Journal of
Advanced Civil and Environmental Engineering
Vol.5, No.2, 2022, pp 84-93
ISSN: 2599-3356
DOI: http://dx.doi.org/10.30659/jacee.5.2.84-93

Road Pavement Condition Index as a Method to Analyze the Level of Road Damage

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(**Received:** 31st August 2022 ; **Revised:** 15th October 2022 ; **Accepted:** 30th November 2022)

Abstract: The pavement Condition Index (PCI) method serves to measure the severity of pavement damage based on 3 main categories: (1) type of damage, (2) severity of damage, and (3) amount or density of damage. PCI is a numerical index whose values range from 0 to 100. A value of 0 indicates the pavement was in very damaged condition, while a value of 100 indicates that the pavement was still excellent. A survey was conducted on Jalan Tregguli - Welahan along ± 1 km divided into several segments to identify road damage. Each segment was 100 m apart. PCI for Trengguli - Welahan road segment which belonged to 0 – 10 (failed) of 0%, 11 – 25 (very bad) of 11%, 26 – 40 (bad) of 28%, 41 – 55 (moderate) of 8%, 56 – 70 (good) of 12%, 71 – 85 (very good) of 19%, and 86 – 100 (Perfect) of 22%, The average PCI for Trengguli Welahan road segment is of 54.36. The findings classified road damages into road patches, longitudinal/transverse cracks, holes, and joint cracks. The PCI value is 54.36 (medium). Based on data on the PCI value and the percentage of damage on the road of Trengguli - Welahan, there is a high correlation between the two variables.

Keywords: PCI; road damage; correlation

1. Introduction

Road infrastructure plays a very important role in human life both now and in the future, especially in industry, trade, and transportation. Therefore, the existing roads must be supported by adequate infrastructure.

All stable roads require regular and periodic priority maintenance. Meanwhile, uneven roads require rehabilitation, repair, and reconstruction work. In Demak regency, 286,351 km of roads are reported to be in good condition, 45,349 km are in normal condition, 76,222 km are in poor condition, and 18,088 km are in critical condition. This means that almost 40% of the existing road network in the area requires maintenance, repair, and reconstruction. This will cost a lot and usually exceed the available funding requirements. Therefore, a system that can filter and indicate the priority scale of handling is needed.

Generally, the roads in Demak Regency, including the Trengguli - Welahan road section, are designed according to the standards set by Bina Marga. However, with the changing composition of the traffic load due to the growth of industrial estates, a lot of road damage has occurred. Therefore, the attention of the authorities is needed. The types of damage include block cracks, bumps and derivatives, potholes, longitudinal and transverse cracks, grooves, road swelling, road patches, and utility excavation patches.

An increase in traffic flow, especially for goods transportation facilities and transportation services, such as the furniture manufacturing industry and the wood industry, is very detrimental and affects the ability to recover road works. From the results of field observations, it can be seen that the traffic volume exceeds the planning capacity. It is even possible that the pavement structure will be damaged more quickly with the current traffic conditions.

Based on the conditions, this paper aimed to analyze road damage levels using the method of road pavement condition index of Trengguli – Welahan to find out whether the roads currently or in the future are still in good condition or need maintenance.

2. Site of Research

A research site is a place where research activities are carried out. Site determination of the research is intended to simplify and clarify the location of the study. Sedo Village, Demak District, Demak Regency, located on Jl. Trengguli Welahan KM 32+700 to KM 33+900 was selected as the research site, considering that the road surface in the area has experienced several types of damage in almost every segment.

3. Research Method

Primary data from the field is needed to evaluate the pavement condition using the Pavement Condition Index Method in the Trengguli – Welahan Section.

Primary data are information obtained directly from the field, such as measurements of the types of pavement damage, types of pavement used, and traffic composition data. These data are obtained by observing the case directly at the location of the study. The survey includes a survey on road surface conditions and the road segment of Trengguli-Welahan along ±1 km divided into several segments. This is done to facilitate the identification of road damage. The surveys conducted include:

a. ***Type of road damage.*** The types of existing road damage are recapitulated for each road segment reviewed. All kinds of damage are assessed visually and marked with paint. Then, a meter measures all types of damage in length, width, and depth.
b. ***The degree of damage.*** Damage is assessed based on the quality of the damage, including heavy, moderate, or light, and quantity.
c. ***Total damage.*** Each type of road damage is recapitulated and summed for each segment under review.

Secondary data are information collected indirectly or through intermediaries. These data are usually in the form of books, records, existing evidence, or good archives broadly published that anyone can access it. The secondary data needed in this research are the site plan.

