of poor scheduling and cost control. In this project author described about a statistical approach named weibull analysis to evaluate schedule performance of design or construction project. Weibull analysis is a common method for failure analysis and for reliability engineering. In this research weibull analysis is used to comparing the reliability of the multiple projects. Various steps of analysis are discussed along with two projects are analyzed and compared, and author also concludes about benefit of weibull analysis for better control or monitors their project.

Hein, David K., Brian," Development of a pavement condition index procedure for interlocking concrete pavements"

In this paper author described in America PMMS is used to calculate maintenance and rehabilitation cost also he was described about calculation of distress quantity, severity, type and this information will help to calculation of pavement condition index. In this paper detailed procedure for the calculation of pavement condition index is described .this is the key point of this research work that will help to predict future deterioration of pavement sections.

Akhai Mudassar Mohammed Shafi, Ahmed Afaque Shakeel, and Siddesh Kashinath Pai, " Life cycle cost analysis of road pavements in rural areas

In this paper author described about future need of road network in India. According to author we are behind the actual plan of constructing the road network. In this paper he described about total cost of construction required for flexible and rigid pavement for per meter square. Also cost of maintenance for flexible and rigid pavement is calculated by using PMGSY report for year 2016.According to him cost of construction of rigid pavement is 20% -25% greater than flexible pavement.

IV. METHODOLOGY

The flowchart illustrates a systematic process for analyzing and prioritizing road maintenance in Sangli District. The first step, Data Collection, involves gathering information about the road network, including its total length and the types of pavement distress commonly observed, such as cracks, potholes, and rutting. Based on this, the Selection of Sample Road Network is performed through methods like random sampling and physical inspection to ensure a representative and unbiased analysis. The next phase, Distress Analysis, involves evaluating the condition of the roads, assessing the severity of damages, and identifying the types of distress affecting the pavement. This leads to the Condition Assessment Rating, where the data is converted into measurable indices, such as the Pavement Condition Index (PCI), to rank roads based on their maintenance needs. Finally, Maintenance Priority is determined using strategies like age-based maintenance, which considers the lifecycle of roads, and Weibull analysis, a statistical method that predicts future deterioration. This structured approach ensures that maintenance resources are allocated efficiently, focusing on the most critical areas to achieve sustainable infrastructure management.

4.1 Sample calculation of PCI for MDR-1

The table summarizes pavement distress severity, highlighting various damage categories (e.g., 1H, 7M, 10H) and their respective quantities, with the total affected area amounting to 897.73 sq. ft.. Among the categories, 10H represents the most severe damage, covering 296.1 sq. ft., followed by 7M with 138.6 sq. ft., and 19H with 169.36 sq. ft.. Other categories, such as 1H and 13H, contribute smaller areas of damage but remain significant. This data underscores the widespread nature of pavement deterioration, emphasizing the need for prioritized maintenance efforts, particularly for the most severely affected categories like 10H, to ensure the longevity and safety of the pavement infrastructure.

Table-1 PCI calculation for MDR-1

Distress Severity	Quantity				Total
1H	54.6	62.32			116.92
7M	69.3	34.1	35.2		138.6
10H	170.5	125.6			296.1
11H	17.64	49.14	12.32	50.63	129.73
19H	76.32	23.56	36.8	32.68	169.36
13H	21.42	8.32	17.28		47.02
					897.73 Sq. ft.

4.2 PCI based graph for NH, SH, MDR

The degradation curve represents the Pavement Condition Index (PCI) of state highways (SH) over time. The blue dashed line shows the standard degradation trend, while the red line indicates the actual degradation of SH roads. Key points include the "sweet spot" (optimal maintenance period before significant deterioration) and the reconstruction threshold when PCI falls below 20. Early maintenance during the sweet spot (PCI: 70–50) is cost-effective, preventing accelerated decline and reducing the need for costly reconstructions later.
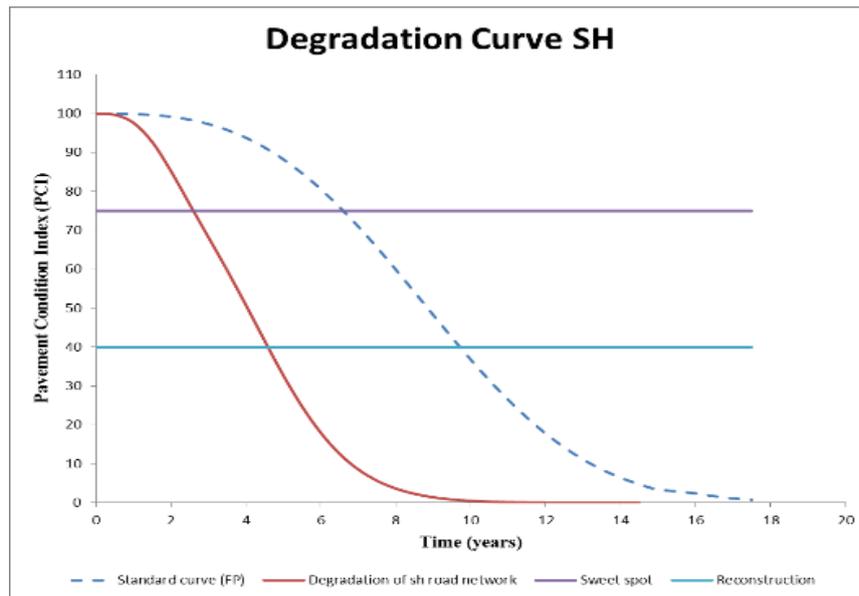
Figure 1: Degradation curve SH,FP

