

# Multi-Index Evaluation of Flexible Pavement Performance: A Comparative Analysis of PCI, IRI, and SDI Approaches

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| Submitted: December 22, 2023 | Revised: August 06, 2025 | Accepted: August 13, 2025 |

| Published: March 01, 2026 |

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## ABSTRACT

The Trans-Sumatra Highway is a national road that stretches from the north to the south of Sumatra Island. Tanjung Kemuning-Linau Road is part of the West Sumatra Trans-Sumatra Road located in Kaur Regency. This road is the main axis road of Bengkulu Province. Its function as a national road does not make Tanjung Kemuning-Linau Road free from road damage. Therefore, an evaluation of the pavement condition is needed to restore the stability of the road in order to achieve the purpose of the road as an important infrastructure in various aspects. The purpose of this study was to identify the types of damage with the level of damage to flexible pavements, and to determine the pavement condition index based on the PCI (Pavement Condition Index) method as the main method, and the IRI (International Roughness Index) method and SDI (Surface Distress Index) as a comparative method. The case study in this study was limited to a 5 km road section, namely at KM 17+500 to 22+500. Based on the results of the study, the types of damage most commonly found were crocodile skin cracks, longitudinal cracks, and patches. The PCI method pavement condition index has an average of 39.90 in the Normal direction, and an average of 41.82 in the Opposite direction. Based on the IRI method, in the Normal direction the average is 8.17 m/km and 7.66 m/km in the Opposite direction. The results of both methods show pavement conditions that fall into the Light Damage class. This is in line with the pavement index based on the SDI method, which has an average of 81.67 in the Normal direction and 80.20 in the Opposite direction which is also classified as light damage. To restore road stability, road improvement efforts are needed in the form of adding a surface layer / overlay. With CESA for a 10-year design life in 2033 of 13,605,740, the appropriate overlay thickness is 10 cm thick. Another road improvement option is to replace flexible pavement with composite pavement. Based on the cumulative calculation of the vehicle axle group in 2063 of 13,139,243.62, the appropriate pavement thickness for a design life of 40 years is 5 cm asphalt concrete as the surface layer, 26.5 cm thick cement concrete, and 10 cm thick subbase layer (LMC).

**Keywords:** road damage, pavement, condition, index, road improvement.

## INTRODUCTION

Smooth, safe, comfortable, and efficient road infrastructure will significantly impact transportation cost efficiency, regional development, and increased regional competitiveness. However, along the road network's journey to achieve this, there has been considerable criticism of the unsatisfactory performance of road users, with some road networks even experiencing damage. Damage frequently occurs, for example, on the Trans-Sumatra Highway, a national road that stretches across the island of Sumatra.

Kaur Regency, located in Bengkulu Province, has a major road, the Tanjung Kemuning-Linau section, which is part of the West Sumatra Trans-Sumatra Highway. According to the official Kaur Regency website, only 12.9% of roads in Kaur Regency are in good condition. Furthermore, 30.1% are in moderate condition, 9.7% are in poor condition, and 47.2% are in severe condition.

To more thoroughly evaluate pavement conditions and structural capabilities, a method is needed that provides damage analysis, classifies pavement conditions, and provides solutions for road damage management. One method that provides such guidelines is the PCI (Pavement Condition Index) method issued [1], [2]. Another method that can be used is the IRI (International Roughness

Index). In this method, the roughness of the pavement surface, which causes vibrations to vehicles, is used as the primary parameter in assessing the road condition index. Proposed a method that can also assess the road pavement index, the SDI (Surface Distress Index). The damage index in the SDI method is obtained from a road condition survey using four elements of damage and dividing them into four levels of road condition [3], [4].

**Traffic Growth Factors**

Traffic growth factors are the number of vehicles using the road each year, influenced by several factors such as regional development and improvements in community welfare.

**Table 1.** Traffic Growth Rate Factors (%) [5]

	Java	Sumatera	Kalimantan	Indonesian Average
Arterial and Urban	4,80	4.83	5.14	4.75
Rural collector	3,50	3,50	3,50	3.5
Village road	1,00	1,00	1,00	1,00

The traffic growth multiplier factor during the design life can be calculated using the equation:

$$R = \frac{(1 + 0,01 i)^{UR} - 1}{0,01 i}$$

Description:

R = Cumulative traffic growth multiplier

i = Annual traffic growth rate (%)

UR = Design life (years)

To calculate the predicted traffic growth in the following year, use the following equation:

$$VLHR = (1 + i)^n \times LHR$$

Description:

i = Annual traffic growth rate (%)

n = Number of years

LHR = Number of vehicles in a given year [6], [7]

**Cumulative Standard Axle Load**

The cumulative standard axle load or Cumulative Equivalent Single Axle Load (CESAL) is the cumulative total axle load of the design traffic on the design lane over the design life, which can be determined using the following equation:

$$ESA_{TH-1} = (\sum LHR_{JK} \times VDF_{JK}) \times 365 \times DD \times DL \times R$$

Description:

ESATH-1: Cumulative equivalent standard axle traffic in the first year.

