Functional Evaluation of Pavement Using the Pavement Condition Index and International Roughness Index

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***Abstract*—Road safety, ride quality, and user satisfaction are all greatly influenced by pavement's functional performance. The Pavement Condition Index (PCI) and the International Roughness Index (IRI), two well-known performance metrics, are used in this study to evaluate flexible pavement technically. This study's main goals are to evaluate the riding quality and surface condition of particular road segments and investigate the connection between PCI and IRI values. The second ring road in Rajkot has been chosen for analysis. These routes were selected in order to assess the pavement's functional performance under various traffic and surface circumstances. The Pavement Condition Index value and international roughness index value for visual surface distress measurement and bump integrator equipment were determined by analyzing the functional condition of the road pavement. The pavement is rated using IRC:82-2023 & IRC: SP:16-2019 on the basis of data analysis.**

***Key Words*—Pavement Evaluation, Bump Integrator, Distress, Functional Evaluation, Surface Condition, Ride Quality**.

I. INTRODUCTION

For transportation to be safe, comfortable, and economical, road pavement performance is important. Highway agencies are now very concerned about pavement surface deterioration due to the rapid increase in axle loads and traffic volume. Therefore, functional evaluation of pavements is crucial to determining their current state and developing proper maintenance and repair plans [1]. The International Roughness Index (IRI) and the Pavement Condition Index (PCI) are two frequently employed indicators for evaluating pavement performance among different evaluation methods [2]. PCI is a numerical indicator that shows the pavement's surface quality based on obvious distresses including patchwork, potholes, cracking, and ravelling. It offers a methodical and uniform way to measure pavement deterioration on a scale from 0 to 100 [3]. IRI, on the other hand, gauges the pavement's longitudinal surface roughness, which has a direct impact on user comfort and ride quality [1]. It is regarded as a reliable indicator for determining functional performance and is reported in terms of slope variance (m/km).

By combining features of riding quality and structural deterioration, PCI and IRI provide an extensive evaluation of pavement condition. IRI measures pavement smoothness, which has a direct connection to vehicle operating costs and passenger comfort, while PCI concentrates on surface defects and their severity. Consequently, the combination of these two indices improves pavement evaluation accuracy and facilitates better pavement management system decision-making.

The purpose of this study is to use PCI and IRI to assess the functional state of specific road segments and to examine the link between these metrics for an efficient pavement performance evaluation. The results of this study will help construct sustainable road infrastructure and enhance pavement maintenance techniques.

II. LITERATURE REVIEW

The functional evaluation of pavement has been widely studied using different distress parameters, statistical models, and automated techniques. Pavement deterioration is influenced by traffic loading, environmental conditions, and material properties, which directly affect ride quality and serviceability [1]. Early studies emphasized the importance of pavement distress identification, where cracks were identified as the primary indicator of pavement failure [2]. Recent advancements focus on automated distress detection using machine learning and deep learning techniques. Studies using U-Net architecture and LiDAR integration reported 95% accuracy in crack length estimation and 0.98 coefficient of determination for crack thickness, demonstrating high statistical reliability of automated evaluation systems [3]. The study revealed that distress parameters such as cracking, potholes, and ravelling significantly influence IRI values. Furthermore, Artificial Neural Network (ANN) models showed higher prediction accuracy compared to Multiple Linear Regression (MLR), confirming the non-linear relationship between distress and roughness [4]. Studies on pothole detection and distress classification further confirm that vision-based methods outperform vibration-based techniques, providing more detailed and accurate assessment of pavement condition [5]. The recent advancement in pavement condition assessment focuses on automation using machine learning and deep learning models. Traditional manual methods and ARAN systems were found to be costly, time-consuming, and subjective [6]. A significant body of research has statistically examined pavement condition assessment and its impact on transportation performance. Traditional PCI evaluation methods were first standardized through the Pavement Condition Index (PCI) framework, where pavement conditions are rated from 0 (failed) to 100 (excellent) based on observed distress severity and density [7]. Pavement roughness—the irregularities that cause a vehicle to bounce—not only ruins the ride but also increases fuel consumption and vehicle maintenance costs. To quantify this, engineers use tools like the Bump Integrator, which measures the "Unevenness Index" in mm/km [8]. Pavement surface conditions, particularly roughness and rutting, have a strong positive effect on accident risks, with increased roughness and rutting associated with higher accident rates [9]. Pavement conditions significantly influence traffic quality, with distress parameters like potholes and rutting directly impacting vehicle headway, average travel speed, and roadway capacity. Studies utilize functional distress ratings and volume-to-capacity ratios to categorize road performance, revealing that better pavement conditions consistently correlate with higher Levels of Service (LOS) [10]. Studies on various Indian State Highways have utilized rebound deflection data alongside visual surveys of surface distresses like rutting and potholes to design necessary overlay thicknesses—such as Bituminous Macadam—required to strengthen in-service roads [11]. The Pavement Condition Index (PCI) is a foundational, standardized metric for assessing the surface health of both asphalt (flexible) and concrete (rigid) pavements on a scale from 0 (failed) to 100 (excellent) [12].