4.3 Maintenance frequency prediction by weibull analysis

Pavement performance models are used to assess the condition of pavements and predict the timing of maintenance and rehabilitation activities. These models are typically influenced by factors such as traffic load and the age of the pavement. In this study, the Weibull Prediction Model is utilized to determine the appropriate timings for maintenance and rehabilitation, which is crucial for cost estimation. The model used in this research is outlined below.
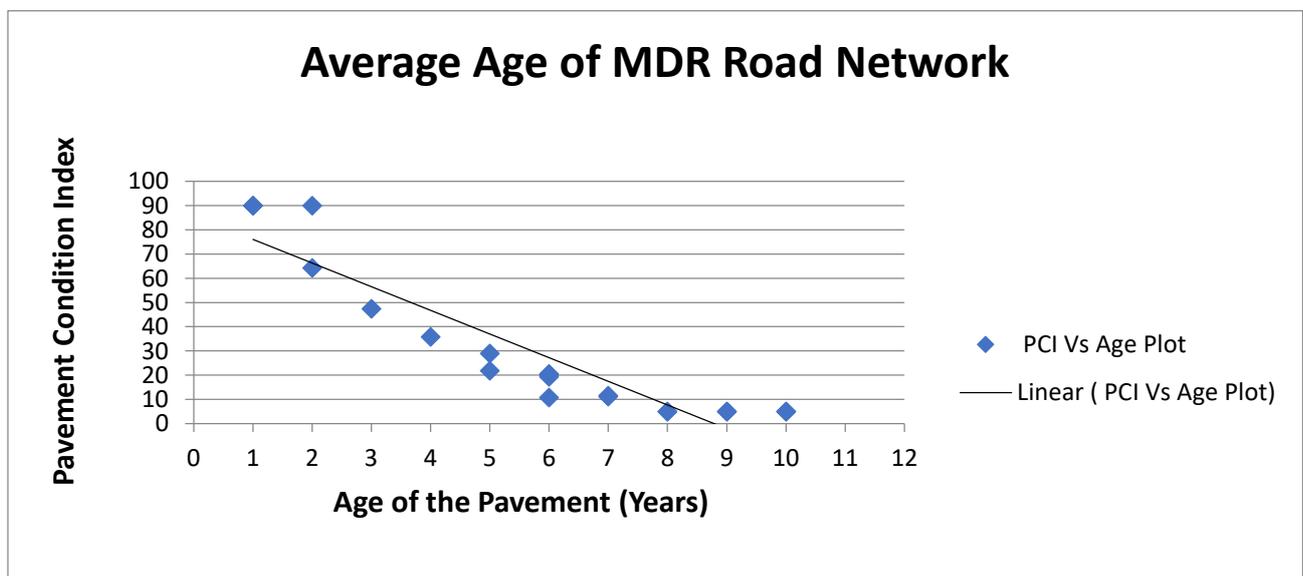

Figure 2: Average age calculation for MDR

Step I –Calculation of Maintenance frequency prediction by weibull analysis:

Step II – Plot the graph of Time (t) vs MR (%)

After obtaining the median rank for each year, graph of straight line is plotted on a Weibull probability graph.

Step III – Determination of Scale Parameter (η)

A straight line is plotted on the graph until it intersects a horizontal line drawn at 63.2%. Once the intersection occurs, a vertical line is drawn downward from the point of intersection to meet the X-axis. The value on the X-axis where this vertical line intersects represents the scale parameter.
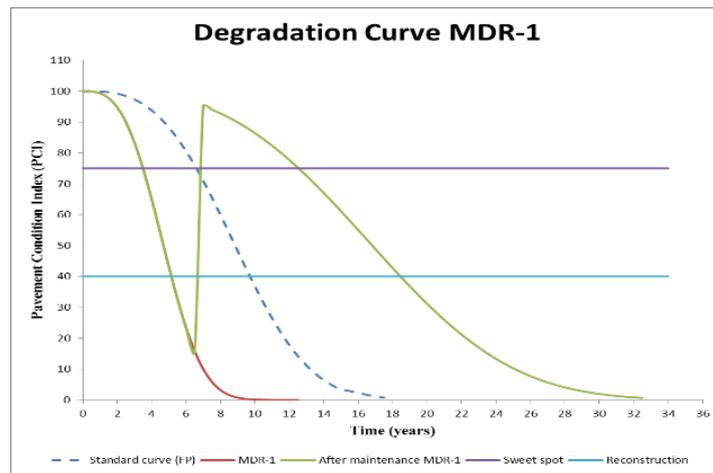
Sample weibull distribution graph for MDR-1

Figure 3: Degradation curveMDR-1

The graph shows that the current PCI of MDR-1 is 11.19, indicating that the road is in a "poor" condition. If maintenance is not carried out at this point, the road will continue to deteriorate at its current rate. However, if maintenance is performed now, the road's service life can be extended by several years.