LHRJK: Average daily traffic for each commercial vehicle type (vehicles per day).

VDFJK: Vehicle Damage Factor for each commercial vehicle type.

DD: Directional distribution factor.

DL: Lane distribution factor.

R: Cumulative traffic growth multiplier.

CESAL: Cumulative equivalent standard axle load during the design life

**Types of Flexible Pavement Damage**

Based on the 2016 Guidelines for Determining the Pavement Condition Index (IKP),

- |                       |                        |                   |
|-----------------------|------------------------|-------------------|
| 1. Alligator cracking | 8. Reflection cracking | 14. Rail crossing |
| 2. Overburden         | 9. Shoulder settlement | 15. Grooving      |

- 3. Block cracking
- 4. Bumping and dents
- 5. Curling
- 6. Subsidence
- 7. Edge cracking
- 10. Longitudinal cracking
- 11. Patching
- 12. Aggregate wear
- 13. Potholes
- 16. Slope
- 17. Slip cracking
- 18. Expansion
- 19. Grain detachment [5]

**IRI (International Roughness Index) Method**

The International Roughness Index (IRI) is a depiction of a longitudinal profile of a road used as a reference for road surface roughness. The roughness index is measured in m/km.

**Table 2.** Relationship between IRI (International Roughness Index) Values and Road Conditions and Management [6], [7]

IRI Value	Condition	Handling Needs
< 4	Good	Routine Maintenance
4 – 8	currently	Periodic Maintenance
8 – 12	Minor Damage	Road Improvement
> 12	Badly Damaged	Road Improvement

**SDI (Surface Distress Index) Method**

In the SDI method, the value of each identified damage determines the road condition by adding up all the damage values obtained. The higher the cumulative damage value, the higher the resulting SDI value.

**Table 3.** Relationship between SDI Values and Road Conditions and Management [7]

SDI Value	Condition	Handling Needs
< 50	Good	Routine Maintenance
50 – 100	currently	Periodic Maintenance
100 – 150	Minor Damage	Road Improvement
> 150	Badly Damaged	Road Improvement

**PCI (Pavement Condition Index) Method**

The PCI method was developed in America by the U.S. Army Corp of Engineers for airport, highway, and parking area pavements. This method provides accurate data and condition estimates that reflect field conditions.

**Table 4.** Pavement Quality Classification Based on PCI Values [8]

PCI Value	Road Condition Category
85 – 100	Excellent
70 – 84	Very Good
55 – 69	Good
40 – 54	Fair
25 – 39	Poor
11 – 24	Verry Poor
0 – 10	Failed

**Damage Management**

The management options for sample unit damage can be determined by the IRI value for each segment.

**Table 5.** Management Needs and Road Stability Level [9], [10]

Road Condition	IRI	Handling Needs	Level of Stability
Good	IRI rata-rata ≤ 4,0	Routine Maintenance	Steady Road
Moderate	4,1 ≤ IRI rata-rata ≤ 8,0	Periodic Maintenance	

Road Condition	IRI	Handling Needs	Level of Stability
Minor Damage	$8,1 \leq \text{IRI rata-rata} \leq 12$	Road Improvement	Unsteady Road
Severe Damage	$\text{IRI rata-rata} \geq 12$	Road Improvement	

The Pavement Condition Index (PCI) method is a standardized system developed by the U.S. Army Corps of Engineers to evaluate the surface condition of road pavements. It is widely documented in ASTM D6433 and used by municipalities and highway agencies to assess maintenance needs and prioritize rehabilitation. The PCI method provides a numerical rating from 0 to 100, where 100 represents a pavement in perfect condition and 0 represents a failed pavement. The assessment is based on a detailed visual survey of pavement distress types, their severity, and their quantity [11].

The PCI evaluation begins by dividing the road network into manageable sample units. Trained inspectors visually identify various types of distress such as cracking, rutting, potholes, raveling, patching, and edge failures. Each distress type is categorized by severity levels—low, medium, or high—and measured in terms of area, length, or number of occurrences. These measurements are then converted into deduct values using standardized curves. The total deduct value is adjusted to obtain a corrected deduct value, which is subtracted from 100 to determine the final PCI score for that pavement section [12]. A pavement classified as good typically has a PCI value between 85 and 100. In this condition, the surface shows minimal distress, mostly hairline cracks or slight weathering. Structural integrity remains strong, ride quality is smooth, and only routine maintenance such as crack sealing or minor surface treatments is required to preserve the pavement's performance [13], [14].

