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Assessment of Surface Crack Patterns and Maintenance Requirements Using IRI on the Sicincin – Kurai Taji Road Segment

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ABSTRACT

The condition of road surfaces significantly affects driving comfort, safety, and transportation efficiency. This study identifies the predominant types of surface cracks on the Sicincin–Kurai Taji road segment and determines suitable maintenance measures based on the International Roughness Index (IRI). The study was conducted along a 5-kilometer road segment. Road roughness data were collected using the Roadroid mobile application, while pavement crack types were identified through visual inspection. The results showed that longitudinal cracks, crocodile cracking, potholes, and patched areas were the most common pavement distress types observed along the road segment. The calculated average IRI value was 7.45, classifying the road condition as moderate, which indicates the need for periodic maintenance. Recommended maintenance measures include overlaying, resurfacing, and patching, selected according to the severity and distribution of pavement distress. The findings suggest that integrating IRI analysis with visual crack identification is a practical and effective approach for assessing pavement conditions and selecting appropriate maintenance strategies. The results can support road authorities in prioritizing maintenance programs, optimizing resource allocation, and extending pavement service life.

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Keywords: pavement roughness; surface cracks; International Roughness Index (IRI); periodic maintenance; road condition evaluation.

1. Introduction

Road infrastructure plays a critical role in supporting socio-economic development, logistics activities, and regional accessibility. In many developing countries, including Indonesia, increasing traffic volumes, particularly heavy vehicle traffic, combined with long-term environmental exposure, accelerate pavement deterioration [1,2]. As roads degrade, surface distress in the form of cracks, potholes, and uneven surfaces becomes apparent, which negatively impacts driver comfort, increases vehicle operating costs, and raises safety concerns [3–5]. Therefore, accurate pavement condition assessment and timely maintenance planning are essential for maintaining pavement performance and extending service life [6].

One of the most widely adopted quantitative metrics for evaluating pavement surface condition is the International Roughness Index (IRI). The IRI, expressed in meters per kilometer (m/km), provides a standardized method for measuring the longitudinal profile of a road and is directly related to ride quality and surface smoothness [7]. Since its development by the World Bank and the University of Michigan in the 1980s, the IRI has become a globally recognized standard for pavement condition assessment [8]. The IRI is not only useful for comparing road performance across networks, but also effective for determining maintenance priorities in pavement management systems [9,10].

However, pavement condition cannot be comprehensively assessed using roughness measurements alone. Visual inspection methods remain necessary to identify the specific types of damage that influence IRI values. Common pavement distress types include longitudinal cracking, alligator cracking, patching, and potholes. These surface failures indicate not only aesthetic issues but also potential structural weaknesses that may worsen over time if left untreated [11–13]. Therefore, the integration of IRI measurements with surface crack classification yields a more comprehensive evaluation of pavement conditions and maintenance needs. In recent years, mobile-based tools such as the Roadroid application have facilitated low-cost, efficient IRI data collection by utilizing smartphone accelerometers and GPS tracking [14].

This technology has been widely adopted in both urban and rural road assessments due to its practicality, simplicity, and cost-efficiency, especially in areas with limited access to traditional profilometers or laser-based survey systems [15]. In Indonesia, several studies have demonstrated the effective use of Roadroid for monitoring local roads, enabling authorities to make data-driven decisions regarding road maintenance programs. The Sicincin–Kurai Taji road segment in West Sumatra Province serves as an important transportation corridor supporting regional trade, daily commuting, and access to public services. Due to its function as a provincial road and the increasing passage of heavy-duty vehicles, the segment is susceptible to surface degradation. Preliminary observations along the 5-kilometer stretch have shown multiple instances of visible cracking and surface roughness, suggesting the need for an in-depth technical evaluation. Despite its strategic importance, limited studies have evaluated the Sicincin–Kurai Taji road segment using an integrated approach that combines IRI measurements and pavement distress assessment.

This study evaluates pavement distress patterns and determines appropriate maintenance requirements based on IRI measurements along the Sicincin–Kurai Taji road segment. By combining digital roughness profiling using the Roadroid application with direct visual observation of surface defects, this research provides a practical, low-cost framework for evaluating pavement condition. The analysis identifies dominant pavement distress types and interprets IRI values to classify maintenance requirements, including routine maintenance, periodic maintenance, and rehabilitation. The final objective is to propose appropriate maintenance strategies for each road section based on its evaluated condition, thereby contributing to more efficient pavement management and budget allocation for local authorities. This paper presents the methodology, results, discussion, and conclusions related to pavement condition assessment and maintenance planning. The conclusion highlights the key findings and offers recommendations for road management practices in similar environments.

