E-ISSN: 2528-388X
P-ISSN: 0213-762X

INERSIA
Vol. 19, No. 2, December 2023

The Evaluation of Pavement Condition Assessment Methods for Road Assets in Coastal Areas

Clarence Deborah Teopilus and Mukhammad Rizka Fahmi Amrozi*

Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

Keywords:
Road Pavement Distress
Road Asset Management
SDI
PCI
PASER

ABSTRACT

The Daendels road is a vital provincial road asset that facilitates the distribution of goods and services, enhances tourism access, and promotes socio-economic development in the southern region of Java Island. The deteriorated condition of the Daendels road pavement has the potential to escalate both the likelihood of accidents and vehicle operating costs. In Indonesia, road distress is measured using the Surface Distress Index (SDI), but certain types of distress are not yet incorporated into the calculation. Therefore, this study aims to identify the typical road distress in the coastal region and then to evaluate and compare several visual methods for evaluating the functional condition of road pavements, i.e., the SDI, Pavement Condition Index (PCI), and Pavement Surface Evaluation and Rating (PASER). Pavement conditions for Daendels Road have different analysis results depending on the method used. The average value of PCI is 50.5 (slightly damaged), the SDI is 164 (severely damaged), and the PASER is 4 (slightly damaged). The statistical analyses indicate that both the SDI-PCI and SDI-PASER methods have a very strong relationship. The SDI-PCI method has a higher correlation and coefficient of determination value (R= -0,929, R^2= 0,8631) than SDI-PASER (R= -0,807, R^2= 0,652). The PCI method is more applicable than the SDI dan PASER as it considers a wider range of pavement distress (19 categories) and more accurately represents the typical distress encountered on the South Coast of Java Island. The pavement condition of Daendels Road is classified as severely damaged with typical distress involving cracking (longitudinal, transversal, alligator, and blocks), patching, and pothole. Hence, a comprehensive plan for road maintenance was suggested, encompassing major rehabilitation using a hot mix asphalt overlay.

1. Introduction

Roads serve as the primary infrastructure for land transportation and have a substantial influence on the economic, social, cultural, and political aspects of a region [1]. According to Government Regulation No. 34/2006, roads are defined as land transportation infrastructure that includes all components of the road, including associated structures and equipment used for vehicular movement, excluding trains, trams, and cable cars [2]. Over time, the continued use of roads will inevitably result in road deterioration and a decrease in the quality performance of the road surface, affecting both its functionality and structural integrity. Consequently, this will have negative consequences for road users [3].

Daendels Road is one of the provincial roads that connects the southern part regions of Java, stretches from the east of Cilacap to the border area of Jogja, Wates. Daendels Road plays a crucial role in facilitating the distribution of products and services, providing access to tourism on the southern coast of Java Island, and driving the socio-economic growth of the region. Thus, the roads should be managed and preserved in good condition [4].

To provide optimal service performance, it is crucial to promptly identify and diagnose the typical distress of road pavement. This allows for proactive road maintenance to be carried out, effectively minimizing additional damage at a reduced expense. Several studies were conducted to evaluate and compare road damage methods [5][6][7]. However, there have not been many case studies found that focus on road pavement distress in coastal areas.

*Corresponding author.
E-mail: fahmi.amrozi@ugm.ac.id

https://dx.doi.org/10.21831/inersia.v19i2.61089
Received August 7th 2023; Revised December 22nd 2023; Accepted December 27th 2023
Available online December 31st 2023

Therefore, this study aims to determine the typical road damage in coastal areas and evaluate and compare several visual survey methods for evaluating the functional condition of road pavements.

Pavement condition evaluation can be used to determine optimal road handling alternatives. There are various methods to evaluate road conditions, including the Pavement Condition Index (PCI), the International Roughness Index (IRI), and the Surface Distress Index (SDI) method. In this study, PCI, SDI, and Pavement *Surface Evaluation and Rating* (PASER) methods were used as visual survey procedures to assess the condition of Daendels Road pavement and propose appropriate road repair or maintenance options. Furthermore, correlation and determination analyses were conducted to ascertain the extent of the relationship and influence of the assessment results of the SDI method (the standard method used by Bina Marga) on the PCI and PASER methods.

2. Method

In this study, PCI, SDI, and PASER methods were used to assess the condition of Daendels Road pavement following the flowchart in Figure 1.

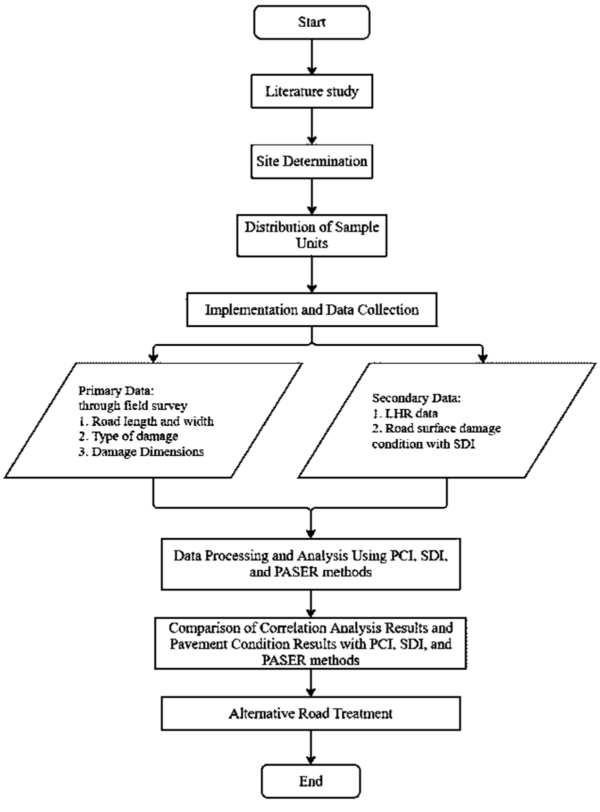

Figure 1. Research flow chart.

