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The relationship model between road surface roughness and functional condition values of the road surface using IKP method and IRI with roadroid application

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ABSTRACT

Pavement damage in road infrastructure is influenced by complex factors, particularly intense traffic and excessive loads, leading to quality decline and rapid deterioration. Evaluating road surface conditions is critical for making accurate maintenance decisions, and it needs both visual inspection and in-depth analysis. Early detection of possible faults is critical for avoiding severe harm and improving urban traffic management. Indeks Kondisi Perkerasan (IKP) and International Roughness Index (IRI) are two methodologies used in this study. Roadroid, an Android app, simplifies road roughness measurement and provides a low-cost alternative. With Indonesia's enormous road network, efficiency is critical. The study investigates the relationship between Android app data and visual evaluations. The advantages include more precise forecasting for road management and more timely and effective maintenance planning. The research results indicate that the Indeks Kondisi Perkerasan (IKP) for the AMD Lintas Timur Pandeglang road shows the highest percentage at 35% in the excellent rating, 23% in the very poor rating, 20% in the fair rating, 10% in the good and poor ratings, and 2% in the failed rating. The International Roughness Index (IRI) values yielded 72% in good condition, 20% in fair condition, 5% in severe damage condition, and 3% in slight damage condition. The equation obtained from both methods is: IKP = -0,824IRI^2 + 6,064IRI + 61,658 with R^2 = 0,245.

ABSTRAK

Kerusakan pada infrastruktur jalan dipengaruhi oleh faktor-faktor yang kompleks, terutama lalu lintas yang intensif dan beban berlebih, yang menyebabkan penurunan kualitas dan kerusakan cepat. Evaluasi kondisi permukaan jalan sangat penting untuk membuat keputusan perawatan yang akurat dan memerlukan inspeksi visual serta analisis mendalam. Deteksi dini kemungkinan kesalahan sangat penting untuk menghindari kerusakan parah dan meningkatkan manajemen lalu lintas perkotaan. Indeks Kondisi Perkerasan (IKP) dan Indeks Kekasaran Internasional (IRI) adalah dua metodologi yang digunakan dalam penelitian ini. Roadroid, sebuah aplikasi Android, menyederhanakan pengukuran kekasaran jalan dan memberikan alternatif berbiaya rendah. Dengan jaringan jalan Indonesia yang sangat besar, efisiensi menjadi krusial. Penelitian ini menyelidiki hubungan antara data IRI yang didapatkan dari aplikasi Android dan evaluasi visual. Manfaatnya adalah prediksi yang lebih akurat terkait manajemen jalan dan perencanaan pemeliharaan yang lebih tepat waktu dan efektif. Hasil penelitian menunjukkan bahwa Indeks Kondisi Perkerasan (IKP) untuk jalan AMD Lintas Timur Pandeglang menunjukkan persentase tertinggi sebesar 35% dalam kategori sangat baik, 23% dalam kategori sangat buruk, 20% dalam kategori cukup baik, 10% dalam kategori baik dan buruk, dan 2% dalam kategori gagal. Nilai International Roughness Index (IRI) menghasilkan 72% dalam kondisi baik, 20% dalam kondisi cukup baik, 5% dalam kondisi kerusakan parah, dan 3% dalam kondisi kerusakan ringan. Persamaan yang diperoleh dari kedua metode adalah: IKP = -0,824IRI^2 + 6,064IRI + 61,658 dengan R^2 = 0,245.

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1. Introduction

Pavement damage can be caused by several complex factors that affect the road infrastructure's condition. Among these factors, intense traffic and excessive loads on the road are important contributors to road damage. Roads frequently traveled by heavy vehicles or a volume of traffic exceeding the road's design capacity experience a decline in quality and rapid deterioration. The increasing number of vehicles also amplifies the pressure on the road surface, leading to the emergence of cracks and potholes.

The evaluation of the functional condition of the road surface plays a crucial role in decision-making to determine the type of road maintenance. It involves not only visual assessment but also in-depth analysis that helps understand the road's performance level. The importance of this evaluation lies in early identification and addressing potential issues before they escalate into more severe damage. Predicting pavement degradation is essential to managing urban traffic since it increases the effectiveness of pavement repair [1][2]. By comprehending the functional condition of the road surface, relevant government bodies can plan timely and effective road maintenance and development.