III. OBJECTIVE OF STUDY

1. To assess pavements functional condition using the Pavement Condition Index (PCI) and International Roughness Index (IRI).
2. To rate flexible pavement and compare it in order to identify which maintenance tasks should be prioritized.

IV. SCOPE OF STUDY

1. To calculated PCI value based on cracking, potholes, rutting, patching, Rut depth, raveling as per IRC:82-2023.
2. To determine IRI using fifth wheel bump integrator as per IRC:SP:16-2019.
3. To find out the rating of flexible pavement from PCI & IRI results and priority for maintenance work.

V. STUDY AREA AND METHODOLOGY

Study Area

The present study is carried out on the Second Ring Road of Rajkot, one of the rapidly developing urban centers in the state of Gujarat. Rajkot is characterized by significant urban expansion, increasing vehicular population, and continuous infrastructure development, which impose considerable stress on the pavement network.

Methodology

This study evaluates the pavement's functionality for Rajkot's second ring road. After defining the problem statement, a thorough analysis of pertinent literature was conducted to determine appropriate evaluation criteria and techniques. Road segments with high traffic volumes and a range of pavement conditions are included in the chosen study region. Two common methods were used to obtain field data. In accordance with IRC:82-2023, a thorough visual distress survey was used to calculate the Pavement Condition Index

(PCI), taking into account factors including cracks, ravelling, potholes, patchwork, and rutting. A bump integrator mentioned in IRC: SP:16-2019 was used to measure pavement roughness in terms of the International Roughness Index (IRI). The functional performance of the pavement was evaluated by methodically analysing and interpreting the gathered data. The road segments were appraised and given priority for the necessary maintenance and rehabilitation actions based on the assessed PCI and IRI values. Key conclusions and suggestions for enhancing pavement performance and serviceability are included in the study's conclusion.

VI. DATA COLLECTION

Geometric features, pavement type, traffic circumstances, surface qualities, and drainage conditions were all included in the structured inventory data of the chosen routes. The functional evaluation that follows using PCI and IRI is based on these data.

Table 1: Inventory data of selected road

Sr. No	Parameter	Second Ring-Road
1	Length of road	20km
2	Selected road-section length	1km
3	Carriageway Width	7.0m
4	Shoulder Width	1.5m
5	Lane Configuration	2-lane
6	Type of road	Urban Road
7	Type of pavement	Flexible
8	Type of surface	Bituminous Concrete
9	Traffic Category	Medium to High
10	Shoulder & Drainage Condition	Good

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VII. RESULT AND DISCUSSION

1) International Roughness Index Analysis

The International Roughness Index (IRI) is a standard measure of road surface roughness, usually expressed in m/km. International Roughness Index (IRI) is measured using Fifth Wheel Bump Integrator Equipment.