The study was conducted on 1.2 km length of Daendels road (STA 29+775 – 30+975) as shown in Figure 2. Daendels Road uses flexible pavement and has a width of 7 m. The roads were subsequently partitioned into sample units to comply with the specified range of sample unit area outlined by the three methods. i.e., for the PCI method, the length of the sample unit is 25 meters (48 sample units), while for the SDI and PASER methods is 100 meters (12 sample units).

The research was conducted by a visual survey and required tools, including: (a) stationery; (b) survey form; (c) measuring tape; (d) handphone camera, (e) calipers; (f) reflective vest and light stick.

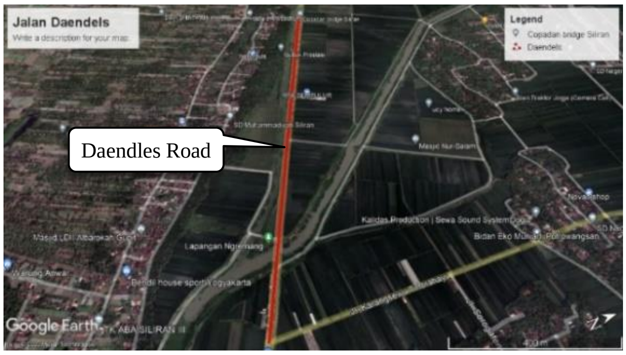

Figure 2. Location of the Daendels Road [8].

2.1 The PCI Method

Pavement Condition Index (PCI) is a method to assess pavement conditions based on the type, density, and level of damage (severity) that occurs on the pavement surface. The Pavement Condition Index (PCI) assessment uses values ranging from 0 to 100 and has criteria for *excellent*, very good, good, fair, poor, very poor, and failed [9].

Density is a type of damage to the area of a sample unit measured in m² or meters of length and produced as a percentage. The density of damage is expressed by Equations 1 and Equation 2.

$$Density = \frac{Ad}{As} \times 100\% \quad (1)$$

$$Density = \frac{Ld}{As} \times 100\% \quad (2)$$

where Ad is the total area of a type of distress for each severity level (m²), As is the area of unit sample (m²), Ld is total length of distress type at each severity level (m).

The deduct value against density graph is utilized to ascertain the reduction score for each category of distress based on the relationship between density and deduct value. Once the density value has been obtained, it is necessary to plot the deduct value graph based on the severity and type of damage. To calculate the q value, the sum of the *individual deduct values* is reduced by the value of any damage that exceeds 5 for airports or unpaved roads and exceeds 2 for paved roads. If a sample unit does not have any reduction values greater than 2, then all reduction values can be utilized as Corrected Deduct Values (CDV). However, if there are two or more reduction values, the maximum NPT is determined as follows.

(a) All deduct values are arranged sequentially from largest to smallest.
(b) Determine the maximum number of deduct values allowed by using Equation 3.

$$m = 1 + \left(\frac{9}{98}\right)(100 - MaxDV) \quad (3)$$

Where m is the number of permit reductions for sample units, MaxDV is the highest deduct value.
(c) The number of individuals DV is subtracted according to the m value of the calculation result. If the sum of the subtraction values is less than m, then all the subtraction values are used to determine the maximum CDV
(d) The deduct value is added so that the Total Deduct Value (TDV) is obtained. q iterates with q being the number of individuals deduct values > 2.

The CDV value is generated based on the TDV and q values. In Figure 3, the TDV value can be plotted by adjusting the q value in the calculation. If the CDV value is less than the highest deduction value, then the CDV value used is the highest individual deduct value.

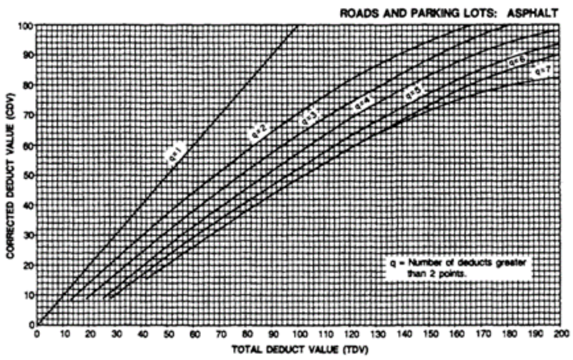

Figure 3. Graphic CDV [5].

The pavement conditions based on the PCI can be seen on Figure 4 while the PCI value for each sample unit calculated by Equation 4.

$$PCIs = 100 - CDVmax \quad (4)$$

with $PCIs$ is Pavement Condition Index for each unit, CDV is Corrected Deduct Value for each unit.

After obtaining the PCI value of each sample unit, the next thing to do is calculate the PCI value on 1 road section [10] using Equation 5.

$$\text{PCI} = \frac{\Sigma PCI(s)}{n} \quad (5)$$

where PCI as the pavement condition index for each unit and n as the number of sample units.

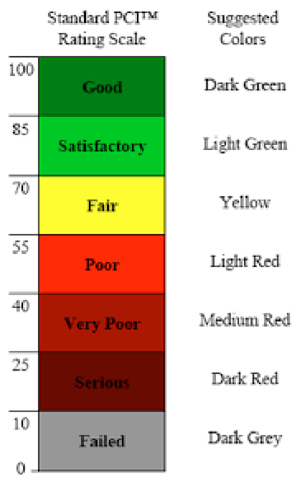

Figure 4. Pavement conditions based on the PCI method [11].