The steps in determining the Value of this method are:

1. Deduct Value (DV).
2. Density (D)
3. Total Deduct Value (TDV).
4. Corrected Deduct Value (CDV)
5. Classification of Pavement Quality.

4. Data Analysis

Several stages as follows were carried out to find the PCI value in the study:

a. Density (*D*)

Density is the percentage of the total area or length of the type of damage relative to the area or total length of the road segment, measured and expressed in m² or meters. Damage density on the road can be determined using Eq. (1) or Eq (2) below.

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

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

With,

A_d = Total area of pavement types by severity (m²)

A_s = total area of sample unit (m²)

L_d = The total length of damage types based on the severity of the damage.

In the damage data for STA 33+200 - 33+300 with a road damage area of 107 m, density can be found as folow:

$$\text{Density (\%)} = \frac{Ld}{As} \times 100\%$$
$$= \frac{107}{700} \times 100\%$$
$$= 15{,}29\%$$

b. Deduct Value (DV)

Deduct Value is a value for each type of damage obtained from the curve of the relationship between density and severity level of damage. Examples of Types of Joint Cracks Damage (8H) can be seen in Fig. 1.

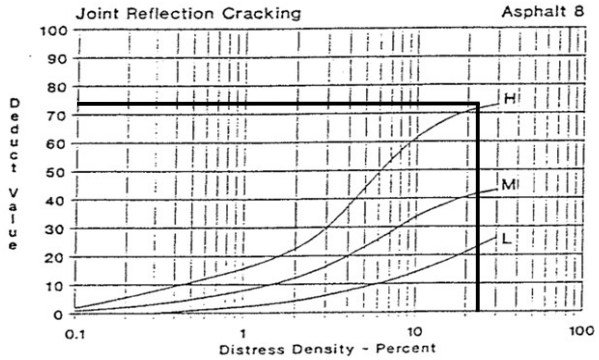

Fig. 1. Example of types of joint cracks damage

Table 1. Density Value dan Deduct Value

Location	Distress Severity	Quantity								Total	Density (%)	Deduct Value
33+200 - 33+300	8H	100	7		63					107	15,29%	63
	10L	3,5	3,5		3					7	1,00%	3
	10M	3,5	3,5	3,5	14	3,5				17,5	2,50%	14
	10H	3,5	3,5	3,5	26					14	2,00%	26
	11M	0,16	18	0,95	28	17,5	5,31	3,6	16	63,3	9,05%	28
	11H	3,5	15,8		27					19,3	2,76%	27

c. Total of Deduct Value *(TDV)*

Total of Deduct Value or TDV is the sum of the deduct values in each sample unit.

If there is only one deduct Value with a value > 2, then the total deduct Value is used as the corrected deduct Value, otherwise, proceed to the following steps.

1. Sort the deduct Value from the largest Value,
2. Determine the Value of m using Eq (3):

$$m = 1 + (9/98)*(100 - HDV) \quad (3)$$

Where:
m = Allowable Value of deduct Value
HDV = Highest Value of deduct Value = 63
m = 1 + (9/98)(100-63)
= 4,398 < 6 (number 6 is the number of data deduction value)

3. Each deduct Value is reduced from the calculation result m. If there is a sum of subtraction values between the deduct Value and m, which is less than m, then all the deduct values can be used for the next calculation.

Table 2. Relationship between DV and m values

No	Deduct Value	$m_i = 1 + (9/98)\ (100 - HDV_i)$	DV - m_i	DV - m_i < m
1	63	4,397959	58,6020408	No
2	28	4,397959	23,6020408	No
3	27	4,397959	22,6020408	No
4	26	4,397959	21,6020408	No
5	14	4,397959	9,60204082	No
6	3	4,397959	-1,39795918	Yes

d. Corrected Deduct Value (CDV)

The Corrected Deduct Value or CDV is obtained from the relationship curve between the total deduct Value (TDV) and the deduction value (DV) by selecting the appropriate curve. Fig. 2 shows how to find the CDV Value with TDV = 161, and q = 6

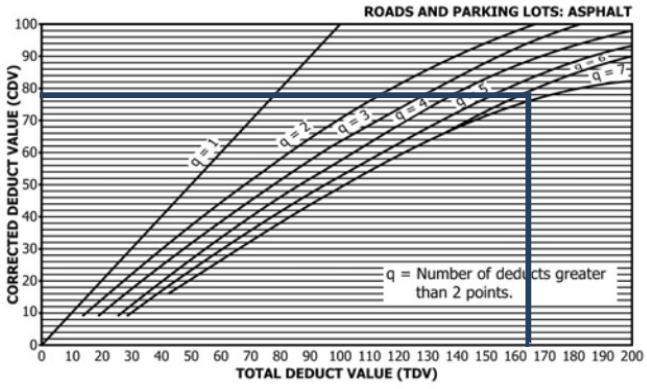

Fig. 2. Graph of CDV with TDV = 161, and q = 6

The result (in Fig. 2. The CDV graph) is known with the Value of TDV = 161 and q = 6, so the Value of CDV = 78 is obtained.

