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Evaluating pavement condition using roadroid and Surface Distress Index (SDI): a case study of Klangon-Tempel Road, Yogyakarta Special Province

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Abstract

Acquiring accurate condition out of pavement evaluation can prove to be a challenge, particularly for local road agencies in Indonesia with limited resources. Conventionally, road condition is expressed in terms of the Surface Distress Index (SDI) and the International Roughness Index (IRI) that need time-consuming and labor-intensive road surveys. Advancements in smartphone technology has paved the way to a lower-cost and more rapid pavement evaluation by using applications such as Roadroids for IRI measurements. This study is aimed at exploring the viability of Roadroids-based IRI for pavement evaluation purposes. Klangon-Tempel road section in Yogyakarta Special Province was selected as the study area, on which a manual SDI and two Roadroid-IRI surveys were conducted. The two Roadroid surveys involved two different vehicle types: a sport utility vehicle (SUV) and a multi-purpose vehicle. The results showed that MPV-survey produced higher IRI values and were more consistent with pavement distresses observed through SDI survey, demonstrating a strong correlation coefficient of r=0.813. In contrast, SUV-survey showed significantly lower IRI values that overestimate overall pavement condition of the study area. No detailed investigation was made, but MPV features such as lower ground clearance and softer suspension system may contribute to cause the different outcomes. Complementing this, a range-based SDI–IRI analysis showed that SDI and IRI are consistent at low-distress levels but display substantial overlap across medium-to-high SDI categories, reflecting their inherently non-linear relationship. The findings suggests that, with appropriate type of vehicle, Roadroid can be a viable choice to conduct rapid IRI-based pavement evaluation, and thereby complement the traditional SDI surveys.

Introduction

The critical role of road newtorks in supporting mobility and development in well known. Maintaining a sufficiently high level of service on networks requires, among others, an effective pavement management system fed by high quality pavement condition data collected in a regular basis. (Haas et al., 1994; Paterson, 1987). However, providing data at a time- and network-wide scale that is representative of the road network remains a challenge for many road agencies in developing countries like Indonesia due to technical and financial constraints. This situation emphasizes the need to develop reliable yet cost-effective evaluation methods.

Assessment of pavement condition in Indonesia has been carried out using Surface

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Distress Index (SDI) method. SDI essentially categorizes the pavement condition of each reviewed segment based on a specific formulation of the level and extent of surface damage commonly found in visual surveys, such as potholes, cracks, and ravelling (Direktorat Jenderal Bina Marga, 2011). SDI surveys require a large number of trained surveyors, are subjective, and have a risk of inconsistency accross a vast road network. (Cafiso, et. al., 2006; Transportation Research Board, 2004). SDI surveys are labor-intensive and time-consuming, requiring trained personnel and subjective visual judgment. Given these weaknesses, along sith the development of mobile phone technology, experiments have begun to develop applications for road condition survey as complementary tools.

In recent years, due to practicality and economic considerations, pavement condition assessments have begun to be conducted using smartphone-based applications as an alternative to manual surveys. (Douangphachanh and Oneyama, 2013). Several applications such as Roadroid (Forslöf and Jones, 2015), RoadLab Pro (Wang and Guo, 2016), and Roadbounce (Yegulla and Sravana, 2023) are designed to obtain International Roughness Index (IRI) values directly from accelerometer and GPS data. Thus, these device are starting to be considered as alternative methods capable of assessing pavement conditions quickly, automatically, and cheaply compared to the use of sophisticated profilers or manual visual-based surveys.

Several studies on road condition measurements using smartpone apps have also been conducted in Indonesia. However, these studies report mixed results regarding the reliability of these apps. Pangesti and Rahmawati (2020), for example, consluded that Roadroid is useful and quite reliable for quickly mapping pavement conditions. This was based on their equivalent IRI (e-IRI) measurements on district roads in Banyumas. Conversely, Rochmawati and Irianto (2020) who used Roadbounce app on a 6-km long of the Waena-Entrop road, reported that IRI-based results indicated poor pavement conditions, while, for comparison, the SDI survey assessed the road as moderate. This mismatch highlighted possible discrepancies between roughness-based and distress-based evaluations. More recently, Fawwaz (2023) examined the Kepanjen–Pagak road segment using both SDI and RoadLab Pro, finding close agreement between the two methods in classifying the pavement as slightly damaged.