2.2 The SDI Methods

The Surface Distress Index (SDI) is an official method to evaluate pavement conditions in Indonesia. Based on the Bina Marga SMO-03/RCS Guideline, the SDI calculation requires 4 measurement factors, i.e., the percentage of crack area, average crack width, number of potholes/km, and average rutting depth of wheel ruts [12]. The assessment for each SDI factor is specified in Table 1 to Table 4 while the pavement conditions presented in Table 5.

(a) Cracks area

Table 1. SDI 1 [12]

Percentage (%)	SDI value 1
None	0
<10	5
10-30	20
>30	40

(b) Crack width

Table 2. SDI assessment 2 [12]

Width (mm)	SDI value 2
None	SDI 1
End, <1	SDI 1
Medium, 1-5	SDI 1
Wide, >5	1 x 2 SDI

(c) Number of potholes

Table 3. SDI 3 rating [12]

Quantity/km	SDI value 3
None	SDI 2
<10	SDI 2 + 15
10-50	SDI 2 +75
>50	SDI 2 +225

(d) Rutting depth of rutting ruts

Table 4. SDI 4 rating [12]

Quantity/km	SDI value 4
None	SDI 3
<1	SDI 3 + (5 x 0,5)
1-3	SDI 3 + (5 x 2)
>3	SDI 3 + 20

Table 5. Pavement conditions based on the SDI values [12]

SDI value	Condition
<50	Good
50 – 100	Medium
100 – 150	Light Damage
>150	Heavy Damage

2.3 The PASER Method

The Pavement Surface Evaluation and Rating (PASER) method is a visual road condition survey developed in the United States and Canada by identifying and assessing the quality of the road surface. In the PASER method, four main parameters need to be considered, i.e. surface damage (raveling, fatness, wear), surface deformation (*rutting*, *shoving*, collapse, and frost heave), *cracking* (transverse, slippage, longitudinal, block, alligator, *and* reflection), potholes and patches [13]. The assessment of the PASER uses a scale of 1 to 10. The PASER value of 1 indicates the condition of the pavement is severely damaged or failed (worst condition), while value 10 indicates the condition of the road pavement is excellent like new (best condition). The assessment process and identification of PASER assessment methods are described as follows:

(a) Pavement Condition Survey
The surveyor observes the condition of the road pavement by dividing the road segment per 100 m length then measuring the quantity and dimension of road distress.
(b) Assessment using the PASER Method
Categorize the rating or quality assessment of road surface distress based on general pavement condition and visible distress in road segment following the PASER Manual guide. During the assessment, it is important to acknowledge that each individual road segment as sample unit may not exhibit all the specified categories of distress for a certain rating. They may possess only one or two types of distress.

3. Result and Discussion

3.1 The PCI

The PCI values and conditions vary for each sample unit (see Table 6). The PCI calculation revealed that the road condition at the starting station of the sample is more deteriorated compared to those at the end. The common type of road distress identified in the Daendels road includes patching, longitudinal and transverse cracking, alligator cracking, potholes, block cracking, and elevation differences between the edge of the pavement and the shoulder of the road (lane/shoulder drop-off).

Table 6. Pavement assessment based on the PCI method

Sample	PCI value	Condition
1	38	Very poor
2	39	Very poor
3	57	Fair
4	21	Serious
5	40	Poor
6	57	Fair
7	34	Very poor
8	56	Fair
9	40	Poor
10	47	Poor
11	12	Serious
12	10	Serious
13	10	Serious
14	25.5	Very poor
15	50	Poor
16	50.5	Poor
17	66	Fair
18	44	Poor
19	30	Very poor
20	44	Poor
21	42	Poor
22	12	Serious
23	12	Serious
24	10	Serious
25	8	Failed
26	2	Failed
27	64	Fair
28	60	Fair
29	54	Poor
30	69	Fair
31	76.5	Satisfactory
32	86	Good
33	84	Satisfactory
34	72.5	Satisfactory
35	86	Good
36	72	Satisfactory
37	76	Satisfactory
38	77	Satisfactory
39	82.5	Satisfactory
40	53	Poor
41	90	Good
42	84	Satisfactory
43	77	Satisfactory
44	75	Satisfactory
45	72.2	Satisfactory
46	49	Very poor
47	67	Fair
48	83.5	Satisfactory

The example of PCI calculation procedures is illustrated as follows:

(a) Density (%)
Patch = 3.84% (L)
Elongated or transverse crack = 2.91% (L)
Elongated or transverse crack = 1.03% (M)
Crocodile skin crack = 2.43% (L)
Crocodile skin crack = 1.85% (L)
Pothole = 2.29% (L)
Pothole = 2.86% (M)
Pothole = 2.86% (H)
Block crack = 1.95% (L)
Lane/shoulder drop off = 2.91% (L)
Lane/shoulder drop off = 4.46% (M)

(b) Deduct Value
The deduct value is obtained from the plot of the density relationship graph with the *deduct value* as shown in Figure 5.

(c) Maximum Corrected Value
The example of the CDV calculation procedures for unit sample 25 is presented in Table 7. The CDV value is obtained from the graph plot of the relationship between TDV and the q value as shown in Figure 6.