Table 3. The Value of CDV Segment 33+200 - 33+300

Location	TDV	q	CDV
33+200 - 33+300	161	6	78
	160	5	82
	148	4	82
	124	3	76
	99	2	70
	73	1	74

e. PCI Value

After obtaining the CDV value, the PCI value is sought for each sample unit calculated using Eq. 4 as following.

$$PCI_s = 100 - CDVmaks \quad (4)$$

PCI_s are the PCI for each segment or research unit, and CDV is the CDV value of each segment.

Table 4. The values of PCI and condition

The Value of PCI	Condition
0-10	Failed
11-25	Very poor
26-40	Poor
41-55	Fair
56-70	Good
71-85	Very Good
86-100	Excellent

Table 5. The values of PCI Segment 33+200 - 33+300

Location	CDV	CDV Max	PCI	Road Condition
32+700 - 32+800	0 - -	0	100	Excellent
32+800 - 32+900	16 - -	16	84	Very Good
33+000 - 33+100	24 0 -	24	76	Very Good
33+100 - 33+200	12 12 -	12	88	Excellent
33+200 - 33+300	78 82 82 76 70 74	82	18	Very Poor
33+300 - 33+400	56 62 62 56 56	62	38	Poor

Location	CDV	CDV Max	PCI	Road Condition
33+400 - 33+500	76 78 80 84 74 72	84	16	Very Poor
33+500 - 33+600	62 66 70 82 70 72	82	18	Very Poor
33+600 - 33+700	66 70 74 66	74	26	Poor
33+700 - 33+800	34 36	36	64	Good
33+800 - 33+900	30 26 22	30	70	Good
The Average PCI			54,36	FAIR

Correlation is a term used to measure the strength of the relationship between variables. Correlation analysis is a way to determine whether there is a relationship between variables. Several statistical techniques can be used in analyzing the relationship between variables: correlation coefficient, determinant coefficient, and regression analysis. The correlation coefficient (r) is a number that states the strength of the relationship between variables or the direction of the relationship of the variables. The Value of r moves from -1 to +1. The strength of the relationship is known from the numerical Value, while the direction is expressed in the form of positive (+) or negative (-). The formula for calculating the r value can be calculated using Eq 5 below

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)}} \quad (5)$$

Where
X = Independent Variable
Y = Dependent Variable
N = Number of Samples

Table 6. Correlation variables between the percentage of damage and the PCI value

No.	(%) Damage (X)	PCI (Y)	XY	X^2	Y^2
1	0,37%	100	0,371	1,380E-05	1,000E+04
2	0,72%	84	0,605	5,184E-05	7,056E+03
3	1,44%	76	1,097	2,082E-04	5,776E+03
4	0,73%	88	0,641	5,308E-05	7,744E+03
5	32,60%	18	5,867	1,062E-01	3,240E+02
6	20,65%	38	7,847	4,264E-02	1,444E+03

7	24,38%	16	3,901	5,945E-02	2,560E+02
8	19,79%	18	3,563	3,918E-02	3,240E+02
9	22,44%	26	5,834	5,036E-02	6,760E+02
10	6,82%	64	4,364	4,649E-03	4,096E+03
11	17,56%	70	12,289	3,082E-02	4,900E+03

Table 7. Correlation Results of Damage Percentage with PCI Value

	(%) Damage	***PCI***
(%) Damage	1	
PCI	-0,91312	1

Table 8. Correlation Value and Correlation Level

Correlation value (r)	Level of Correlation
0	Uncorrelated
0,01 – 0,20	Very low
0,21 – 0,40	Low
0,41 – 0,60	Slightly low
0,61 – 0,80	Moderate
0,81 – 0,99	High
1	Very high

Table 8 shows the correlation value between the percentage of damage and the PCI value of -0.913; this Value is then compared with the distribution of the r-table values with a significance level of 5% and 1%, as shown in Table 9.