A moderate condition generally corresponds to PCI values between 55 and 70. At this stage, the pavement exhibits more noticeable cracking, minor rutting, patching, or surface wear. Although the structural capacity may still be adequate, the deterioration is progressing. Preventive maintenance or light rehabilitation, such as overlays or localized repairs, is often necessary to prevent further decline. Minor damage, often associated with PCI values between 70 and 85, reflects early stages of deterioration. Distresses are present but limited in extent and severity [15]. These may include isolated transverse or longitudinal cracks and slight surface roughness. Maintenance interventions at this stage are cost-effective and aimed at slowing deterioration before it becomes structurally significant [16].

Severe damage is indicated by PCI values below 40. In this condition, extensive cracking, potholes, deep rutting, and possible base or subgrade failures are evident. The pavement may pose safety risks and significantly reduce ride comfort. Major rehabilitation or full-depth reconstruction is typically required, as routine maintenance is no longer sufficient to restore serviceability [17].

## RESEARCH METHOD

This research took place on the Tanjung Kemuning-Linau Road, Bengkulu Province, starting from KM 17+500 to 22+500. The research period, from data collection to data processing, was May 2023 to July 2023. The research method used was quantitative, as it employed statistical or quantification procedures. In this study, the population was the West Sumatra Cross-Island Highway (Jalinbar). The sampling technique chosen was purposive sampling, as sampling was based on the researcher's consideration of which samples were most appropriate and considered representative of the population. The analysis stage began with digitizing road damage using OSIRIS software. The output damage dimensions were used to calculate the pavement condition index using the PCI method. The PCI value was then compared with secondary data from the IRI and SDI indices. The selection of a repair method was made after identifying the most appropriate treatment needs.

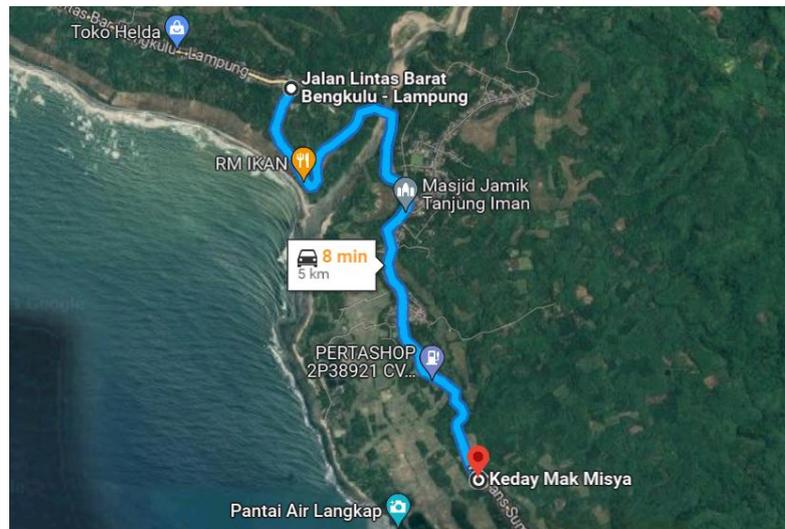


Figure 1. Research Location Source: [18]

**RESULTS AND DISCUSSION**

**Traffic Volume**

Daily traffic data in 2023 totaled 6,859, dominated by class 1, 3, 6B, and 4 vehicles.

Table 6. LHR for the Tanjung Kemuning-Linau Section 2020-2023 [19]

Type	Years				Average
	2020	2021	2022	2023	
1	3750	3043	2512	3697	3250.5
2	313	1251	59	47	417.5
3	1046	3	1705	1562	1079
4	631	535	562	681	602.25
5a	8	16	0	6	7.5
5b	7	7	21	8	10.75
6a	53	277	303	25	164.5
6b	457	237	566	807	516.75
7a	16	14	33	22	21.25
7b	0	0	0	0	0
7c	4	0	0	1	1.25
8	9	1	0	3	3.25
Total	6294	5384	5761	6859	6074.5

**Identification of Damage Types**

The results of the road damage digitization revealed that the largest damage volumes were crocodile skin cracks, covering 1,201.88 m<sup>2</sup>, and patches, covering 228.49 m<sup>2</sup>. The longest total damage length was longitudinal cracks, measuring 731.69 m.