Table 7. The CDV calculation for unit sample 25

Iteration	Deduct Value				*TDV*	*q*	*CDV*
1	71	51	32	17.24	171,24	4	92
2	71	51	32	2	156	3	91
3	71	51	2	2	126	2	84
4	71	2	2	2	77	1	78

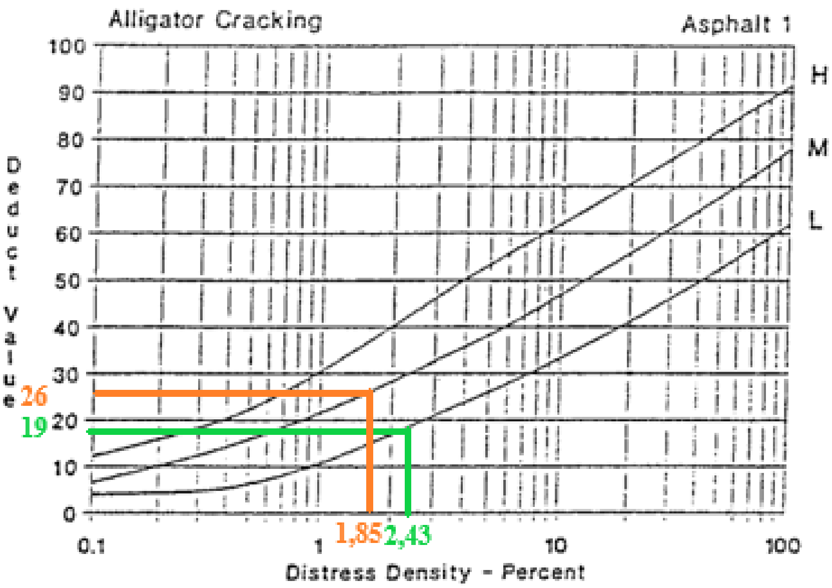

Figure 5. Deduct value for crocodile crack [9].

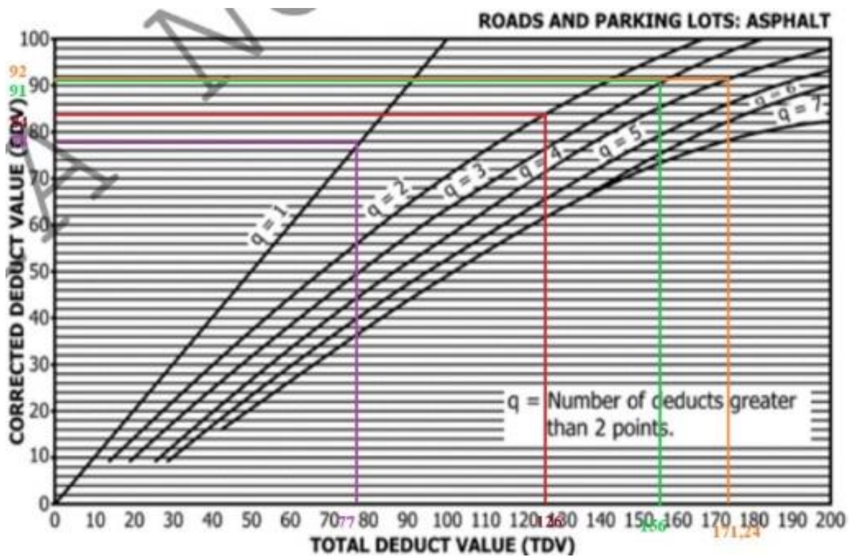

Figure 6. The CDV for unit sample 25 [4].

(d) PCI value
The determination of the corrected reducing value (NPT) has been obtained, so the largest NPT value with a value of 92 is taken, then the PCI value obtained is 8. Accordingly, pavement conditions with PCI value 8 are classified as *failed.*

3.2 The SDI

The analysis for the SDI method utilized two distinct types of data, i.e., primary data from a visual survey and secondary data sourced from the Bina Marga. The calculation of the SDI assessment for sample number 7 is demonstrated as follows.

(a) SDI Value Calculation 1
Sample unit 7 total crack area of 91.85 m² with a sample unit width of 7 m. Then the crack percentage value is as follows:

$$\%\ Cracks = \frac{91{,}85\ \text{m}^2}{100 \times 7\ \text{m}} \times 100\% = 13{,}12\%$$

Then the value of SDI 1 based on Table 1 is 20

(b) SDI Value Calculation 2
The average crack width of sample unit 7 is 9.2 mm. The calculation of SDI 2 based on Table 2 is as follows:

$$SDI\ 2 = SDI\ 1\ \times 2$$
$$SDI\ 2 = 20\ \times 2 = 40$$

Then the value of SDI 2 based on Table 2 is 40.

(c) SDI Value Calculation 3
A total of 30 holes were identified along 100 m. Since one hundred meters is equivalent to 0.1 kilometers, the quantity of holes can be determined by multiplying the number of holes by 10. According to Table 3, the SDI 3 value is as follows.

$$SDI\ 3 = SDI\ 2 + 225$$
$$SDI\ 3 = 40 + 225 = 265$$

Then the value of SDI 3 based on Table 3 is 265.

(d) SDI Value Calculation 4
In sample unit 7 no depth of wheel marks was found so the SDI value 4 based on Table 4 is equal to SDI 3, i.e. 265.

(e) Pavement Condition
The final analysis results of SDI 4 (SDI 265) can determine pavement conditions. Based on Table 5, SDI 256 for sample 7 is categorized as Heavy Damaged or severely damaged conditions.

The SDI analysis outcomes using primary data for the rest unit samples are presented in Table 8 while the SDI values using secondary data are shown in Table 9.

