Evaluation of Flexible Pavement Distress Levels and Treatment Strategies on Timor Raya Road Km 9

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ABSTRACT

This study aims to evaluate flexible pavement conditions and establish treatment priorities based on the level of distress in each segment. A quantitative-descriptive approach was employed using the Pavement Condition Index (PCI) method. The study object was a hypothetical 1,000 m road section divided into 10 sample units, each 100 m long with an area of 700 m². The dataset used in this manuscript is simulated and includes surface-distress indicators consisting of cracking, potholes, rutting, and patching. The analytical stages included distress identification, density calculation, determination of deduct value and corrected deduct value, PCI calculation, condition classification, and treatment-priority assignment. The simulation results produced PCI values ranging from 27 to 76, with an average value of 51.9, indicating an overall poor pavement condition. Unit U8 had the highest PCI value of 76 and was classified as good, whereas U10 had the lowest PCI value of 27 and was classified as very poor. Segments with low PCI values were prioritized for rehabilitation, while segments in good and fair conditions were directed toward routine, preventive, or periodic maintenance. The results demonstrate that PCI can support systematic surface-condition evaluation and treatment prioritization; however, decisions regarding major rehabilitation or reconstruction must be verified through structural assessment, drainage evaluation, traffic analysis, and other technical investigations. This study provides a pavement-condition assessment framework that can subsequently be applied to actual field-survey data.

Keywords: *flexible pavement; road distress; Pavement Condition Index; rehabilitation; road maintenance*

ABSTRAK

Penelitian ini bertujuan mengevaluasi kondisi perkerasan lentur jalan dan menyusun prioritas penanganan berdasarkan tingkat kerusakan pada setiap segmen. Penelitian menggunakan pendekatan kuantitatif-deskriptif dengan metode Pavement Condition Index (PCI). Objek penelitian berupa ruas jalan hipotetik sepanjang 1.000 m yang dibagi menjadi 10 unit sampel, masing-masing sepanjang 100 m dengan luas 700 m². Dataset dalam naskah ini merupakan data simulasi yang meliputi indikator kerusakan permukaan berupa retak, lubang, alur, dan tambalan. Tahapan analisis meliputi identifikasi kerusakan, perhitungan density, penentuan deduct value dan corrected deduct value, perhitungan nilai PCI, klasifikasi kondisi, serta penentuan prioritas penanganan. Hasil simulasi menunjukkan nilai PCI berkisar antara 27–76 dengan nilai rata-rata 51,9 sehingga kondisi rata-rata ruas termasuk kategori buruk. Unit U8 memiliki nilai PCI tertinggi sebesar 76 dan termasuk kondisi baik, sedangkan U10 memiliki nilai PCI terendah sebesar 27 dan termasuk kondisi sangat buruk. Segmen dengan nilai PCI rendah menjadi prioritas rehabilitasi, sedangkan segmen dengan kondisi baik dan sedang diarahkan pada pemeliharaan rutin, preventif, atau berkala. Hasil menunjukkan bahwa PCI dapat digunakan untuk mengevaluasi kondisi permukaan dan menyusun prioritas penanganan secara sistematis, tetapi keputusan rehabilitasi atau rekonstruksi harus diverifikasi melalui pemeriksaan struktural, drainase, lalu lintas, dan investigasi teknis lainnya. Penelitian ini memberikan kerangka penilaian kondisi perkerasan yang dapat diterapkan pada data survei lapangan aktual.

Kata Kunci: *perkerasan lentur; kerusakan jalan; Pavement Condition Index; rehabilitasi; pemeliharaan jalan*

1. INTRODUCTION

Road infrastructure plays an essential role in supporting the mobility of people and goods. Road performance is strongly influenced by pavement condition. In flexible pavements, deterioration can progress from superficial distress to more severe damage when appropriate treatment is not provided in a timely manner. Common forms of distress include cracking, potholes, rutting, raveling, and patching (Gupta et al., 2014; Dhiaulhaq & Fauzan, 2022).

Quantitative condition evaluation is required so that maintenance programs are not based solely on subjective visual judgments. ASTM D6433-24 defines the Pavement Condition Index (PCI) as a numerical indicator of pavement surface condition derived from observed distress. PCI can support the identification of maintenance needs and prioritization, but it does not directly measure structural capacity, skid resistance, or pavement roughness (ASTM International, 2024; Yamali et al., n.d.).

In Indonesia, the 2024 Road Pavement Design Manual (Manual Desain Perkerasan Jalan 2024; MDP 2024) issued by the Directorate General of Highways provides a technical reference for pavement rehabilitation and reconstruction design. Therefore, surface-condition evaluation should be integrated with structural assessment, traffic data, material characteristics, and drainage conditions before the final treatment type is selected (Direktorat Jenderal Bina Marga, 2024).

Flexible pavement is a layered system generally consisting of an asphalt surface course, base course, subbase where required, and subgrade. Its performance is influenced by traffic loading, material quality, subgrade condition, climate, drainage, and construction quality. Identification of distress type, severity, and extent is therefore an important basis for pavement-condition assessment (Gupta et al., 2014; Alimohammadi, 2020).