2. Materials and Method

This study was conducted along a 5 kilometer segment of the Sicincin to Kurai Taji road in West Sumatra Province, Indonesia, stretching from STA 54000 to STA 59000. The road segment serves as a vital provincial link with substantial daily traffic, including both light and heavy vehicles, making it prone to surface deterioration. The aim of this research was to evaluate the existing surface crack patterns and determine the necessary maintenance actions using the International Roughness Index (IRI) as a performance indicator. The study utilized both primary and secondary data. Primary data were collected through field surveys using the Roadroid application installed on an Android smartphone, which measured IRI values by detecting vertical acceleration and GPS movement during a drive through survey. The smartphone was mounted on a vehicle windshield, and measurements were recorded every 100 meters while maintaining a consistent speed above 15 kilometers per hour. The Roadroid app recorded essential data such as roughness (eIRI), vehicle speed, and location, which were then exported for further analysis.

In addition to IRI measurements, visual inspections were carried out to identify and classify the types of surface cracks. The road segment was divided into 100 meter intervals, where the types of cracks such as longitudinal cracks, crocodile or alligator cracks, potholes, and patches were observed and documented. Crack dimensions, severity levels (low, medium, or high), and densities were recorded using field forms, measuring tools, and digital photography. Crack classification followed the Pavement Condition Index (PCI) methodology in accordance with ASTM D6433 20, which allowed categorization of pavement damage based on its severity and extent. The secondary data used in the study included traffic volume data (Lalu Lintas Harian Rata rata or LHR), road classification, and pavement design specifications obtained from the West Sumatra Public Works Department.

Data analysis was performed by correlating the observed crack types with their respective IRI values to determine whether there was a relationship between surface distress and ride quality. The IRI values were interpreted based on Bina Marga guidelines: values less than or equal to 4.0 meters per kilometer indicated good road condition, between 4.1 and 8.0 meters per kilometer indicated moderate condition requiring periodic maintenance, and values greater than 8.0 meters per kilometer suggested poor condition requiring major rehabilitation. Maintenance recommendations such as patching, overlaying, or resurfacing were formulated based on the combined results of surface crack identification and IRI classification. This methodology provides a cost effective and integrated approach for evaluating pavement condition and guiding infrastructure management decisions.

All procedures in this study were noninvasive and conducted in public roadway environments. Therefore, no ethical approval was required, as the research did not involve human or animal subjects. The data and materials used in this study, including raw IRI values and crack observation records, are available upon request and will be uploaded to a publicly accessible repository prior to publication to ensure transparency and reproducibility of the findings.

3. Result

This section presents the findings obtained from both IRI measurements using the Roadroid application and visual surface crack inspections along the 5-kilometer Sicincin – Kurai Taji road segment. The data were analyzed to assess surface roughness levels and identify the dominant types and severity of cracks across road sections. Based on the analysis, the results are presented in the following subheadings.

International Roughness Index (IRI) Results

The International Roughness Index (IRI) values were obtained at 100-meter intervals using the Roadroid application. IRI measurements varied across different sections, with values ranging from 3.45 to 12.56 m/km. The average IRI value along the entire segment was 7.45 m/km, which classifies the road condition as moderate and indicates the need for periodic maintenance.

Table 1. Summary of IRI Values from STA 54+000 to STA 59+000

STA Section	Speed (km/h)	eIRI (m/km)	Road Condition
54+000 – 54+100	43	7.26	Moderate
54+100 – 54+200	45	6.58	Moderate
54+200 – 54+300	48	10.59	Slightly Damaged
58+600 – 58+700	45	12.56	Poor
57+000 – 57+100	40	3.45	Good
58+300 – 58+400	40	9.79	Slightly Damaged
58+800 – 58+900	35	7.40	Moderate
59+000 – End	40	7.87	Moderate

Based on the collected data and analysis across all measurement segments, the total average International Roughness Index (IRI) value was calculated to be 7.45 m/km, which classifies the overall road condition as moderate, indicating the need for periodic maintenance interventions.

The graphical representation of eIRI values along the Sicincin – Kurai Taji road segment is presented in Figure 1, which illustrates the variation in surface roughness across each 100-meter section based on the Roadroid application measurements.