Table 8 and Table 9 indicate a significant difference in the results of pavement conditions. This is owing to the different survey timeframes, with the Bina Marga conducting a road condition investigation in July while primary data gathering in December. As the survey was conducted using a visual survey, the subjectivity of the assessment will also have a significant impact on the assessment outcomes.

Table 8. The SDI analysis results using primary data

Unit sample	SDI value	Pavement Conditions
1	235	Heavy damaged
2	235	Heavy damaged
3	235	Heavy damaged
4	235	Heavy damaged
5	265	Heavy damaged
6	265	Heavy damaged
7	265	Heavy damaged
8	85	Medium
9	40	Good
10	10	Good
11	10	Good
12	85	Medium

Table 9. The SDI analysis results using secondary data

Unit sample	SDI value	Pavement Conditions
1	0	Good
2	0	Good
3	0	Good
4	0	Good
5	0	Good
6	2.5	Good
7	2.5	Good
8	2.5	Good
9	2.5	Good
10	2.5	Good
11	0	Good
12	0	Good

3.3 The PASER

The PASER method closely resembles the PCI method as it considers two types of data, i.e. the type and dimension of pavement distress. Table 10 presents the outcome analysis for the PASER method.

Table 10. Analysis results based on the PASER method

Unit sample	Condition	Value
1	Very poor	2
2	Poor	3
3	Good	6
4	Fair	4
5	Very poor	2
6	Poor	3
7	Very poor	2
8	Good	7
9	Good	6
10	Good	6
11	Good	6
12	Good	6

3.4 Comparison of Pavement Conditions

Based on pavement condition results from PCI, SDI, and PASER methods, they have different outcomes and range of condition categories. To account for variations in damage condition values across the PCI, SDI, and PASER methodologies, equalization is carried out following the Regulation of the Minister of Public Works number 13/M.PRT.2011 concerning Road Maintenance and Inspection Procedures. The deterioration categories were converted into four categories following the SDI method i.e., good, medium, light damaged, and heavy damaged. Thus, the pavement condition can be compared between the three methods. Furthermore, the unit sample must be equal, thus the PCI also counted for a 100 m unit sample. The equalization of pavement conditions for the PCI, SDI, and PASER methods can be seen in Table 11.

Table 11. Pavement condition equalization

Unit Sample	Pavement Conditions			
	PCI per 100 m	SDI - Primary data	SDI - Secondary Data	PASER
1	Heavy damaged	Heavy damaged	Good	Heavy damaged
2	Light damaged	Heavy damaged	Good	Heavy damaged
3	Heavy damaged	Heavy damaged	Good	Medium
4	Heavy damaged	Heavy damaged	Good	Light damaged
5	Light damaged	Heavy damaged	Good	Heavy damaged
6	Heavy damaged	Heavy damaged	Good	Heavy damaged
7	Heavy damaged	Heavy damaged	Good	Heavy damaged
8	Good	Medium	Good	Medium
9	Good	Good	Good	Medium
10	Good	Good	Good	Medium
11	Good	Good	Good	Medium
12	Medium	Medium	Good	Medium

Table 11 indicated that the PCI, SDI, and PASER methods give a different assessment value and distress category on the pavement condition for Daendels Road STA Road 29+775 – 30+975. The Pavement conditions result in an average PCI value of 50.5 (light damage), an SDI value of 164 (heavy or severe damage), and a PASER value of 1.04 (light damage). These differences occurred as they considered different numbers and types of pavement distress were considered in the calculation procedure.

3.5 Correlation and Determination

Correlation and determination are concepts in statistics that quantify the relationship between variables. In this study, regression analyses using SPSS software are used to test the relationship between the SDI, PCI, and PASER methods. The SDI as the standard measurement method in Indonesia was used as independent variables while the PCI and PASER methods as dependent variables. Four types of regression analyses were carried out, i.e., simple linear regression, polynomial, logarithmic, and exponential. The regression analysis with the highest R^2 value can be considered as the best relationship model [14]. In addition, the relationship between the X and Y variables may also be assessed using significance values or tcount and ttable values.

(a) The significance values.
If the significance value < 0.05, it can be claimed that the two variables have a relationship (correlated) while if the significance value > 0.05 indicates that the two variables have no relationship (not correlated).

(b) tcount and ttable values
If the value of tcount > ttable, it can be stated that variable X influences variable Y. Meanwhile, If the value of tcount < ttable, it can be stated that variable X does not affect variable Y.

(c) Relationship degree
The correlation coefficient intervals reveal the relationship between the X and Y variables. In this situation, the stronger the correlation between the two variables, the higher the value (closer to one). The degree of relationship and coefficient interval can be seen in Table 12.

Table 12. Relationship rates and coefficient intervals [15]

Correlation Coefficient (R)	Relationship Level
0.00 – 0.199	Very low
0.20 – 0.399	Low
0.40 – 0.599	Medium
0.6 – 0.799	Strong
0.8 – 1.000	Very Strong

3.5.1 Simple linear regression analysis

(a) The value of significance
The analysis outputs from SPSS for the SDI-PCI relationship are presented in Figure 7. The linear regression analyses show a sig. value of 0.000, it can be concluded that the SDI variable influences the PCI variable.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
SDI	-.195	.025	-.929	-7.937	.000
(Constant)	82.516	4.753		17.362	.000

Figure 7. The significance value for the SDI-PCI relationship.

(b) Tcount and ttable values

ttable = (α/2); N-K-1 or DF residual)
ttable = (0.05/2; 10)
ttable = (0.025; 10)
ttable = 2.228

As the calculated result of tcount is -7.937 and ttable is 2.228 (tcount < ttable), it can be stated that variable the SDI variable (X) does not affect the PCI variable (Y)

(c) Correlation coefficient analysis
The correlation coefficient analysis results for the SDI and PCI can be seen in Table 13.