PCI values range from 0 to 100, where higher values indicate better pavement condition. PCI calculation involves determining distress density, deduct value (DV), total deduct value (TDV), corrected deduct value (CDV), and the PCI value based on the maximum CDV. Subsequent treatment strategies should consider both the severity of distress and its probable causes (ASTM International, 2024; Yamali et al., n.d.).

This study aims to: (1) identify the level of flexible pavement distress; (2) determine the PCI value for each sample unit; (3) determine the average condition of the road section; and (4) formulate treatment strategies based on distress priorities. The practical contribution of this study is a structured condition-evaluation workflow through which surface-distress data can be translated into maintenance priorities. The novelty of the manuscript lies in integrating condition assessment and treatment strategy within a PCI-based analytical framework while explicitly positioning structural and drainage verification as prerequisites for final engineering decisions.

2. METHODS

2.1 Research Design

A quantitative-descriptive approach was used to evaluate flexible pavement condition based on surface-distress data. For the purpose of this illustrative manuscript, a hypothetical road section 1,000 m long with an effective width of 7.0 m was used. It is important to emphasize that all numerical values analyzed in this study constitute a simulated dataset and must not be interpreted as actual field-survey results for Timor Raya Road Km 9.

2.2 Study Area / Object of Study

The study object was modeled as a hypothetical 1,000 m road section with an effective width of 7.0 m. The section was divided into 10 sample units, each 100 m long, giving an area of 700 m² per sample unit. This division was used to generate segment-level condition values that could be compared systematically.

2.3 Data Collection

The dataset consisted of simulated primary-type inventory data representing visual pavement distress. Recorded parameters included percentage of cracking, pothole area, rutting length, and percentage of patching. In actual field application, these variables must be obtained through direct measurement within each sample unit and supported by pavement-surface documentation (ASTM International, 2024).

2.4 Data Analysis

The analysis followed these stages: (1) geometric survey and subdivision into sample units; (2) distress-type inventory; (3) measurement of distress length, area, or quantity; (4) calculation of distress density; (5) determination of DV and CDV according to the PCI procedure; (6) calculation of PCI; (7) condition classification; and (8) formulation of treatment strategies. In general, the PCI value is calculated using Equation (1):

$$PCI = 100 - CDVmax \tag{1}$$

where CDVmax is the maximum corrected deduct value derived in accordance with the PCI procedure (ASTM International, 2024).

2.5 Standards, Codes, and Technical References

The analysis refers to ASTM D6433-24 for the Pavement Condition Index survey procedure and to the 2024 Road Pavement Design Manual (03/M/BM/2024) as an Indonesian technical reference for pavement rehabilitation and reconstruction. These documents provide the technical basis for interpreting surface condition and formulating preliminary treatment recommendations (ASTM International, 2024; Direktorat Jenderal Bina Marga, 2024).

3. RESULTS

The simulated dataset results are presented in Table 1. PCI was used as the principal numerical indicator for classifying the condition of each sample unit.

Table 1. Pavement-condition evaluation based on the simulated dataset

Unit	STA	Area (m²)	Cracking (%)	Potholes (m²)	Rutting (m)	Patching (%)	PCI	Condition	Treatment
U1	0+000–0+100	700	4.2	2.8	18	3.5	72	Good	Routine / preventive
U2	0+100–0+200	700	7.5	4.2	25	5.2	61	Fair	Periodic maintenance

U3	0+200–0+300	700	10.3	6.5	32	7.1	48	Poor	Rehabilitation
U4	0+300–0+400	700	12.5	8.4	41	9.3	39	Very poor	Major rehabilitation / reconstruction
U5	0+400–0+500	700	5.8	3.5	22	4.1	66	Fair	Periodic maintenance
U6	0+500–0+600	700	15.2	10.2	48	11.5	32	Very poor	Major rehabilitation / reconstruction
U7	0+600–0+700	700	8.1	5.6	29	6.4	55	Fair	Periodic maintenance
U8	0+700–0+800	700	3.6	2.1	15	2.8	76	Good	Routine / preventive
U9	0+800–0+900	700	11.7	7.8	37	8.6	43	Poor	Rehabilitation
U10	0+900–1+000	700	17.5	12.5	55	13.2	27	Very poor	Major rehabilitation / reconstruction

Source: Author's analysis, 2026

The average PCI was calculated as follows:

$$\text{Average PCI} = \Sigma\text{PCI} / n = 519 / 10 = 51.9$$

Accordingly, the average condition of the modeled road section falls within the poor category.

3.1 Distress-Level Analysis

The PCI values indicate considerable variation among segments. U8 had a PCI value of 76 and was classified as good, whereas U10 had a PCI value of 27 and was classified as very poor. U6 also showed very poor condition with a PCI of 32. U3, U4, U7, and U9 ranged from fair to poor and require attention to prevent further deterioration (Setyawan et al., 2015; Dhiaulhaq & Fauzan, 2022).

Within the simulated dataset, increases in cracking percentage, pothole area, rutting length, and patching percentage were associated with lower PCI values. This observed pattern, however, cannot substitute for the formal PCI procedure because deduct values depend on the specific distress type and severity level (Gupta et al., 2014).