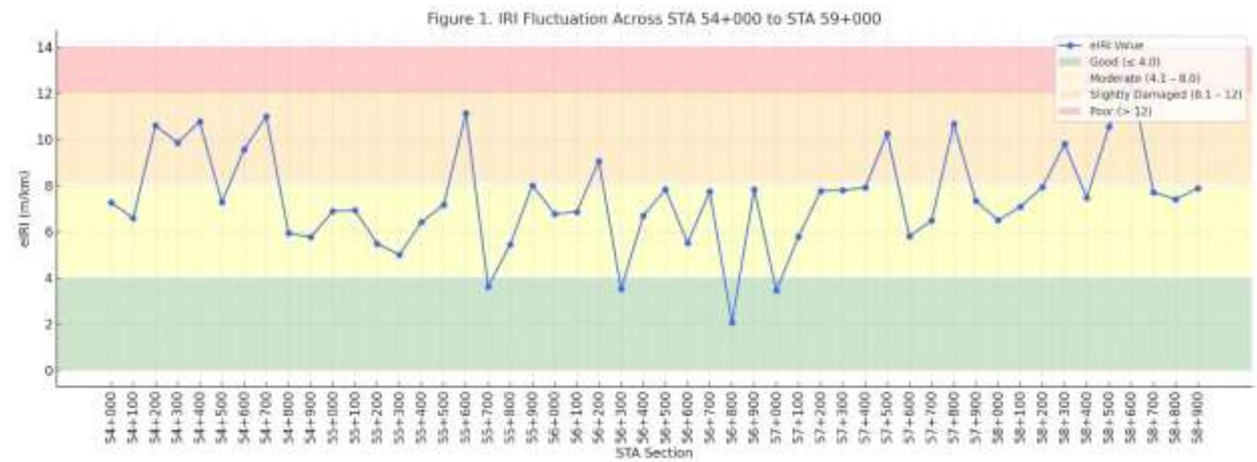

Figure 1. IRI Fluctuation Across STA 54+000 to STA 59+000
(a) eIRI values recorded per segment; (b) Road condition classification by IRI ranges)

This figure the variation in International Roughness Index (IRI) values across the 5-kilometer segment of the Sicincin – Kurai Taji road. The blue line indicates the measured eIRI values at each 100-meter interval. The background color bands represent standard road condition categories: green for good (IRI ≤ 4.0 m/km), yellow for moderate (IRI between 4.1 and 8.0 m/km), orange for slightly damaged (IRI between 8.1 and 12.0 m/km), and red for poor conditions (IRI > 12.0 m/km). Most segments fall within the moderate condition range, while several sections exceed 8.0 m/km, indicating surface distress that requires periodic maintenance or structural rehabilitation. This data helps prioritize maintenance activities based on objective surface roughness indicators.

Surface Crack Types and Distribution

Field observations revealed that the dominant types of surface distress were longitudinal cracks, crocodile cracks (alligator cracking), potholes, and patches. Severity levels were recorded for each crack, and damage density was calculated. Most cracks were classified as medium severity, with significant occurrences in STA 58+000 to 58+400.

Table 2. Surface Crack Observation at STA 58+000 – 58+400

STA Section	Type of Crack	Severity Level	Area (m^2)	Damage Density (%)
58+000 – 58+100	Patching	Medium	2.80	0.56
58+000 – 58+100	Longitudinal Crack	Medium	8.19	1.63
58+100 – 58+200	Crocodile Crack	Medium	7.64	1.52
58+200 – 58+300	Longitudinal Crack	Medium	6.20	1.24
58+300 – 58+400	Crocodile Crack	Medium	9.50	1.90

Maintenance Recommendations Based on IRI

Based on the IRI classifications and visual damage patterns, the corresponding maintenance actions were identified as follows:

a. Moderate road segments (IRI 4.1–8.0): Require periodic maintenance including asphalt overlays and crack sealing.
b. Poor segments (IRI > 8.0): Require major rehabilitation, such as milling and resurfacing or full-depth patching.
c. Good segments (IRI ≤ 4.0): Scheduled for routine maintenance only.

Table 3. Maintenance Strategy Recommendation

STA Segment	eIRI (m/km)	Crack Type Dominance	Maintenance Action
58+000 – 58+100	6.49	Longitudinal	Periodic overlay
58+300 – 58+400	9.79	Crocodile	Full-depth resurfacing
58+600 – 58+700	12.56	Mixed cracks	Structural rehabilitation

57+000 – 57+100	3.45	Minimal cracking	Routine maintenance

These findings indicate that IRI data, when supported by field visual inspection, provide strong indicators for identifying critical areas requiring immediate attention. Sections with IRI values above 8.0 are clearly correlated with the presence of complex crack types and greater surface degradation. Maintenance prioritization can thus be data-driven, ensuring efficient allocation of limited resources while improving road safety and ride quality.