These contrasting results underscore the importance of validating smartphone-based roughness indices against established visual-based indices such as SDI. Furthermore, factors such as vehicle type, suspension characteristics, and survey speed may strongly influence smartphone-based measurements (Yu and Wix, 2023). This study contributes to the literature by investigating the correlation between Roadroid-derived IRI and SDI on a 3.5 km section of the Klangon–Tempel road in Yogyakarta Special Province, Indonesia, with special emphasis on the role of survey vehicle type (SUV vs. MPV). The Klangon-Tempel road section is considered a good study area for some reasons: it exhibits diverse pavement conditions, including transition from lowland to hilly terrain, which generate a wide range of surface roughness profiles suitable for Roadroid validation. In addition, it has manageable traffic, safe accessibility, and appropriate length to support experimental runs and GPS data collection consistenly.

Methodology

This research method includes study area, roadroid survey, visual survey, Surface Distress Index (SDI) and data analysis.

Study Area

Classified as Primary Collector-3 according to Yogyakarta Special Province Governatorial Decree No. 328/KEP/2022, Klangon-Tempel road spans 21 km long and serves as an important regional connector from Sleman to Bantul counties in Yogyakarta Special Province, linking the southern lowland areas to the northern mountainous areas near Mount Merapi (Figure 1). The surveyed section was

STA 8+500 to 12+000 with a total length of 3.5 km, consisting of two lanes with asphalt pavement. The road was divided into 35 segments of 100 meters each to allow consistent analysis across both survey methods.

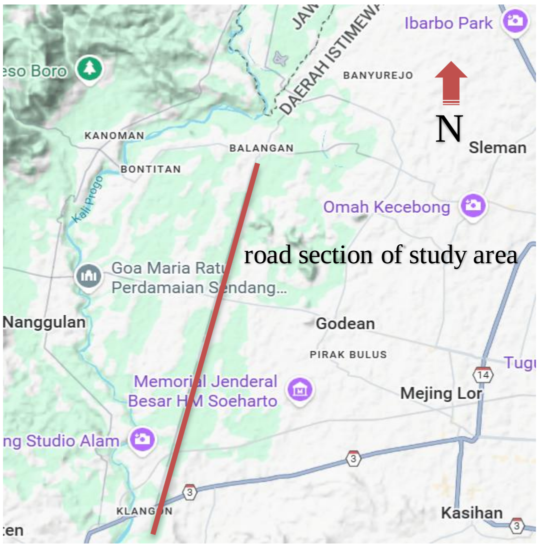

Figure 1. Study Area (Klangon-Tempel Road)

The road experiences moderate traffic dominated by mixed passenger vehicles and light to medium trucks. Heavy trucks serving Yogyakarta-Bawen toll road project also traverse this road segment to carry construction materials. Its topographical setting and relatively high traffic intensity make it prone to surface distress and unevenness (Figure 2), which makes it suitable for evaluating pavement monitoring techniques.

Roadroid Survey

Pavement roughness was measured using Roadroid, a smartphone-based application that calculates the International Roughness Index (IRI) from accelerometer and GPS data (Roadroid AB, 2021; Forslöf & Jones, 2015). IRI has been known world wide as a standardized measure of road surface roughness, which is the overall ride quality of an asphalt road pavement (Paterson, 1987; Sayers & Karamihas, 1998). It is calculated using a quarter-car vehicle math model, whose response is accumulated to yield a roughness index with units of slope, such as in/mi or m/km (see, for example, Piryonesi & El-Diraby, 2021).

Two separate surveys, each went North-bound and South-bound, were conducted in this study to examine the influence of vehicle characteristics:

Survey 1: conducted using a Mitsubishi-Pajero Sport Utility Vehicle (SUV)

Survey 2: conducted using a Toyota-Avanza Multi-Purpose Vehicle (MPV)

In both surveys, the smartphone was mounted securely on the vehicle dashboard to minimize extraneous vibration. Roadroid setting

Figure 2. Pavement condition in some segments of the study area

configuration allows the smartphone to be mounted in vertical or horizontal position (Figure 3). Data collection was performed at an average driving speed of 30–40 km/h. Prior to collecting the data, the vehicle type preset values was selected according to the type of survey vehicle. The raw IRI data produced by Roadroid were exported and averaged for each of the 35 segments, resulting in segment-wise IRI values that could be directly compared with visual survey data.