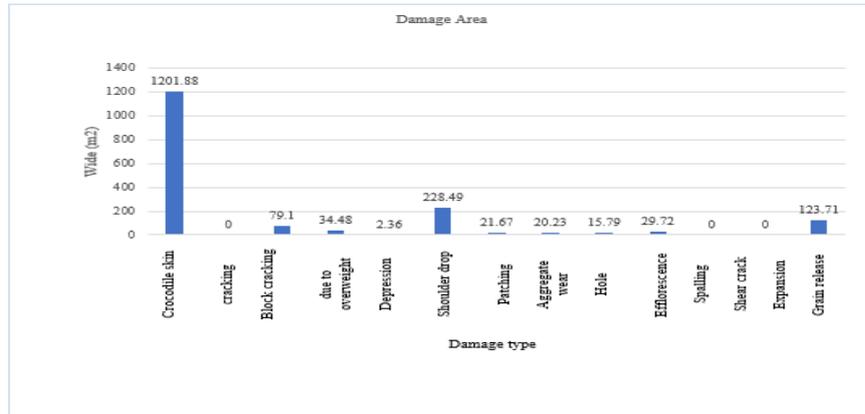


Figure 2. Summary of Damage Area Source: 2023 Research

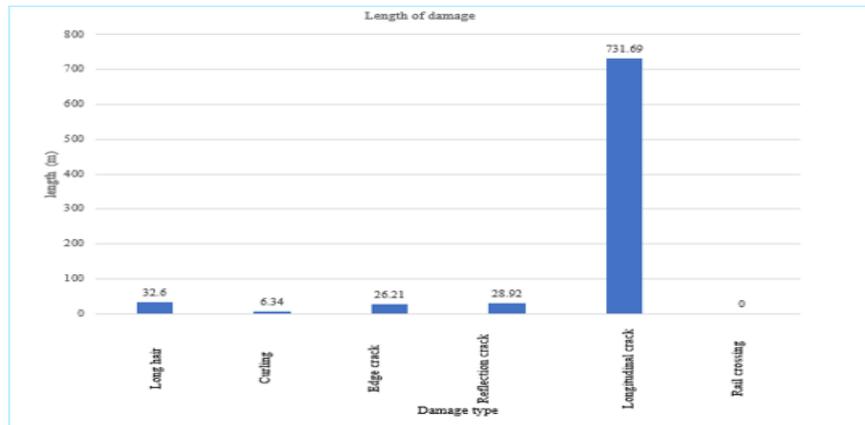


Figure 3. Summary of Damage Length Source: 2023 Research

### Pavement Condition Index (PCI) Method

In the left lane, the lowest PCI value was 23 at KM 21+000. The highest PCI value was 64 at KM 18+300 and 22+300. In the right lane, the lowest PCI value was 23 at KM 21+000. The highest PCI value was 64 at KM 18+300 and 22+300. In the right lane, the lowest PCI value was 18 at KM 18+600. The highest PCI value was 68 at KM 21+600.