Table 13. Model summary for the SDI-PCI relationship

R	R^2	Adjusted R^2	Std. Error of the estimate
0.929	0.863	0.849	8.735

Based on Table 14, a correlation value (R) of 0.929 indicates that the level of relationship between the SDI variable and the PCI variable is very strong. The determination value (R^2) is 0.863, which means that the influence of the SDI value on the PCI variable is 86.3%, while the remaining 13.7% is influenced by other variables which not considered in this study. The analysis outputs from SPSS for the SDI-PASER relationship are presented in Figure 8.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
SDI	-.015	.003	-.807	-4.328	.001
(Constant)	6.799	.649		10.471	.000

Figure 8. The significance value for the SDI-PASER relationship.

(a) The value of significance
The significance value Result for SDI-PASSER Simple Linear Regression is 0.001. It can be concluded that the SDI variable (X) influences the PCI variable (Y).

(b) Tcount and ttable values

ttable = (α/2); n-k-1 or df residual)
ttable = (0.05/2; 10)
ttable = (0.025; 10)
ttable = 2.228

The calculated result of tcount is -4.328 < ttable of 2.228 (tcount < ttable), it can be concluded that the SDI variable (X) does not affect the Paser variable (Y)

(c) Correlation coefficient analysis
The results of the R^2 for the SDI-Paser relationship are presented in Table 14. The correlation value (R) for SDI-PASER is 0.807, stating that the level of relationship between the SDI and the PASER variable is very strong. The determination value (R^2) is 0.652. It means that the influence of the SDI value on the PASER variable is 65.2%, while the remaining 34.8% is influenced by other variables.

Table 14. Model summary for the SDI-PASER relationship

R	R^2	Adjusted R^2	Std. Error of the estimate
0.807	0.652	0.617	1.193

3.5.2 Exponential analysis

The exponential regression analysis for the SDI-PCI relationship can be seen in Table 15, while for SDI and PASER relationship can be seen in Table 16.

Table 15. Model summary for the SDI-PCI relationship

R	R^2	Adjusted R^2	Std. Error of the estimate
0.871	0.758	0.743	0.253

Table 16. Model summary for the SDI-PASER relationship

R	R^2	Adjusted R^2	Std. Error of the estimate
0.785	0.616	0.577	0.325

Table 15 shows that the correlation value (R) for SDI-PCI is 0.871. The data suggests a high degree of correlation between the SDI variable and the PCI variable, as indicated by the determination value (R^2) of 0.758. Meanwhile, Table 16 shows that the SDI-PASER has a strong correlation value (R) of 0.785, indicating a high level of association between the SDI and the PCI variable. The determination value (R^2) is 0.616.

3.5.3 Logarithmic analysis

The SPSS output of logarithmic regression analysis results for SDI and PCI method can be seen in Table 17 while logarithmic regression analysis results for SDI and PASER method can be seen in Table 18.

Table 17. Model summary for the SDI-PCI

R	R^2	Adjusted R^2	Std. Error of the estimate
0.841	0.708	0.679	12.756

Based on Table 17, a correlation value (R) of 0.841 is obtained, stating that the level of relationship between the SDI variable and the PCI variable is very strong and the determination value (R^2) is 0.708.

Table 18. Model summary for the SDI-PASER

R	R^2	Adjusted R^2	Std. Error of the estimate
0.670	0.448	0.393	1.502

Based on Table 18, a correlation value (R) of 0.67 is obtained, stating that the level of relationship between the SDI variable and the PASER variable is strong, and the determination value (R^2) is 0.448.

3.5.4 Polynomial analysis

The SPSS output for polynomial regression analysis of the SDI-PCI method is presented in Table 19 while the output for the SDI-PASER method is presented in Table 20.

Table 19. Model summary for the SDI-PCI

R	R^2	Adjusted R^2	Std. Error of the estimate
0.93	0.865	0.835	9.13

Based on Table 19, a correlation value (R) of 0.93 is obtained, stating that the level of relationship between the SDI variable and the PCI variable is very strong and the determination value (R^2) is 0.865

Table 20. Model summary for the SDI-PASER

R	R^2	Adjusted R^2	Std. Error of the estimate
0.868	0.753	0.698	1.059

Based on Table 20, a correlation value (R) of 0.868 is obtained, stating that the level of relationship between the SDI variable and the PCI variable is very strong and the determination value (R^2) is 0.753.

Four regression analysis tests have been carried out and the resume can be seen in Table 21. Based on the regression analyses, the highest R^2 value can be identified in the polynomial regression test. However, in determining the analysis, several things need to be considered according to the requirements, including:

(a) The scatterplot diagram of polynomial regression analysis does not form a parabola and the significant test does not meet the requirement as the sig. value > 0.05 which means that variable X does not affect variable Y.

(b) The output of logarithmic and exponential regression analysis results has a lower R^2 value than the simple linear regression analysis and polynomial analysis. Comparative testing of tcount and ttable values is also not satisfied as tcount < ttable, meaning variable X has also no significant effect on variable Y. Based on those considerations, the polynomial model can be excluded.