Conventional pavement distress indices, like the U.S. Army Corps of Engineers' Pavement Condition Index (PCI), calculate coefficients of distress based on subjective judgments [3]. The selection of road maintenance approaches can be determined by assessing the surface condition visually. Several parameter-based approaches can be utilized for assessing road conditions, among which were used in this study are the Indeks Kondisi Perkerasan (IKP) and the International Roughness Index (IRI). Indeks Kondisi Perkerasan (IKP) is an indicator used to assess road pavement conditions (Pd 01-2016-B) [4]. On the other hand, the Indeks Kondisi Perkerasan (IKP) is a parameter of roughness calculated from the cumulative ups and downs of the longitudinal profile divided by the measured surface distance/length [5]. Roadroid is a mobile application on Android smartphones developed by a company in Sweden that functions to measure road roughness [6]. The examination is conducted through a simple method, recording the existing pavement conditions every 100 meters and documenting them in a form.

The overall length of national roads in Indonesia is 47,000 km. This length excludes expressways, provincial highways, and city/county roads. With such a large road network, an effective and efficient approach for analyzing pavement conditions is required to determine ideal road surface conditions and develop appropriate maintenance strategies. Visually assessing surface conditions is a low-cost option because it does not require expensive technology. This strategy, however, is time-consuming and requires a large number of staff, offering a substantial obstacle to road management. A Swedish startup has created an Android-based application named "roadroid" to analyze road surface roughness. The application is simple to use and does not require any complicated hardware, merely a smartphone running the Android operating system. The purpose of this study is to analyze the strength of the correlation between the roughness values acquired using the Android app and the visual assessment of road conditions using the Pavement Surface Index (IKP) method. The advantages of this research include the ability of this Android-based application to reliably anticipate pavement surface quality values for road administration.

The objectives of this study are to assess the pavement condition using the Indeks Kondisi Perkerasan (IKP), to evaluate the road roughness condition based on the International Roughness Index (IRI) utilizing the Roadroid Application, and to determine the relationship between the values of Indeks Kondisi Perkerasan (IKP) and International Roughness Index (IRI).

2. Methodology

Every road pavement structure will undergo a progressive deterioration process from the moment the road is first opened for traffic [7]. To address this, a method is needed to determine the road condition so that a road maintenance program can be formulated. Broadly, road damage can be divided into two parts: structural damage, which includes pavement failure or damage to one or more pavement structure components that render the pavement unable to withstand traffic loads, and functional damage that disrupts the safety and comfort of road users, leading to an increase in vehicle operating costs (VOC).

2.1. Indeks Kondisi Perkerasan (IKP)

Indeks Kondisi Perkerasan (IKP) is a system for assessing the condition of the road pavement based on the type, severity, and extent of damage that occurs, and can be used as a maintenance reference. The calculation of IKP is based on the results of a visual road condition survey identified by the type of damage, severity level, and quantity [8]. Severity Level refers to the level of damage for each type of damage. The levels of damage used in the IKP calculation are low severity level (L), medium severity level (M), and high severity level (H). Deduct value is the reduction value for each type of damage obtained from the relationship curve between density and deduct value. Deduct value is also differentiated by the level of damage for each type of damage [9-11]. Total Deduct Value (TDV) is the total value of individual deduct values for each type of damage and level of damage present in a sample unit. Corrected Deduct Value (CDV) is obtained from the relationship curve between the TDV value and the CDV value by selecting the curve according to the number of individual deduct values that have values greater than 2. If the CDV value is known, then the IKP value for each sample unit can be determined by subtraction, the value 100 is subtracted from the CDV.

This IKP value ranges from 0 (zero) to 100 (hundred) with criteria of excellent, very good, good, fair, poor, very poor, and failed as seen in Table 1.

Table 1. Correlation between IKP value and road condition.

IKP value	Road condition
0 – 10	(Failed)
10 – 25	(Very Poor)
25 – 40	(Poor)
40 – 55	(Fair)
55 – 70	(Good)
70 – 85	(Very Good)
85 – 100	(Excellent)

2.2. International Roughness Index (IRI)

The International Roughness Index (IRI) is a roughness parameter calculated from the cumulative up and down surface profile within the longitudinal direction divided by the measured surface distance/length. The recommended units are meters per kilometer (m/km) or millimeters per meter (mm/m). By using the Roadroid tool, the International Roughness Index (IRI) value can be obtained to assess road pavement performance (Prahara et al., 2021) (Arianto et al., 2018). Roadroid is an application on an Android smartphone developed by a company in Sweden that functions to measure road roughness. The steps to use the Roadroid application are as follows:

- Prepare the necessary tools, including survey vehicle, Android smartphone with the Roadroid application installed, and a holder as an aid.
- Attach the smartphone to the center of the front windshield of the designated vehicle type.
- Another tool prepared is the holder used to attach the smartphone to the vehicle's front windshield.
- Use an Android smartphone capable of supporting the Roadroid application.
- During the survey, ensure that GPS and cellular data are enabled and stable so that Roadroid can accurately determine the vehicle's location. This is crucial in providing accurate directions to the driver and assisting them in navigating the road accurately.
- Open the Roadroid application.
- Perform fitting adjustment/calibration when the vehicle is on a flat surface to make the calibration process easier. Calibration will be successful if the OK button or the values on x, y, z are green.
- Configure the Roadroid application.
    1. User email (Equipment ID)
    2. Android Device
    3. Vehicle Type
    4. cIRI Vehicle Sensitivity
    5. eIRI Sample Length
    6. Auto Photo Capture Sample Length
    7. Low Speed Lat/Lng Threshold
    8. Visible Bump Button
    9. Screen Orientation
- Record the screen while collecting Roadroid data.
- Determine the IRI value resulting from the Roadroid application survey.
- In determining the IRI value, several classifications are needed, and these IRI value classifications can be seen in Figure 1 (Sayers, 1986).

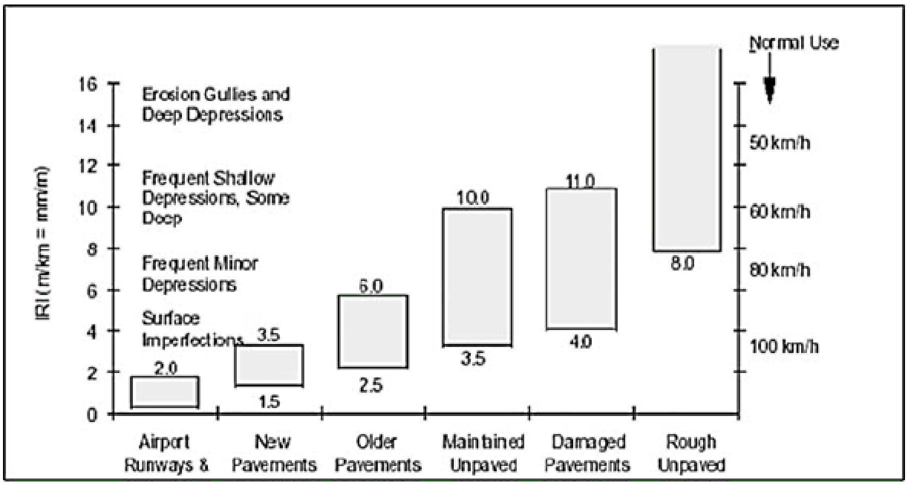

Figure 1. Range of values of international roughness indeks (Sayers, 1986)

In this study, the survey or measurement of Road Surface Roughness was conducted using the Roadroid application. Meanwhile, the Road Condition Index was obtained through direct visual measurement and assessment in the field. The research location is on the AMD Lintas Timur Pandeglang road section.

The research begins with a literature review. After conducting the literature review, the next step is to select a location to be the study object. Subsequently, secondary data collection is carried out, including road length, geometric conditions, road maps, and road classification. Following that, road conditions are assessed using the IKP method. The road is divided into segments, with each segment evaluated for the quantity, type, and severity of damage. The values for these three parameters are then calculated to obtain the IKP score, repeated for the entire road. After the assessment using the IKP method, the next step is to calculate the International Roughness Index (IRI) using the Roadroid application. The Roadroid application, installed on a cellphone, is then mounted in a vehicle with the help of a holder. The Roadroid application is configured according to standards, and testing is conducted along the road being studied. Subsequently, the IRI values are obtained. The next step involves calculating the correlation between the two methods, followed by analysis and discussion to draw conclusions.

Data collection in this study involved gathering both primary and secondary data, which would be used as research materials.

- Primary Data

The data on the types of road damage and the dimensions of road damage were obtained through surveys. Primary surveys involve direct field assessments to observe the existing conditions. The primary survey conducted aimed to identify the types and dimensions of road damage. The survey followed the Pd 01-2016-B methodology. Data for calculating the International Roughness Index (IRI) was collected using the Roadroid application.