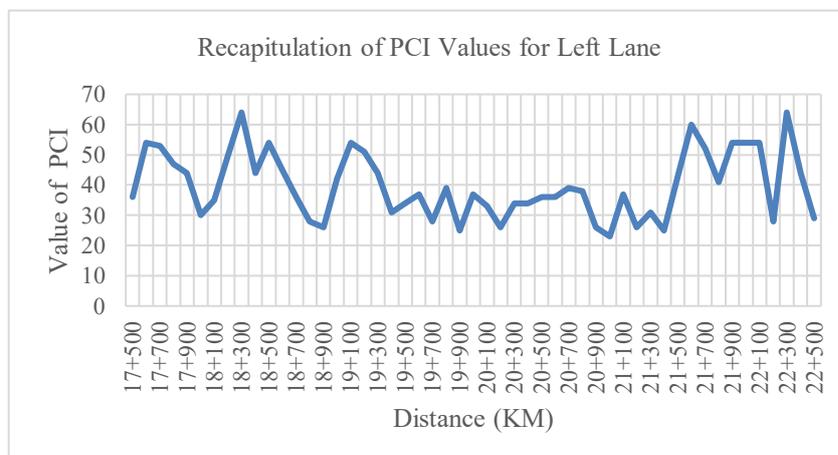


Figure 4. Recapitulation of PCI Values for the Left Lane Source: 2023 Research

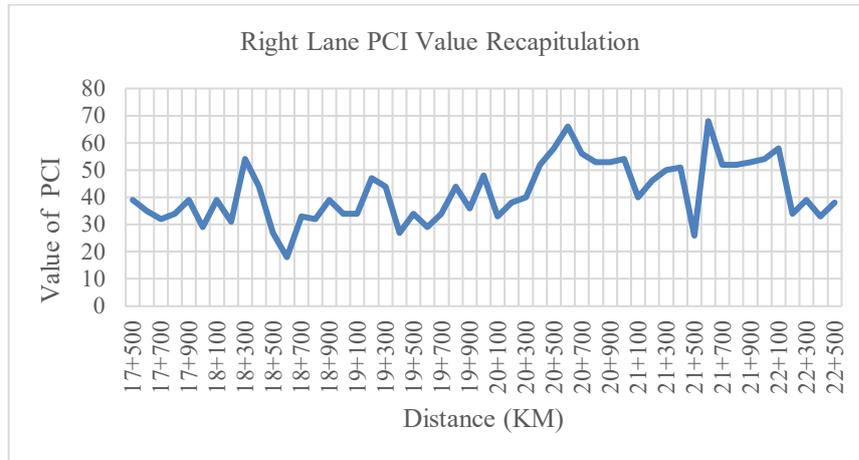


Figure 5. Summary of PCI Values for the Right Lane Source: 2023 Research

**Pavement Condition Index (IRI) Method**

In the left lane, the lowest IRI value was 4.5 at KM 21+600 and KM 22+100. The highest IRI value was 10.4 at KM 19+500. In the right lane, the lowest IRI value was 3.4 at KM 20+600. The highest IRI value was 12.2 at KM 19+300.

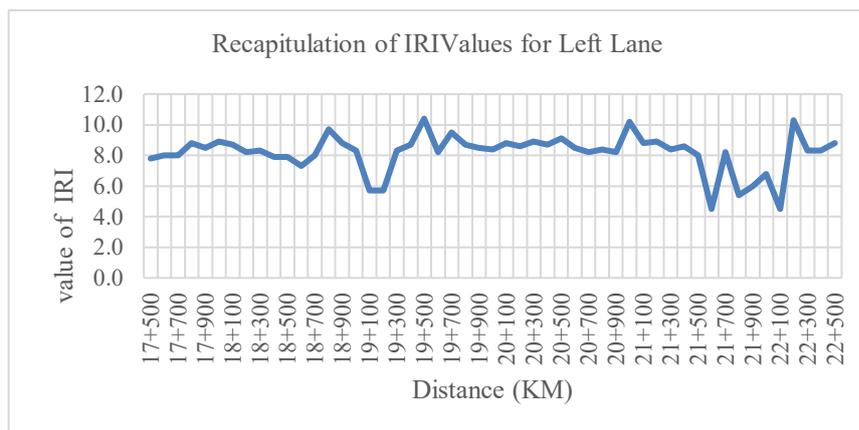


Figure 6. Summary of IRI Values for the Left Lane Source: 2023 Research

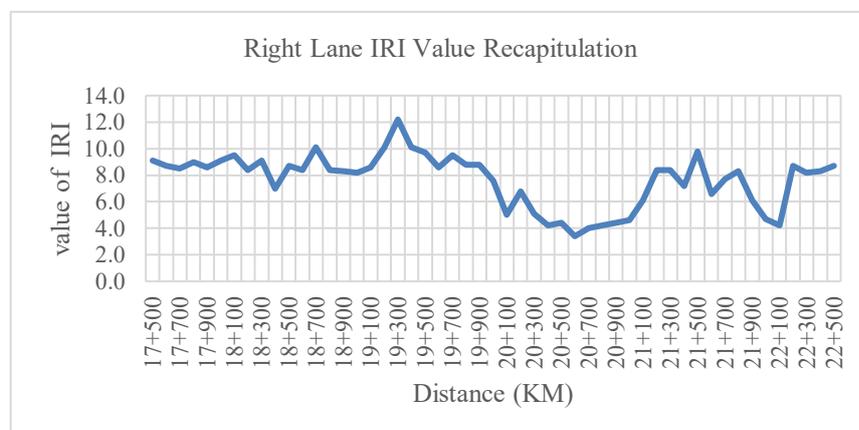
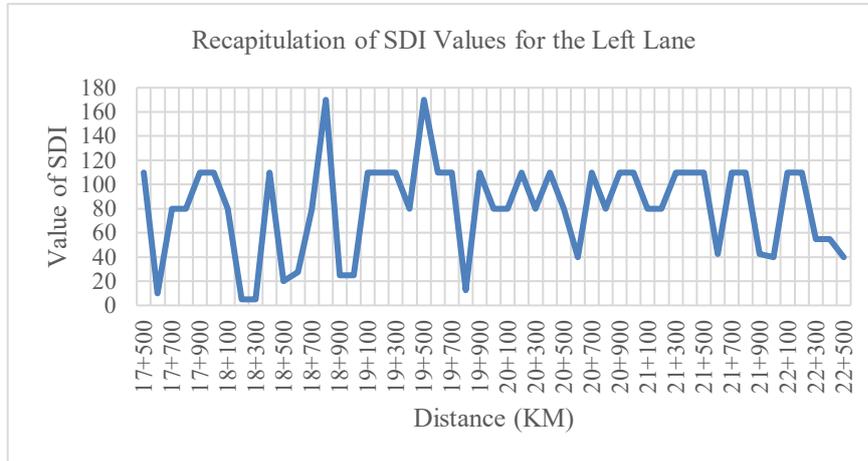