4.4 Maintenance priority

Prioritizes of road maintenance is given by age and condition. Roads constructed earlier, like MDR-47 (10 years old), receive higher priorities for repair, while newer roads, like NH-4(P-B), are lower priority. This systematic approach ensures timely maintenance, focusing resources on aging roads to prevent further deterioration and optimize infrastructure management.

4.4.1 Average age calculation for NH, SH, MDR

The Weibull prediction model reveals significant differences in the lifecycle of flexible and rigid pavements, comparing standard pavement characteristics to the actual performance of Sangli District's roads. Standard flexible pavements for NH, SH, and MDR are designed to last 15 years, with a sweet spot for maintenance at 7 years, and an end of service life at 10 years. However, existing roads in Sangli show reduced performance, with NH averaging a 6-year lifespan, SH at 4 years, and MDR at 5.5 years. Maintenance for these roads must begin earlier, with the sweet spot occurring at 2–3.6 years and the end of service life at 3–5.1 years. Rigid pavements, while designed to last 35 years with maintenance every 15 years, show reduced lifespans in Sangli, with the sweet spot at 7 years and an end of service life at 9 years. Shorter intervals for maintenance and renovation highlight accelerated deterioration, requiring frequent interventions. This analysis underscores the need for improved construction quality and proactive maintenance to optimize pavement life and reduce long-term costs.

V. RESULTS

Based on the surveys conducted, economic analysis, and weibull analysis the finals results can be summoned up as below.

5.1. Survey Result

5.1.1 Physical inspection:

Physical inspection is done to detect the distress in the road network and the common distresses obtained results are tabulated in Table 2.

Table 2: Result of common distresses in flexible pavement

Sr. No.	Flexible pavement	Rigid pavement
1	Alligator cracking	Corner break
2	Edge cracking	Divided slab
3	Patching	Polished aggregate
4	Potholes	Linear cracking
5	Ravelling /Weathering	

5.1.2 Distress intensity:

Distress severity is divided into three level high severity, medium severity and low severity. Severity of distresses obtained in the road network is tabulated in Table 4.2.

Table 3: Result of distress intensity

Sr. no.	Flexible pavement		Rigid pavement	
	Distress	Severity	Distress	Severity
1	Alligator cracking	High	Corner break	High
2	Edge cracking	High	Divided slab	High
3	Patching	High	Polished aggregate	High
4	Potholes	High	Linear cracking	High
5	Ravelling/Weathering	High	Pumping	Medium
6	Polished aggregate	Medium	Scaling, map cracking	Low
7	Bleeding	Low	Patching	Low

5.1.3 Condition survey:

PCI calculated by using PCI data sheet and average PCI of road network is tabulated in Table

Table 4: Result of condition analysis

Sr. No.	Road network	Average PCI	Poor condition roads %
1	National highway	49.89	50
2	State highway	53	83.3
3	Major district roads	39	75

VI. CONCLUSION

- The average Pavement Condition Index (PCI) is as follows: NH roads have a PCI of 53, SH roads have a PCI of 49.89, and MDR roads have a PCI of 39. All road groups fall within the PCI range of 0-55, indicating that all are in poor condition.

- The "sweet spot" for pavement condition occurs at the following intervals after construction:

  - For NH rigid pavement, it is 7 years.

  - For NH flexible pavement, it is 2 years.

  - For SH and MDR road groups, it is 3.5 years and 3.6 years, respectively.

- The "renovation spot" occurs at the following intervals after construction:

  - For NH rigid pavement, it is 9 years.

  - For NH flexible pavement, it is 3 years.

  - For SH and MDR road groups, it is 5 years and 5.1 years, respectively.

- The maintenance frequency for flexible pavement in the NH road network is:

  - First maintenance: 2 years after construction.

  - Second maintenance: 1.5 years after the first maintenance.

  - Reconstruction: 1.1 years after the second maintenance.

- The maintenance frequency for rigid pavement in the NH road network is:

  - First maintenance: 7 years after construction.

  - Second maintenance: 5.2 years after the first maintenance.

  - Reconstruction: 3.9 years after the second maintenance.

- The maintenance frequency for flexible pavement in the SH road network is:

  - First maintenance: 3.5 years after construction.

  - Second maintenance: 2.6 years after the first maintenance.

  - Reconstruction: 1.9 years after the second maintenance.

- The maintenance frequency for flexible pavement in the MDR road network is:

  - First maintenance: 3.6 years after construction.

  - Second maintenance: 2.7 years after the first maintenance.

  - Reconstruction: 2 years after the second maintenance

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