Table 21. Recapitulation of regression analysis for the SDI with the PCI and the PASER methods

Method	Regression Type	Equation	R	R^2
PCI	Linear	$y = -0.1953x + 82.529$	-0.929	0.863
	Exponent	$y = 87{,}564_{e}{}^{-0{,}004x}$	-0.919	0.844
	Logarithmic	$Y = -15.12\ln(x)+120.82$	-0.841	0.708
	Polynomial	$y = -0.0002x^2-0.1345x + 80.584$	-0.930	0.865
PASER	Linear	$y = -0.0145x + 6.7988$	-0.807	0.652
	Exponent	$y = 7.2423_{e}{}^{-0{,}004x}$	-0.777	0.603
	Logarithmic	$Y = -1.032\ln(x)+9.2096$	-0.670	0.449
	Polynomial	$y = -0.0001x^2+0.0202x + 5.6887$	-0.868	0.753

Afterward, the most appropriate regression analysis for this case study is the simple linear regression which results in subsequent best R and R^2 values. The simple linear analysis resulted in a correlation coefficient (R) of -0.929 and -0.807. This states that the relationship between SDI with PCI and PASER has a very strong relationship. Since the value of R is negative, the correlation between the SDI and PCI is the opposite, i.e., the higher the SDI value the lower the PCI value but it has the same meaning that the road condition is worsened. Meanwhile, the coefficient of determination value (R^2) for PCI and PASER methods are 0.8631 and 0.652. From these results, it can be stated that based on the simple linear regression, the SDI value is influenced by the PCI value by 86.31%, while the remaining 13.69% is influenced by variables outside the study. Similarly, the influence of the PASER on the SDI scores was 65.2%, while the remaining 34.8% was influenced by variables outside the study.

3.6 Typical Road Distress and Alternative Treatments

Road distress in Daendels Road varies for each unit sample. To achieve optimum service performance, it is necessary to tailor alternative road maintenance or treatment to the specific type of road damage encountered. The dominant types of pavement distress identified in Daendels Road STA 29+775 – 30+975 are presented in Table 22.

Table 22. Dominant types of road distress

Dominant Type of Distress	Number of Sample Units	Damage Percentage
Longitudinal/Transverse Cracking	37	25 %
Patching	31	21 %
Alligator Cracking	28	19 %
Pothole	28	19 %
Block Cracking	25	17 %

Table 22 shows that the common type of road distress identified in the Daendels road includes cracking, patching, and potholes. Longitudinal and cracking in asphalt pavement typically caused by fatigue cracking or top-down cracking, while transverse cracking is often caused by thermal cracking or top-down cracking [11][16][17]. The underlying factor is the displacement caused by fluctuations in temperature changes and the age hardening of the asphalt results in a higher thermal stress. Alligator cracking which was also identified in Daendels Road indicates that the typical coastal pavement distress is not only caused by temperature load but also caused by fatigue failure under repeated traffic loading.

The key aspect of pavement condition assessment involves the identification of various types of pavement distress and linking them to the potential cause This is important in selecting an appropriate maintenance and rehabilitation technique [13][18].

Alternative road treatments in this study were selected following the Minister of Public Works' Guidelines for the Selection of Preventive Maintenance Technology for Road Pavement, i.e., 13/PRT/M/2011 [19] and 07/SE/DB/2017 [20]. By utilizing the outcomes of PCI, IRI, and PASER analysis, the road condition values and alternative treatments along Daendels Road can be visualized in the form of a stripmap format (see Figure 9). The strip map graphic provides a concise visualization and presentation of the road condition with alternative treatment, serving as a valuable communication tool for engineers and policymakers, particularly those without a road preservation background. Three alternative treatments were proposed including rehabilitation and reconstruction. Alternative 3, rehabilitating the entire road section using a hot mix asphalt overlay, is considered the best alternative as it is more practical, efficient, and easier to implement.