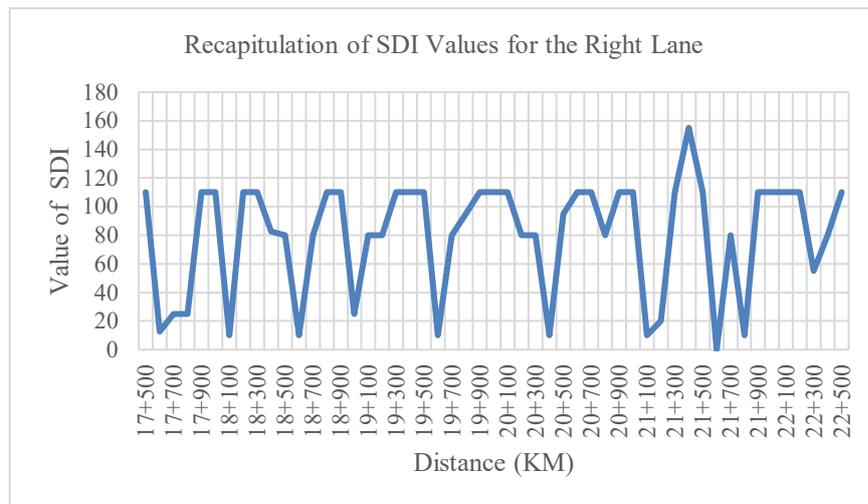
Figure 7. Summary of IRI Values for the Right Lane Source: 2023 Research

**Pavement Condition Index (SDI) Method**

In the SDI method, the lowest SDI value for the left lane was 5 at km 18+200, 18+300, and 18+500. The highest SDI value was 170 at km 18+800 and 19+500. For the right lane, the lowest SDI value was 0 at km 21+600. Meanwhile, for the right lane, the highest SDI value was 155 at km 21+400.



**Figure 8.** Summary of Left Lane Traffic Values Source: 2023 Research



**Figure 9.** Summary of Right Lane SDI Values Source: 2023 Research

The results of determining the level of road damage using the PCI, IRI, and SDI methods yielded the same highest level of damage, namely Minor Damage. The percentage summary is presented in Figures 10 and 11.