Figure 3. Smartphone setup on the vehicle dashboard

Visual Survey and Surface Distress Index

A visual pavement survey was conducted in accordance with the Indonesian Directorate General of Highways guideline (Direktorat Jenderal Bina Marga, 2011). The survey involved recording common surface distresses such as cracking, ravelling, and potholes, along with their extent and severity. These observations were then converted into a Surface Distress Index (SDI) score, which classifies road condition into categories ranging from "very good" to "poor." The same 35 segments used in the Roadroid survey were applied to ensure comparability of results.

Data Analysis

The analysis involved four stages as follows:

Descriptive analysis of pavement condition. IRI values from both SUV and MPV surveys were classified according to internationally recognized IRI thresholds (Paterson, 1987; Huang, 2004). SDI values were classified following the Bina Marga (2011) guideline.

Comparison between Roadroid and SDI results. Roadroid results from the SUV and MPV surveys were compared against SDI scores to identify consistencies and discrepancies in pavement condition classification

Correlation analysis. A Pearson correlation analysis (Eq. 1) was conducted to assess the statistical relationship between IRI (from both vehicle types) and SDI scores across the 35 segments. Scatter plots and regression analysis were used to illustrate the degree of agreement. Special attention was given to the MPV survey results, since preliminary observations indicated a stronger correspondence with SDI.

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{\{n\sum x^2 - (\sum x)^2\}\{n\sum y^2 - (\sum y)^2\}}} \quad (1)$$

Range-based relationship analysis. Realizing that mapping subjective visual ratings (SDI) to instrumented roughness (IRI) may results in noisy, non-linear, or heteroskedastic relationship, a range-based relationship analysis was also conducted using empirical binning approach. SDI–IRI data were grouped into four quantile-based SDI bins, and for each bin the median and 10th–90th percentile IRI range were computed to capture typical and extreme roughness levels. This range-based approach better reflects the non-linear and heterogeneous relationship between visual distress and measured roughness. The SDI bins (Q1 to Q4) were generated from the SDI distribution.

Results and Discussion

The results of the research are discussed as follows.

Roadroid Pavement Condition (IRI)

When conducted using SUV, the average IRI values were relatively low across most of the 35 segments. According to international IRI thresholds (Paterson, 1987; Huang, 2004), these values suggested that the road was in good condition. This result, however, was inconsistent with field observations, showing

Table 1. Summary of IRI values for SUV dan MPV surveys

IRI value (m/km)	Surface Condition	SUV Survey		MPV Survey	
		Segment Quantity	Percent (%)	Segment Quantity	Percent (%)
< 4	Good	23	66	2	6
4 - 8	Moderate	6	17	6	17
8 - 12	Bad	6	17	14	40
>12	Poor	0	0	13	37

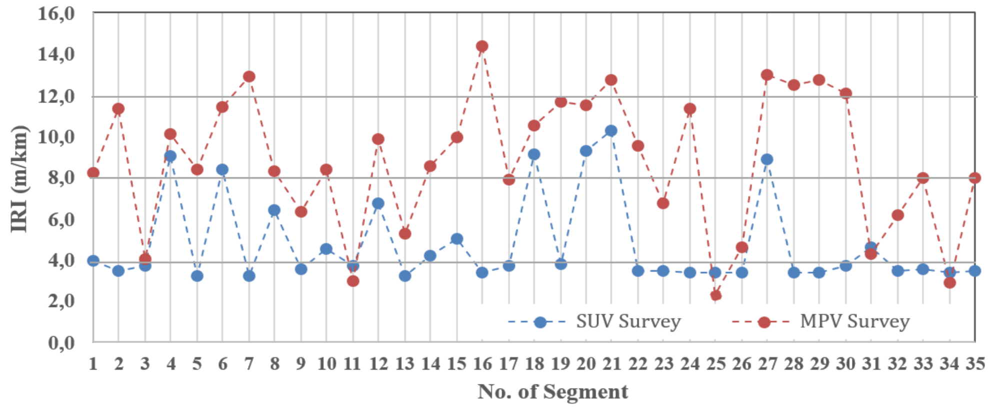

Figure 4. Comparison of average IRI values between SUV and MPV across 35 segments

several segments affected by cracking, ravelling, and potholes.