4. DISCUSSION

The evaluation demonstrates that pavement condition is not uniform along the modeled road section; therefore, a single treatment strategy should not be applied indiscriminately to all segments. The average PCI value of 51.9 indicates a poor overall condition, but this mean conceals a wide range of segment conditions from 27 to 76. Segment-based decision-making is therefore more informative for prioritizing maintenance and rehabilitation (Sahin et al., 2014; Boyapati & Kumar, 2015).

U10 and U6 represent the highest priorities because they have the lowest PCI values, 27 and 32, respectively. In the simulated dataset, these values indicate high levels of surface distress. Nevertheless, major rehabilitation or reconstruction should not be prescribed solely from PCI. Structural capacity, base and subgrade conditions, and drainage performance should be investigated before a final intervention is selected (ASTM International, 2024; Boyapati & Kumar, 2015).

U4, with a PCI of 39, is also classified as very poor, whereas U9 and U3, with PCI values of 43 and 48, respectively, are classified as poor. These segments require rehabilitation or periodic treatment depending on the distress mechanism. Cracks should be treated according to their characteristics to reduce water infiltration; potholes should be repaired by removing deteriorated material and applying suitable patching; and rutting should be investigated further because it may reflect deformation within the asphalt layer, base, or subgrade.

U1, U2, U5, and U8 are comparatively better. Routine and preventive maintenance on segments in good condition can slow deterioration and preserve serviceability. For segments in fair condition, periodic maintenance should be planned before deterioration progresses to a poor condition that would require more expensive treatment (Sahin et al., 2014).

These findings are consistent with the use of PCI as a surface-condition indicator for supporting maintenance prioritization, while rehabilitation or reconstruction design requires additional technical data. Accordingly, PCI is more appropriately positioned within pavement management as a condition-screening and initial prioritization tool rather than as the sole basis for treatment design (ASTM International, 2024; Alimohammadi, 2020).

4.1 Treatment Priorities

1. U10 (STA 0+900–1+000), PCI 27 — very poor — major rehabilitation/reconstruction after structural verification.
2. U6 (STA 0+500–0+600), PCI 32 — very poor — major rehabilitation/reconstruction after structural verification.
3. U4 (STA 0+300–0+400), PCI 39 — very poor — major rehabilitation/reconstruction according to investigation results.
4. U9 (STA 0+800–0+900), PCI 43 — poor — rehabilitation.
5. U3 (STA 0+200–0+300), PCI 48 — poor — rehabilitation.
6. U7 (STA 0+600–0+700), PCI 55 — fair — periodic maintenance.
7. U2 (STA 0+100–0+200), PCI 61 — fair — periodic maintenance.
8. U5 (STA 0+400–0+500), PCI 66 — fair — periodic maintenance.
9. U1 (STA 0+000–0+100), PCI 72 — good — routine/preventive maintenance.
10. U8 (STA 0+700–0+800), PCI 76 — good — routine/preventive maintenance.

4.2 Study Limitations

The principal limitation of this study is that the dataset consists of simulated values for a hypothetical road section. Consequently, the PCI results and treatment recommendations must not be interpreted as the actual condition of a specific road segment. A field-based study should use primary survey data, distress documentation, traffic information, pavement age, drainage condition, roughness indicators such as the International Roughness Index (IRI) where available, and structural assessment (Setyawan et al., 2015; Alimohammadi, 2020).

5. CONCLUSION

This study concludes that PCI values for the 10 sample units range from 27 to 76, with an average of 51.9; therefore, the average pavement condition represented by the simulated dataset is classified as poor. U8 represents the best condition with a PCI of 76, whereas U10 represents the poorest condition with a PCI of 27, followed by U6 with a PCI of 32.

Treatment priority should be assigned to segments with low PCI values. However, decisions to undertake major rehabilitation or reconstruction must be verified through assessment of structural capacity, base and subgrade conditions, and drainage. Segments in good and fair condition should receive routine, preventive, or periodic maintenance to limit further deterioration and preserve service life.

5.1 Implications and Recommendations

Road-condition surveys should be conducted periodically using consistent sample units so that changes in pavement condition can be monitored over time. Field studies should complement PCI data with traffic information, pavement age, drainage condition, IRI or other roughness indicators where available, and structural assessment. Final treatment selection should follow applicable Directorate General of Highways technical requirements and the findings of field investigations (Sahin et al., 2014; Moazami et al., 2011).

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AUTHOR CONTRIBUTIONS

Benny Tua Siahaan was solely responsible for conceptualization, methodology, development of the simulated pavement-distress dataset, PCI-based analysis, interpretation of results, formulation of treatment priorities, manuscript preparation, critical review, editing, and approval of the final version for publication.

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CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this article.

DATA AVAILABILITY STATEMENT

The simulated dataset used in this study is contained within the article. Additional supporting calculation records, if available, may be obtained from the corresponding author upon reasonable request.

ETHICAL STATEMENT

This study used a simulated pavement-condition dataset and did not involve human participants, personal data, or experimental animals. The numerical results presented in this article must not be interpreted as actual field-survey measurements of Timor Raya Road Km 9.

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