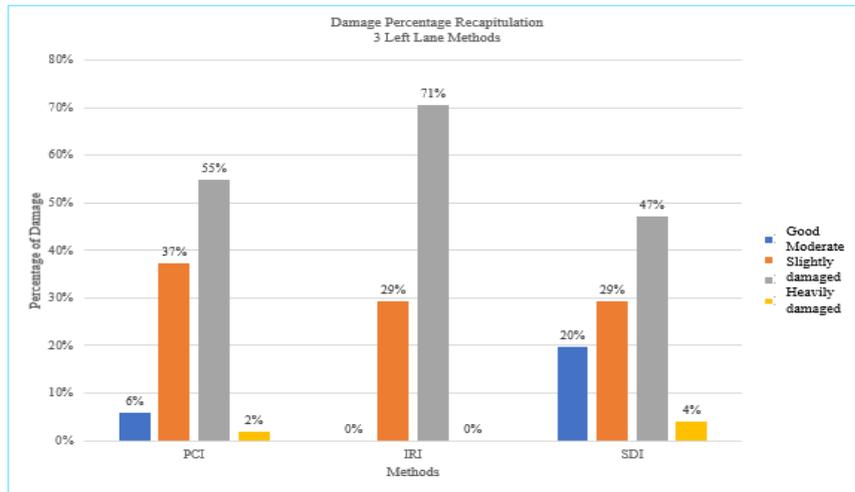


Figure 10. Summary of Left Lane Damage Levels Source: 2023 Research

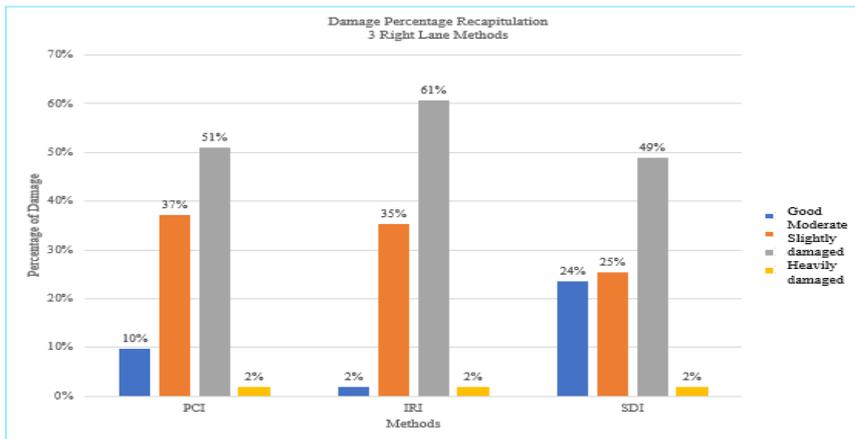


Figure 11. Summary of Right Lane Damage Levels Source: 2023 Research

With the high percentage of light damage, road improvement efforts are needed to restore the road's stability. Road improvements can be achieved by adding an asphalt layer/overlay.

**Overlay Planning**

In overlay planning, the cumulative standard axle load (CESA) is required to determine the appropriate overlay thickness.

Table 7. CESA Calculation

Group	LHR 2023	LHR 2024	LHR 2033	VDF5 Actual	ESA (2023-2024')	ESA (2024-2033)
				-	0	0
1 - 5A	5993	6282	9163	-	0	0
				-	0	0
				-	0	0
				-	0	0
5B	8	8	13	1,0	1.460	15.338
6A	25	26	40	0.50	2.281	23.966
6B	807	846	1293	7,40	1.089.854	11.449.798
7A	22	23	35	20,00	80.300	843.617
7B	0	0	0	-	0	0

Group	LHR 2023	LHR 2024	LHR 2033	VDF5 Actual	ESA (2023-2024')	ESA (2024-2033)
7C	1	1	2	51.70	9.435	99.125
Total	<b>6856</b>	<b>7187</b>	<b>17611</b>	<b>CESA</b>	<b>1.173.895</b>	<b>12.431.845</b>
					<b>13.605.740</b>	

Source: 2023 Research Results

The calculation of the allowable back deflection (D) is performed by plotting the CESA value on the following allowable back deflection graph:

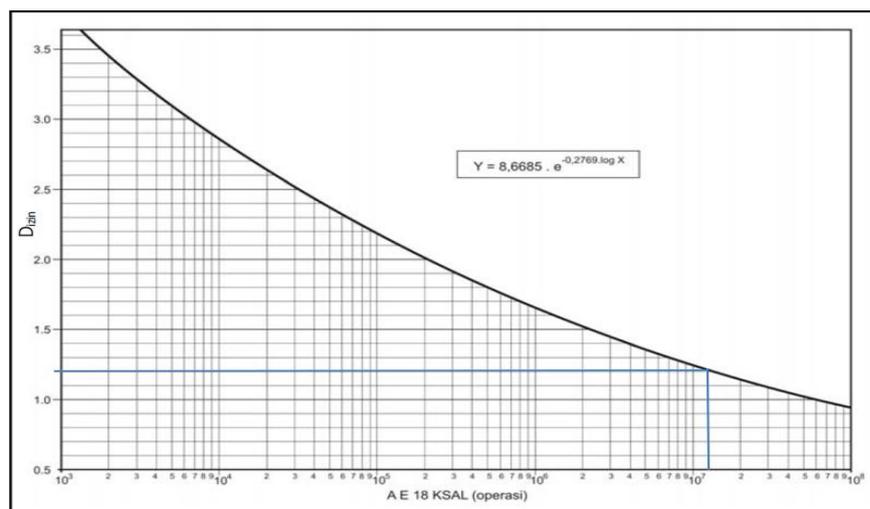


Figure 12. Allowable Back Deflection Source: 2023 Research Results

Therefore, the allowable deflection obtained is 1.2 mm.

The overlay thickness is determined using the following equation:

$$T = \frac{2.303 \log D - 0.408(1 - \log \text{CESA})}{0.08 - 0.013 \log \text{CESA}}$$

$$T = \frac{2.303 \log (1.2) - 0.408(1 - \log 13,605,740)}{0.08 - 0.013 \log 13,605,740}$$

$$T = 90,76 \text{ mm}$$

$$T \approx 10 \text{ cm}$$

## CONCLUSION

The research results show that the total LHR volume of the Tanjung Kemuning-Linau Road Section in 2023 was 6859. The most common types of damage found on the Tanjung Kemuning-Linau Road were crocodile skin cracks, longitudinal cracks, and patches. These three types of damage have moderate to high severity levels. The pavement condition index for the left lane using the PCI method has an average of 39.90 and for the right lane it has an average of 41.82. In the IRI method, the average index is 8.17 m.km and 7.66 m.km for the right lane average. In the SDI method, the left lane produces an average of 81.67 and 80.20 for the right lane. All methods produce an average level of damage of Light Damage. As a repair solution to restore road stability, road improvement efforts are needed in the form of adding a surface layer/overlay. This overlay is designed for a design life of 10 years with a thickness of 10 cm.