By contrast, the Roadroid survey conducted with a Multi-Purpose Vehicle (MPV) produced significantly higher IRI values, ranging from moderate to poor categories. These values aligned more closely with the visible deterioration recorded in the field. The findings demonstrate that Roadroid's output is sensitive to the type of vehicle used (Figure 4). Vehicle's suspension system and ground clearance are indicated to contribute to the different results.

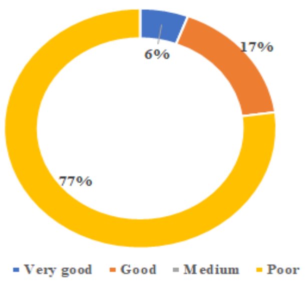

Figure 5. Pie chart of SDI condition categories across the surveyed road

Pavement Condition based on SDI

The SDI survey, conducted according to Bina Marga (2011) guidelines, identified a range of surface distresses across the Klangon–Tempel Road. Out of the 35 segments, only a small proportion were classified as "good" or "very good," while the majority fell into "poor" category (Figure 5). Typical surface distresses included block cracking, edge cracking, potholes, and ravelling. These findings (Table 2) suggest that the pavement condition of the surveyed section has already deteriorated to a level requiring periodic or routine maintenance interventions. Importantly, the SDI results reflected the actual distress types and their severity, providing more detail than roughness indices alone.

Comparison between Roadroid and SDI results

A direct comparison between Roadroid and SDI revealed substantial differences between the two Roadroid surveys (Figure 4 and Table 2). The SUV-based survey consistently underestimated surface deterioration, classifying many segments as being in "good" condition, despite the presence of visible distress. By contrast, the MPV-based survey results showed closer alignment with the SDI assessment.

Table 2. SDI values and corresponding condition categories per segment

Segment No.	SDI Value	Surface Condition Category
1	232,5	Poor
2	245	Poor
3	80	Good
4	247,5	Poor
5	245	Poor
6	247,5	Poor
7	230	Poor
8	247,5	Poor
9	245	Poor
10	240	Poor
11	80	Good
12	255	Poor
13	230	Poor
14	247,5	Poor
15	232,5	Poor
16	230	Poor
17	245	Poor
18	240	Poor
19	265	Poor
20	232,5	Poor
21	247,5	Poor
22	245	Poor
23	230	Poor
24	225	Poor
25	0	Very Good
26	90	Good
27	240	Poor
28	230	Poor
29	230	Poor
30	230	Poor
31	82,5	Good
32	80	Good
33	230	Poor
34	0	Very Good
35	80	Good
Average	**198,79**	**Poor**

These findings echo those reported in earlier Indonesian studies. For instance, Pangesti and Rahmawati (2020) also found Roadroid useful for categorizing roads as generally good, with average e-IRI of 3.96, although their study did not explicitly compare with SDI. In contrast, Rochmawati and Irianto (2020) observed that Roadbounce-generated IRI values rated the road in poor condition, whereas SDI suggested a medium rating, indicating potential inconsistency between the two indices. Our study differs by showing that when Roadroid is used with an MPV, the resulting IRI values align much more closely with SDI, thus reducing such discrepancies. Similarly, Fawwaz (2023) reported strong agreement between RoadLab Pro (another smartphone-based IRI tool) and SDI, suggesting that under certain conditions related with vehicle choice, road type, and survey setup, smartphone-based roughness indices can reflect distress-based conditions accurately.

Taken together, these studies support the argument that smartphone-based IRI tools can be reliable, but their validity is highly sensitive to methodological choices. Our study adds to this body of evidence by identifying vehicle characteristics, particularly suspension softness and ground clearance, as a key determinant of whether Roadroid results align with SDI.