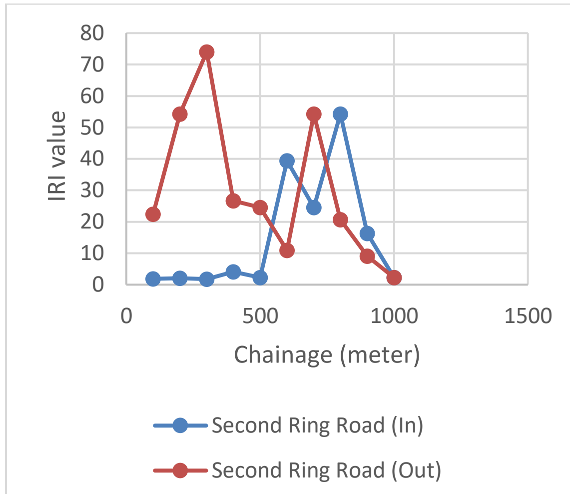

Figure 1: Chainage wise IRI

The graph shows IRI values along chainage for the Second Ring Road in both directions. The “Out” direction has higher variability with sharp peaks early on, while the “In” direction stays low initially and rises moderately mid-section. Both directions show decreasing IRI values toward the end of the stretch.

2)Pavement Condition Index Analysis

As per IRC:82-2023 code Final PCI value in between greater then 40 to 60 then Maintenance Recommendations is Minor Rehabilitation of Pavement.

Table 2: PCI data of selected road

Second Ring-Road		
Final PCI Value		
Type of Distress	IN	OUT
Crack	83.2	97.47
Ravelling	1.16	1.78

Potholes	51.4	33.43
Patch Work	90.16	99.11
Rut depth	98.93	98.93
IRI	0.8	0.18
Total	325.65	330.9
Average	54.275	55.15
Pavement Condition	Fair	Fair

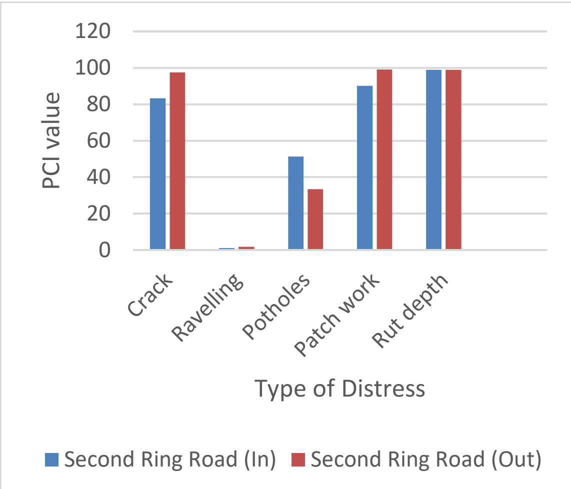

Figure 2: Distress wise PCI

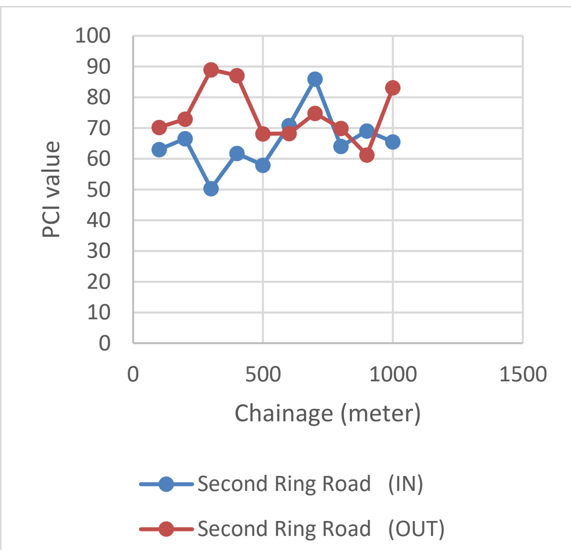

Figure 3: Chainage wise PCI

VII. CONCLUSION

PCI averages were 54.275 (IN direction) and 55.15 (OUT direction), rating the pavement as "Fair" per IRC:82-2023, primarily due to potholes (51.4 IN, 33.43 OUT) while other distresses like cracking and rut depth scored higher. IRI measurements via bump integrator showed low roughness (0.8 m/km IN, 0.18 m/km OUT) per IRC:SP:16-2019, indicating good ride quality overall with variability along chainage.

This study demonstrates that the Second Ring Road in Rajkot exhibits fair functional performance, with PCI values between 40-60 signaling the need for minor rehabilitation focused on potholes and ravelling. Integrating PCI and IRI provides a robust framework for prioritizing maintenance, supporting sustainable urban infrastructure amid growing traffic. Future work could incorporate automated distress detection for enhanced precision.

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