- Secondary Data

Secondary data refers to information obtained indirectly. The author acquired data related to road classification and the location map of the AMD Lintas Timur Pandeglang road section from relevant authorities or sources.

3. Results and Discussion

3.1. Results of Indeks Kondisi Perkerasan (IKP)

The total road samples investigated on the AMD Lintas Timur Pandeglang road section are divided into 40 sample units, consisting of 20 sample units on the left lane and 20 sample units on the right lane. The summary of the Indeks Kondisi Perkerasan (IKP) values for all sample units can be seen in Table 2 below.

Table 2. IKP values

No. Sample	STA	IKP	Condition	No. Sample	STA	IKP	Condition
1	0+100	61	Good	21	2+00	6	Failed
2	0+200	65	Good	22	1+900	50	Poor
3	0+300	82	Good	23	1+800	42	Poor
4	0+400	96	Very Good	24	1+700	50	Poor
5	0+500	42	Poor	25	1+600	90	Very Good
6	0+600	32,5	Very poor	26	1+500	100	Very Good
7	0+700	89	Very Good	27	1+400	81	Good
8	0+800	100	Very Good	28	1+300	100	Very Good
9	0+900	70	Good	29	1+200	45	Poor
10	1+00	100	Very Good	30	1+100	69	Good
11	1+100	100	Very Good	31	1+00	46	Poor
12	1+200	100	Very Good	32	0+900	38	Very poor
13	1+300	100	Very Good	33	0+800	35	Very poor
14	1+400	100	Very Good	34	0+700	78	Good
15	1+500	100	Very Good	35	0+600	64	Good
16	1+600	69	Good	36	0+500	48	Poor
17	1+700	100	Very Good	37	0+400	58	Good
18	1+800	100	Very Good	38	0+300	63	Good
19	1+900	35	Very poor	39	0+200	77	Good
20	2+00	48	Poor	40	0+100	55	Poor

From a total of 40 evaluated samples, varied results were obtained ranging from 6 to 100. With an average IKP value of 69.6 indicating an overall good condition. From the assessment of road pavement conditions using the Indeks Kondisi Perkerasan (IKP) values on the AMD Lintas Timur Pandeglang road section, the highest percentage is 35% in the "excellent" rating, 23% in the "poor" rating, 20% in the "fair" rating, 10% in both the "good" and "very poor" ratings, and 2% in the "failed" rating (Figure 2).

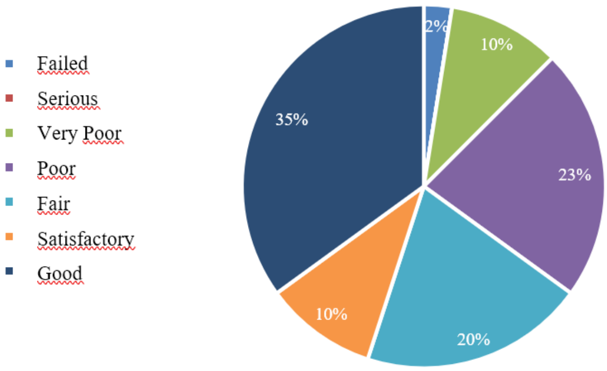

Figure 2. IKP value percentage

3.2. Roughness Value

The calculation of the International Roughness Index (IRI) was conducted using the Roadroid application, and the IRI values were obtained. The IRI values for the left lane and the right lane at STA 0+00-2+00 can be found in Table 3 below.

Table 3. IRI values

No. Sample	STA (m)	IRI	Condition	No. Sample	STA (m)	IRI	Condition
1	0+100	6,9	Good	21	2+00	12,2	High severity
2	0+200	4,3	Good	22	1+900	10,3	Low severity
3	0+300	1,7	Good	23	1+800	1,4	Good
4	0+400	2	Good	24	1+700	1,2	Good
5	0+500	4,4	Good	25	1+600	1,2	Good
6	0+600	13,3	High severity	26	1+500	1,2	Good
7	0+700	5,3	Good	27	1+400	1	Good
8	0+800	4,6	Good	28	1+300	1,7	Good
9	0+900	2,3	Good	29	1+200	1,1	Good
10	1+00	2	Good	30	1+100	1,5	Good
11	1+100	3	Good	31	1+00	1,4	Good
12	1+200	3,5	Good	32	0+900	1,8	Good
13	1+300	1,8	Good	33	0+800	1,2	Good
14	1+400	2,2	Good	34	0+700	5,5	Good
15	1+500	1,4	Good	35	0+600	5,2	Good
16	1+600	5,1	Good	36	0+500	1,5	Good
17	1+700	3,9	Good	37	0+400	1,4	Good
18	1+800	2,3	Good	38	0+300	1,8	Good
19	1+900	1,8	Good	39	0+200	1,7	Good
20	2+00	3,6	Good	40	0+100	1,2	Good