4. Discussion

The findings of this study demonstrate that the Sicincin – Kurai Taji road segment exhibits varying levels of surface roughness and distress, with the average International Roughness Index (IRI) value recorded at 7.45 m/km, indicating a moderate condition that warrants periodic maintenance. This aligns with the classification established by Bina Marga standards [1], where roads with IRI values between 4.1 and 8.0 m/km require overlay or resurfacing to maintain serviceability. Field inspections also revealed that longitudinal cracks and crocodile cracking are the predominant forms of surface distress, particularly in segments with IRI values exceeding 8.0 m/km. These distress patterns may indicate pavement fatigue and aging processes commonly associated with repeated traffic loading and inadequate pavement support conditions [2,3].

The observed relationship between higher IRI values and extensive pavement cracking is consistent with findings reported in previous studies. For example, Ferina (2021) and Adiman (2021) observed similar trends on West Sumatra's provincial roads, where sections with significant alligator cracking and patching showed elevated IRI values and diminished ride quality [4,5]. These findings suggest that integrating IRI measurements with visual pavement distress assessment provides a more comprehensive evaluation of pavement condition. Moreover, Roadroid provided a practical and efficient tool for pavement condition assessment, consistent with observations reported by Pangesti and Rahmawati (2020) [6].

The results indicate that pavement distress severity should be considered alongside IRI values, as localized defects may contribute to future deterioration even in sections classified as moderate. The identification of patching and potholes in segments with IRI values below 8.0 suggests that localized failures may not always be reflected in global roughness indicators. Therefore, periodic pavement assessments should be complemented by visual inspections to identify early distress that may not yet influence ride quality but could contribute to future structural deterioration [7].

The methodology adopted in this study supports low-cost and scalable pavement assessment, particularly suitable for local governments with limited access to advanced equipment. It also enables data-driven prioritization of maintenance actions, which is crucial for efficient resource allocation. However, several limitations should be acknowledged, including the dependence of Roadroid measurements on smartphone sensor performance, potential inaccuracies on highly textured surfaces, and the limited spatial scope of the study. Further calibration and validation against standard profilometers are recommended for critical segments.

These findings support previous research emphasizing the importance of integrating multiple pavement condition indicators within road asset management practices. By combining quantitative (IRI) and qualitative (crack type and severity) indicators, decision-makers can implement more targeted interventions. For example, pavement sections exhibiting severe alligator cracking may require more extensive rehabilitation measures, whereas sections characterized by longitudinal cracking and moderate IRI values may be suitable for periodic maintenance treatments, subject to detailed engineering evaluation.

Future studies should consider incorporating traffic loading, environmental conditions, and subgrade characteristics to improve the predictive capability of pavement performance assessments. Furthermore, the application of machine learning techniques to analyze large datasets from mobile applications like Roadroid may offer new opportunities for automated classification and forecasting of road deterioration patterns.

In conclusion, the findings suggest that IRI-based evaluations combined with detailed crack identification can support the development of practical pavement maintenance strategies. Such an approach is particularly valuable in developing regions, where road networks are extensive and maintenance resources are limited. By adopting accessible tools and data-driven methods, local authorities can ensure safer, smoother, and more sustainable road infrastructure.

5. Conclusions

The study found that the Sicincin–Kurai Taji road segment exhibits moderate pavement condition based on combined IRI measurements and visual distress assessment. The results indicated that the average IRI value across the 5-kilometer segment was 7.45 m/km, which falls within the moderate category according to Bina Marga standards, suggesting the need for periodic maintenance. Dominant forms of surface distress identified during field observations included longitudinal cracks, crocodile cracking, potholes, and patches—particularly prevalent in segments with IRI values exceeding 8.0 m/km. These findings suggest an association between higher surface roughness levels and the occurrence of more extensive pavement distress. The application of the Roadroid mobile tool proved to be a practical, low-cost alternative for IRI data collection in regions with limited access to advanced equipment. The combination of quantitative and qualitative data in this study provided a clearer picture of pavement performance, supporting more informed maintenance planning. However, limitations remain, particularly regarding the lack of structural pavement data such as subgrade conditions and layer thicknesses, which could affect long-term durability predictions. Despite these limitations, the study contributes to road maintenance research by demonstrating the applicability of an integrated pavement condition assessment framework for local and provincial roads.

In light of these findings, future studies are recommended to include additional parameters such as traffic load intensity, pavement composition, and seasonal climate variation to enhance the accuracy of condition assessments. The integration of image-based data with IRI readings using artificial intelligence or machine learning techniques also presents a promising direction for developing automated pavement monitoring systems. For practitioners, it is suggested that road authorities adopt a dual-method assessment combining IRI measurements and surface distress surveys to inform maintenance prioritization more effectively. Maintenance actions such as overlays and patching should be applied in a timely manner to sections showing early signs of degradation to avoid more costly rehabilitation in the future. Future studies may apply this approach to other road classifications, including urban roads and national highways, to evaluate its applicability under different traffic and environmental conditions.

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