Correlation analysis

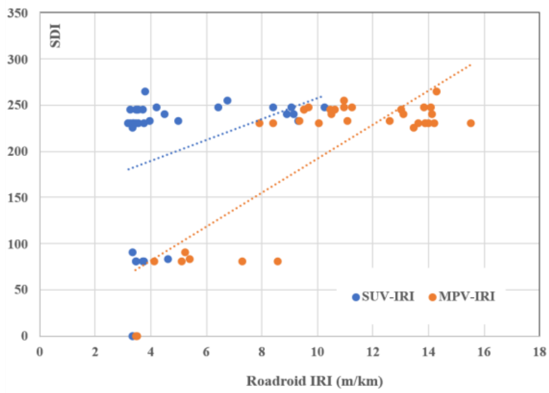

Figure 6. Scatter plot of SUV-IRI vs SDI and MPV-IRI vs SDI

Scatter plot between SDI and both IRI is depicted in Figure 6. The two trend lines shows that SUV-IRI generally overestimates SDI, while MPV-IRI, in contrast, is a better predictor of SDI. The Pearson correlation analysis between SDI and IRI values across the 35 segments revealed a strong positive relationship when using the MPV (r = 0.8129) as compared to using SUV (r = 0.3179). This indicates that lower SDI scores (worse surface condition) corresponded closely with higher IRI values, demonstrating that the MPV-based Roadroid survey effectively captured pavement deterioration consistent with visual observations.

The findings of this study align with several previous studies examining the reliability of smartphone-based IRI measurements using SDI data as a comparison. A study by Pangesti and Rahmawati (2020) on district roads in Banyumas, Central Java, demonstrated the utility of the Roadroid app for mapping an monitoring road conditions based on e-IRI. A study by Rochmawati and Irianto (2020) using the Roadbounce app on a 6-km road section in Papua found discrepancies between e-IRI and SDI results: their IRI results indicated poor road conditions, while the SDI classified the same road as fair. This study also found discrepancies, particularly in Roadroid e-IRI using SUV with SDI. This suggests that discrepancies between objective roughness measures and visual-based indices often occur. Fawwaz (2023), on the other hand, applied RoadLab Pro on the Kepajan-Pagak road in East Java found good agreement between IRI and SDI, both indicating slightly deteriorated conditions. This good agreement is also reported in the current study, especially between the IRI from MPV survey and the SDI.

Results reported in the present study demonstrate a middle ground: when using the appropriate vehicle type (MPV), Roadroid results show high correlation with SDI. However, when using an SUV, the outcome resembles the divergence. This suggests that smartphone-based IRI applications are not inherently inconsistent, but their accuracy depends heavily on survey conditions, including the type of vehicle selected to conduct the survey.

Range-based relationship analysis

Table 3 summarizes the computed IRI ranges per SDI bin. For low SDI (Q1≈ 0-90), typical IRI values are 5 to 7 m/km, ranging from 3,5 to 9,5 m/km. This bin represents the best pavement condition in the dataset. This

Table 3. Summary of computed IRI ranges per SDI Bin

SDI Bin	Count	Median IRI	Mean IRI	P10	P25	P75	P90
Q1	9	5,23	6,24	3,50	4,12	7,29	9,54
Q2	11	12,62	11,87	8,40	9,70	13,95	14,23
Q3	8	10,56	11,35	9,50	10,21	13,03	13,42
Q4	7	11,23	12,14	10,44	10,95	13,95	14,15

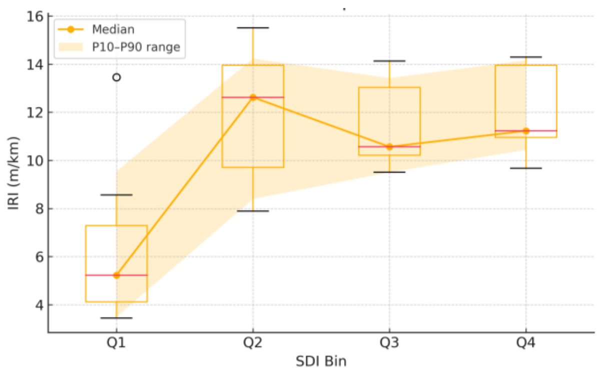

Figure 7. SDI-IRI range plot

matches expectation that low distress correlates with smoother surface. For medium SDI (Q2, Q3), IRI medians are around 10,5 to 12,6 m/km, representing a mixed situation but clearly rougher than Q1. As for high SDI (Q4 ≈ 245 to 265), IRI values are similar to Q2-Q3 with a median of 11,2 m/km. This means that SDI and IRI are not linearly correlated. As depicted in Figure 7, once SDI enters the medium-high range, IRI values overlap strongly, and SDI is no longer a good predictor of IRI magnitude. Interpretation of coverage of P10 to P90 ranges which include about 75 to 87% of the actual IRI values shows that there are noisy, subjective SDI scores.