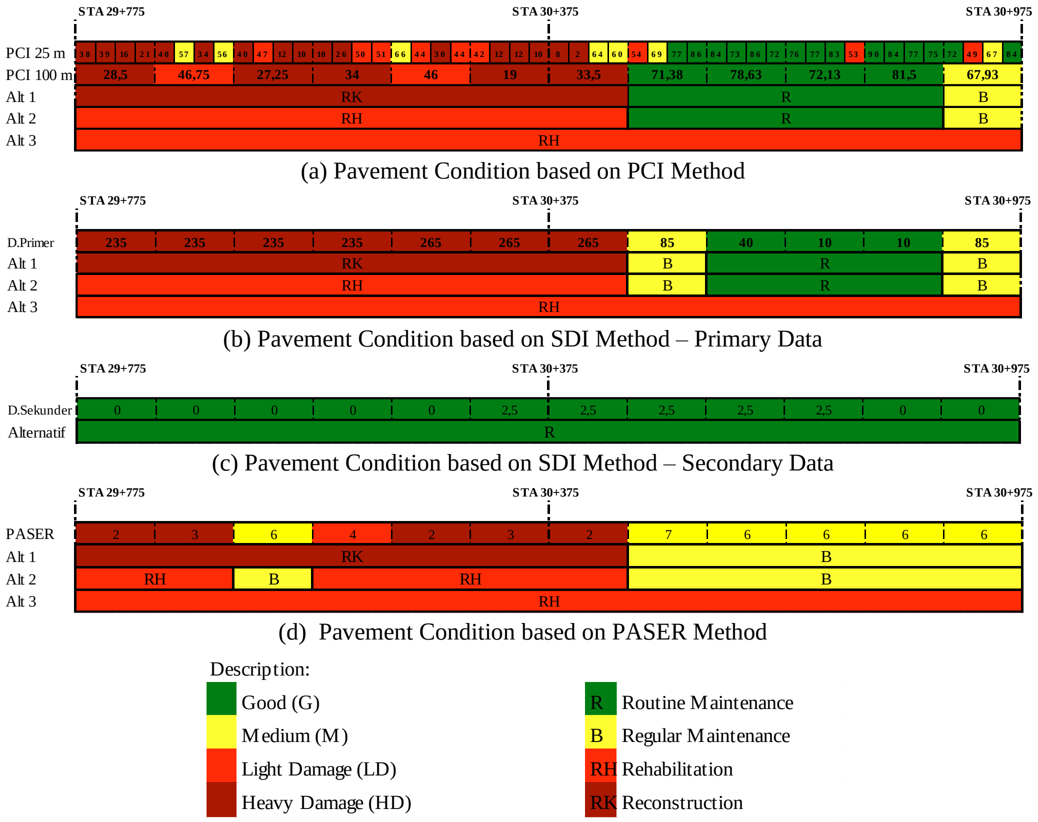

Figure 9. Strip map of pavement conditions and alternative treatments for Daendels Road.

4. Conclusions

The main types of pavement distress identified on Daendels Road, situated in a coastal area, are cracking (longitudinal, transversal, crocodile, and blocks), patching, and potholes. The PCI, SDI, and PASER methods give a different score value and distress category for the pavement condition of Daendels Road. The differences occurred as they considered different numbers and types of pavement distress that were considered in the calculation. The SDI method has a strong relationship with the PCI and PASER methods. However, the SDI-PCI has a better correlation than the SDI-PASER as it has a higher coefficient of determination value (R^2). The PCI method is considered the most suitable and applicable approach as it considers a wider range of distress types (19 categories) and more accurately represents the typical distress found on road pavements on the South Coast of Java Island. The overall condition of the pavement on the Daendels road is categorized as severely damaged. Three alternatives are proposed. Alternative 3, which involves rehabilitating the entire road section using a hot mix asphalt overlay, is considered the best alternative due to its greater practicality, efficiency, and ease of implementation.

References

[1] M. R. F. Amrozi and H. T. Evdorides, "Economic Optimisation of Road Network Accessibility," in *Bituminous Mixtures and Pavements VII*: CRC Press, 2019, pp. 499-506.

[2] *Peraturan Pemerintah Republik Indonesia Nomor 34 Tahun 2006 tentang Jalan*, P. R. Indonesia, 2006.

[3] M. R. F. Amrozi and R. P. Isheka, "Optimizing The Functional Performance of Road Network using Vulnerability Assessment to Cope with Unforeseen Road Incidents," in *Journal of the Civil Engineering Forum*, 2022, vol. 8, no. 1, pp. 67-80.

[4] K. H. Widodo *et al.*, *Logistik Indonesia : Teori, Kebijakan, dan Praktik*. Yogyakarta: Deepublish, 2022.

[5] T. P. Barrette, "Comparison of PASER and PCI pavement distress indices," 2011.

[6] T. Ratliff and J. Amenta, "Developing a Correlation Between the Five Pavement Condition Ratings Used by the Federal Lands Management Agencies," 2015.

[7] M. Mubarikah, E. Elianora, and M. Yusa, "Studi Perbandingan Penilaian Kerusakan Jalan Dengan Metode Bina Marga, PCI (Pavement Condition Index) Dan Metode PASER (Pavement Surface Evaluation And Rating Sistem) Pada Ruas Jalan Garuda Sakti, Pekanbaru," *Jurnal Online Mahasiswa (JOM) Bidang Teknik dan Sains*, vol. 5, pp. 1-18, 2018.

[8] Google Earth. "Jalan Daendels pada Google Earth." https://earth.google.com (accessed.

[9] *ASTM D6433-07: Standard practice for roads and parking lots pavement condition index surveys*, ASTM, 2007.

[10] H. C. Hardiyatmo, *Pemeliharaan Jalan Raya*. Gadjah Mada University Press, 2009.

[11] M. Y. Shahin, *Pavement management for airports, roads, and parking lots*, 2nd Edition ed. Springer, 2005.

[12] D. J. B. M. Kementerian PUPR, "Panduan Survai Kondisi Jalan (Indonesian Integrated Road Management System - IIRMS," 2011.

[13] D. Walker, *Asphalt PASER Manual* (Pavement Surface Evaluation and Rating). Wisconsin Transportation Information Center, 2002.

[14] K. N. Febriyani, "Korelasi Tingkat Kerusakan Jalan Terhadap Variasi Kecepatan dan Kepadatan Lalu Lintas dengan Metode PCI pada Ruas Jalan Raya Candi, Kec. Candi, Kab. Sidoarjo," *ejournal.unesa.ac.id*, pp. 1-13, 2020.

[15] Sugiyono, *Statistika Untuk Penelitian*. 2007.

[16] I. L. Al-Qadi, T. Scarpas, and A. Loizos, *Pavement cracking: mechanisms, modeling, detection, testing and case histories*. CRC Press, 2008.

[17] M. J. Alam, M. E. Karim, and M. S. Hoque, "Causes of Damage of Rural Road in Coastal Areas of Bangladesh," *Geotechnical Engineering (00465828)*, vol. 51, no. 4, 2020.

[18] M. M. Rahman, M. M. Uddin, and S. L. Gassman, "Pavement performance evaluation models for South Carolina," *KSCE Journal of Civil Engineering*, vol. 21, pp. 2695-2706, 2017.

[19] *Peraturan Menteri Pekerjaan Umum Republik Indonesia Nomor 13/PRT/M/2011 Tentang Tata Cara Pemeliharaan Dan Penilikan Jalan*, K. PUPR, 2011.

[20] *Panduan Pemilihan Teknologi Pemeliharaan Preventif Perkerasan Jalan*, K. PUPR, 2017.