Based on Table 3 above, the overall assessment for both lanes from STA 0+00 to STA 2+00 describes the road's service function. For the AMD Lintas Timur Pandeglang road section, the IRI values show that 72% of the road is in good condition, 20% is in fair condition, 5% is in severe damage condition, and 3% is in light damage condition. The assessment results with the IRI values cannot be directly used as the basis for road pavement or for implementing a road maintenance program because the IRI values do not fully indicate the maximum extent of pavement damage Figure 3).

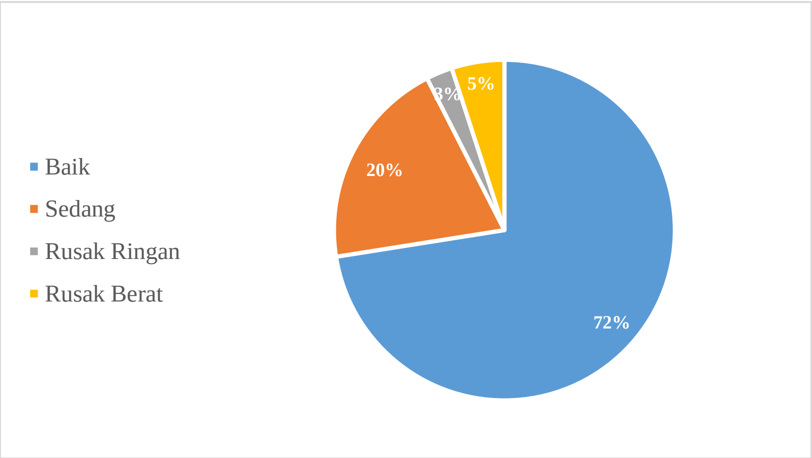

Figure 3. IRI value in percentage

3.3. Correlation Relationship Between IKP Values And IRI Values

The pavement condition assessment results using the Indeks Kondisi Perkerasan (IKP) and the International Roughness Index (IRI) can be seen in Table 4 below.

Table 4. Comparison of Pavement Condition between IKP and IRI Values.

STA (m)	IKP		*IRI*		STA (m)	IKP		*IRI*	
	Index	Road Condition	Index	Road Condition		Index	Road Condition	Index	Road Condition
0+100	61	Good	6,9	Good	0+100	6	Failed	12,2	High severity
0+200	65	Good	4,3	Good	0+200	50	Poor	10,3	Low severity
0+300	82	Good	1,7	Good	0+300	42	Poor	1,4	Good
0+400	96	Very Good	2	Good	0+400	51	Poor	1,2	Good
0+500	42	Poor	4,4	Good	0+500	82	Good	1,2	Good
0+600	32,5	Very poor	13,3	High severity	0+600	100	Very Good	1,2	Good
0+700	89	Very Good	5,3	Good	0+700	81	Good	1	Good
0+800	100	Very Good	4,6	Good	0+800	100	Very Good	1,7	Good

STA (m)	IKP		*IRI*		STA (m)	IKP		*IRI*	
	Index	Road Condition	Index	Road Condition		Index	Road Condition	Index	Road Condition
0+900	70	Good	2,3	Good	0+900	45	Poor	1,1	Good
1+00	100	Very Good	2	Good	1+00	69	Good	1,5	Good
1+100	100	Very Good	3	Good	1+100	46	Poor	1,4	Good
1+200	100	Very Good	3,5	Good	1+200	38	Very poor	1,8	Good
1+300	100	Very Good	1,8	Good	1+300	35	Very poor	1,2	Good
1+400	100	Very Good	2,2	Good	1+400	78	Good	5,5	Good
1+500	100	Very Good	1,4	Good	1+500	64	Good	5,2	Good
1+600	69	Good	5,1	Good	1+600	45	Poor	1,5	Good
1+700	100	Very Good	3,9	Good	1+700	58	Good	1,4	Good
1+800	100	Very Good	2,3	Good	1+800	63	Fair	1,8	Good
1+900	35	Very poor	1,8	Good	1+900	77	Good	1,7	Good
2+00	48	Poor	3,6	Good	2+00	55	Poor	1,2	Good