The above finding agrees with the earlier correlation results, confirming that SDI and IRI share only a weak-to-moderate association. The divergence suggests that SDI captures several surface defects that do not significantly influence ride quality, while IRI primarily responds to profile roughness. This finding also confirms similar findings by studies that compare between distress indices and profile roughness (for example: Azhary et. al. 2023 and Kirbas, 2018)

Practical Implications

The results of this study offer several practical insights related to using smartphone apps, particularly Roadroid, in assessment of pavement conditions:

Vehicle selection. IRI measurements by apps such as Roadroid is found to be sensitive to vehicle characteristics. Although the app features vehicle type selection, experiments with two different types of vehicle (SUV and MPV) did not produce similar condition data. Based on the results, this study suggests the use of MPVs or vehicles with similar dynamic responses when conducting roughness surveys.

Complementary use with visual surveys. In cases where vehicle selection or other operating conditions may bias IRI results, visual-based manual SDI surveys are needed to complement the e-IRI surveys. This dual approach will increase confidence in pavement condition assessments.

Scalable implementation. Roadroid-based survey offers rapid, cost-effective data collection along continuous road segments. Given its affordability and ease of use, it can be adopted by district- or municipality-level road agencies for network-level monitoring. It may be particularly useful for quickly mapping sections with potentially severe deterioration, which can then be prioritized for visual inspection and maintenance.

MPV- and SUV-based IRI and SDI-IRI relationship. The comparison between SUV- and MPV-based IRI measurement shows that the MPV produces roughness values that are more consistent with surface distress observations. The higher SDI-IRI correlation obtained from the MPV survey suggests that this vehicle’s dynamic characteristics enable Roadroid to capture pavement surface more accurately. However, the range-based SDI-IRI analysis provides additional insight into the nature of the relationship between the two indeces. Even when using the more reliable MPV-based IRI data, the SDI-IRI association is not linear. Multiple distress types captured by SDI do not increase longitudinal profile roughness proportionally. This reinforces the view that improved IRI measurement enhances consistency with SDI where possible, but cannot eliminate the fundamental non-linearity caused by the differing physical bases of the two measures.

Conclusions

This study evaluated pavement surface conditions along the 3.5 km Klangon–Tempel road in Yogyakarta Special Province using two complementary approaches: a visual survey (Surface Distress Index, SDI) and a smartphone-based roughness survey (Roadroid). The findings highlight that vehicle type strongly influences Roadroid’s IRI output. The survey conducted with an SUV produced IRI values that underestimated surface distress when compared with SDI. Meanwhile, the other survey, using an MPV with lower ground clearance and softer suspension, produced higher IRI values that are more consistent with SDI results. A strong correlation (r = 0.813) was observed between IRI (MPV) and SDI, confirming the latter as more representative of actual pavement condition.

Comparison of the results produced by this study and those of earliar Indonesian studies report an alignment: smartphone-based IRI data are not always consistent with visual-based SDI data. Therefore some practical considerations are suggested related to the reliability of using smartphone-based roughness applications. These include vehicle type selection, complementary use with visual survey, and scalable implementation.

The range-based analysis confirmed that SDI and IRI do not exhibit linear relationship, particularly at medium-to-high distress levels, where their value ranges overlap substantially. Therefore, while Roadroid can complement SDI surveys when used with appropriate vehicle, SDI and IRI should be interpreted as related but non-equivalent indicators of pavement condition.

Future research is needed to expand on this and earlier studies. Tests involving multiple vehicle classes, varying speeds, and different pavement types on a broader road network are needed to establish best practies for smartphone-based, particularly Roadroid, pavement evaluation.

References

Azhary, N. Y., Ratnaningsih, A., Rohman, A. (2023). Road performance relationship analysis using PCI and IRI methods on Tukum East Ring Road. *International Journal of Science: Basic and Applied Research,* 69 (1), 112-123.