## REFERENCES

- [1] ASTM D6433-07.
- [2] Aptarila, G., Fadrizal, L. dan Alfian, S. 2020. "Analisis Kerusakan Jalan Metode SDI Taluk Kuantan-Batas Provinsi Sumatera Barat". Jurnal Teknik Sains. 7(1)

- [3] Giyatno. 2016. “*Analisis Kerusakan Jalan Dengan Metode PCI Kajian Ekonomis Dan Strategi Penanganannya (Studi Kasus Ruas Jalan Ponorogo – Pacitan Km 231+000 Sampai Dengan Km 246+000, Km 0+000 Di Surabaya)*”.
- [4] Kartika, A.F. 2018. “*Analisa Kondisi Perkerasan Jalan Menggunakan Metode PCI Pada Kecamatan Sukolilo Kota Surabaya - Propinsi Jawa Timur*”. Surabaya: Institut Teknologi Sepuluh Nopember
- [5] Road Pavement Design Manual (2017)
- [6] Bina Marga (2011)
- [7] Kurniawan, R. 2016. “*Analisa Kondisi Kerusakan Jalan Pada Lapis Permukaan Menggunakan Metode Pavement Condition Index (PCI) (Studi Kasus: Ruas Jalan Argodadi, Sedayu, Bantul Yogyakarta)*”. Surabaya: Universitas Muhammadiyah Yogyakarta
- [8] Maharani, A., Supto B. 2018. “*Perbandingan Perkerasan Kaku Dan Perkerasan Lentur (Studi Kasus Ruas Jalan Raya Pantai Prigi – Popoh Kab. Tulungagung)*”. Jurnal Perencanaan dan Rekayasa Sipil.1(02)
- [9] Mulyono, A.T. 2007. “*Model Monitoring Dan Evaluasi Pemberlakuan Standar Mutu Perkerasan Jalan Berbasis Pendekatan Sistemik*”. Semarang: Universitas Diponegoro
- [10] Permadi, Diki. Barkah W., dan Yeyet H. 2021. ”*Analisis Kondisi Permukaan Perkerasan Jalan Dengan Menggunakan Metode Survey SDI Dan RCI Serta Penanganannya*”.
- [11] S Syaiful, H Rusfana. (2022). Rigid Pavement Planning in Traffic: Case Study in Cihorang Road and Pemuda Road, Bogor Regency, INDONESIA. Journal of Applied Engineering Science 20 (2), 485-497.
- [12] T Triyanto, S Syaiful, R Rulhendri. (2019). EVALUASI TINGKAT KERUSAKAN JALAN PADA LAPIS PERMUKAAN RUAS JALAN TEGAR BERIMAN KABUPATEN BOGOR. ASTONJADRO 8 (2), 70-79.
- [13] S Syaiful, L Lasmana. (2020). A STUDY ON LEVEL OF RAILWAY ROAD DAMAGE WITH SUSTAINABLE PCI METHOD. ARPN Journal of Engineering and Applied Sciences 15 (8), 962-968.
- [14] Paikun, P., & Perkasa, R. W. (2024). Analysis of Damage to Caringin Cikukulu Road, Sukabumi District Using the Pavement Condition Index (PCI) Method. ASTONJADRO, 13(3), 675–685. <https://doi.org/10.32832/astonjadro.v13i3.15035>.
- [15] Brahmana, I. C. S., Hasibuan, G. C. R., & Anas, M. R. (2024). The Usage of Surface Distress Index (SDI) and Pavement Condition Index (PCI) to Evaluate The Condition of Jamin Ginting National Road (BTS. Medan City - BTS. Karo Regency). ASTONJADRO, 13(3), 922–929. <https://doi.org/10.32832/astonjadro.v13i3.16028>.
- [16] Setiawan, A., Putu Artawan, I., Yuniarto, E., Bachtiar, E., & Yudha Alam, G. (2024). Analysis of Road Damage Using Road Condition Survey Data and Handling Designs (Case Study of the Pasangkayu - Baras Section). ASTONJADRO, 13(2), 550–562. <https://doi.org/10.32832/astonjadro.v13i2.15409>.
- [17] Puspito, B. A. (2025). Development of the South Java Coastal Crossroads (Case Study of the Legundi-Planjan Road Section, Gunungkidul Regency, Special Region of Yogyakarta Province). ASTONJADRO, 14(4), 1047–1059. <https://doi.org/10.32832/astonjadro.v14i4.18945>
- [18] Google Maps 2025.
- [19] Directorate General of Highways, 2023.