Based on Table 4, it shows the variation in data between the IKP values and the IRI values. It is evident that there is a relatively significant variation in some samples. The correlation analysis between the IRI values and the IKP values was conducted using several possible equations, including linear, logarithmic, polynomial, and exponential equations, and the results were evaluated based on the R^2values. Further explanation can be found in the following analysis. The analysis conducted involves a Polynomial Analysis of IRI Values with IKP Values for both lanes, resulting in the equation IKP = -0.82IRI^2 + 6.064IRI + 61.658, with an R^2 value of 0.245.

The coefficient of determination (R^2) indicates that the equation can explain the influence of road roughness (IRI) on road pavement damage (IKP) to the extent of 24.15%, while 75.85% of the road roughness value has no impact on the pavement condition index. For further clarity, please refer to Figure 4.

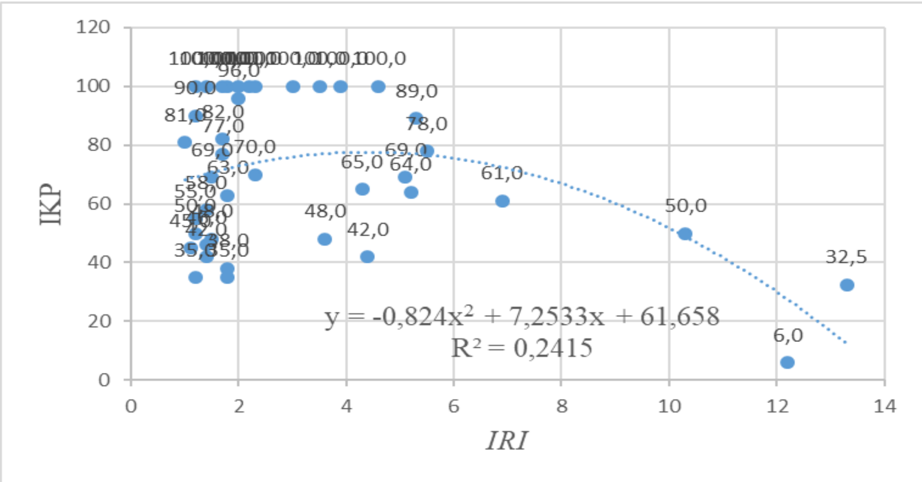

Figure 4. Correlation between IRI and IKP

From Figure 4, the obtained R^2 value is 0.2415, indicating that the correlation relationship between the IRI values and the IKP values is positively correlated. Based on Figure 4, the correlation relationship between IRI and IKP reveals a positive relationship, suggesting that when there is pavement damage, it affects road surface roughness. Therefore, the nature of the correlation between the IRI and IKP values is positive. However, the correlation value is not very strong because the data for IKP and IRI were collected differently. For IKP data collection, it involved comparing the area of damage to the sample area, while IRI data were obtained using Roadroid, which is attached to a vehicle where the vehicle's wheels only pass over specific spots of damage.

4. Conclusion

From this study, it can be concluded that the Indeks Kondisi Perkerasan (IKP) values for the AMD Lintas Timur Pandeglang road section indicate a predominant "excellent" condition at 35%, while 23% are rated as "poor," 20% as "fair," 10% as both "good" and "severe," and 2% as "failed." Additionally, the road roughness level (IRI) on the AMD Lintas Timur Pandeglang road section is categorized as predominantly "good," constituting 73%, along with "fair" at 20%. The least dominant IRI conditions are "severe," with a percentage of 5%, and "light," with a percentage of 3%.

The relationship between road surface damage values (IKP) and road roughness values (IRI) was analyzed using a polynomial analysis. It resulted in the equation IKP = -0,82IRI^2 + 6,064IRI + 61,658 with a coefficient of determination (R^2) of 24.15%. The R^2value indicates that the equation can explain the influence of road roughness (IRI) on pavement damage (IKP) to the extent of 24.15%, while 75.85% of the road roughness value has no impact on pavement condition.

Further studies related to the research theme are needed, starting with investigations in case study locations with suboptimal conditions. Adjustments are necessary for the Roadroid application, such as addressing vibrations on the holder and optimizing the smartphone's position. Additionally, correlation with other methods, specifically skid resistance, is required for comparison with the methods explored in this research.

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