Bina Marga (2011). *Survey Guide for Road Condition Data* (in Bahasa Indonesia). Jakarta: Directorate General of Highway Administration (Bina Marga), Ministry of Public Works and Settlements.

Cafiso, S., Di Graziano, A, Battiato, Sebastiano. (2006). Evaluation of Pavement Surface Distress Using Digital Image Collection And Analysis. *Proc. Seventh International Congress on Advances in Civil Engineering*, pp. 1-10, October 11-13, 2006 Yildiz Technical University, Istanbul, Turkey

Douangphachanh, V., & Oneyama, H. (2013). Estimation of road roughness condition from smartphones under realistic settings. In *Proceedings of the 13th International Conference on ITS Telecommunications* (ITST) (pp. 433-439). IEEE.

Fawwaz, N. (2023). *Evaluation of Pavement through Surface Distress Index (SDI) and International Roughness Index (IRI) using RoadLab Pro application on Kepanjen-Pagak road section in Malang Regency*. Final Project Report (in Bahasa Indonesia). Universitas Islam Malang.

Forslöf, L., & Jones, H. (2015). Roadroid: Continuous road condition monitoring with smart phones. *Journal of Civil Engineering and Architecture*, *9*(4), 485-496. doi: 10.17265/1934-7359/2015.04.012

Haas, R., Hudson, W. R., & Zaniewski, J. P. (1994). *Modern pavement management*. ISBN 0894645889. Krieger Publishing Company.

Huang, Y. H. (2004). *Pavement analysis and design* (2nd ed.). Pearson Prentice Hall.

Islam, S., Buttlar, W. G., Aldunate, R. G., & Vavrik, W. R. (2014). Measurement of pavement roughness using android-based smartphone application. *Transportation Research Record*, *2457*(1), 30-38.

Kirbas, U. (2018). IRI Sensitivity to the influence of Surface Distress Flexible Pavements. *Coatings,* 8(8), 271-290.

Pangesti, R., & Rahmawati, I. (2020). Evaluasi penilaian jalan menggunakan IRI Roadroid di ruas jalan kabupaten Banyumas. *Prosiding Seminar Nasional Inovasi Teknologi Terapan Politeknik Negeri Balikpapan.* Balikpapan. ISBN 978-602-51450-2-5 pp. 34-45.

Paterson, W. D. (1987). *Road deterioration and maintenance effects: Models for planning and management*. ISBN 0801835909. World Bank.

Piryonesi, S. M., El-Diraby, T. E. (2021-02-01). Using Machine Learning to Examine Impact of Type of Performance Indicator on Flexible Pavement Deterioration Modeling. *Journal of Infrastructure Systems*. 27 (2): 04021005. doi:10.1061/(ASCE)IS.1943-555X.0000602

Roadroid AB. (2021). *Roadroid technical whitepaper*. Roadroid AB. Retrieved from https://www.roadroid.com

Rochmawati, A., & Irianto, E. (2020). Studi penilaian kondisi kerusakan jalan dengan metode nilai International Roughness Index (IRI) dan Surface Distress Index (SDI): Studi kasus Jalan Alternatif Waena–Entrop. *Dintek: Jurnal Teknik*, 13(2), 7–15.

Sayers, M. W., Karamihas, S.M. (1998). *The Little Book of Profiling*. University of Michigan Transportation Research Institute.

Transportation Research Board (2004). *Automated Pavement Distress Collection Techniques A Synthesis of Highway Practices*. NCHRP Synthesis 334. The National Academies: Washington D.C.

Wang, W., & Guo, F. (2016). *RoadLab: Revamping road condition and road safety monitoring by crowdsourcing with smartphone app*. Transportation Research Board 95th Annual Meeting (No. 16-2116).

Yegulla, V. P., & Sravana, P. (2023). Testing and evaluation of Roadbounce-mobile phone app based technology for road roughness measurement. *i-Manager's Journal on Civil Engineering,* 13(3).

Yu, Q., Fang, Y., & Wix, R. (2023). Evaluation framework for smartphone-based road roughness index estimation systems. *International Journal of Pavement Engineering*, *24*(1), 2183402.