Table 9. Distribution of r_{table} Values with a significance level of 5% and 1%

N	Level of Significance		N	Level of Significance	
	5%	1%		5%	1%
3	0,997	0,999	38	0,32	0,413
4	0,95	0,99	39	0,316	0,408
5	0,878	0,959	40	0,312	0,403
6	0,811	0,917	41	0,308	0,398
7	0,754	0,874	42	0,304	0,393
8	0,707	0,834	43	0,301	0,389
9	0,666	0,798	44	0,297	0,384
10	0,632	0,765	45	0,294	0,38
11	0,602	0,735	46	0,291	0,376
12	0,576	0,708	47	0,288	0,372
13	0,553	0,684	48	0,284	0,368
14	0,532	0,661	49	0,281	0,364
15	0,514	0,641	50	0,279	0,361
16	0,497	0,623	55	0,266	0,345
17	0,482	0,606	60	0,254	0,33
18	0,468	0,509	65	0,244	0,317
19	0,456	0,575	70	0,235	0,306
20	0,444	0,561	75	0,227	0,296
21	0,433	0,549	80	0,22	0,286

N	Level of Significance		N	Level of Significance	
	5%	1%		5%	1%
22	0,432	0,537	85	0,213	0,278
23	0,413	0,526	90	0,207	0,267
24	0,404	0,515	95	0,202	0,263
25	0,396	0,505	100	0,195	0,256
26	0,388	0,496	125	0,176	0,23
27	0,381	0,487	150	0,159	0,21
28	0,374	0,478	175	0,148	0,194
29	0,367	0,47	200	0,138	0,181
30	0,361	0,463	300	0,113	0,148
31	0,355	0,456	400	0,098	0,128
32	0,349	0,449	500	0,088	0,115
33	0,344	0,442	600	0,08	0,105
34	0,339	0,436	700	0,074	0,097
35	0,334	0,43	800	0,07	0,091
36	0,329	0,424	900	0,065	0,086
37	0,325	0,418	1000	0,062	0,081

After looking at the results of the correlation and distribution of r-table values with a significance level of 5%, the following correlation figures are obtained:

- r_{count} = -0,91312
- r_{table} = 0,602
- r_{count} with negative numbers, which means there is an inverse comparison between variables.
- Coefficient values are between 0.8 – 0.9 (high correlation between variables)

Considering the comparison results between r-count and r-table, as the Value of r-count is smaller than r-table, it can be inferred there is a relationship between the percentage of road damage and the PCI value. Looking at the results of rcount, the negative number obtained can indicate an inverse comparison between variables. The coefficient value is between 0.8 and 0.9; this shows a high correlation between variables.

From the correlation results between the percentage of road damage and the calculation of the PCI value, the correlation number is not too large, with an r_{count} of r-0.91312. From the correlation value, it can be concluded if the total percentage of damage to the road is high, the PCI value is small.

The following is a linear correlation graph between the percentage of damage and the results of the PCI value calculation. From the graph, it appears that the equation number is y = -248.78x + 87.722, where Y is the variable of the PCI value and X is the variable of the percentage of damage.

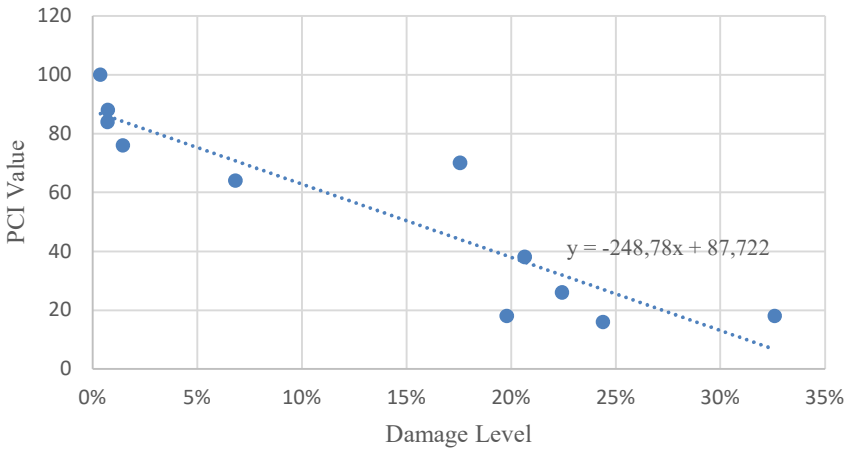

Fig. 3. Correlation Graph of Damage Percentage with PCI Value

In the case of the road of Trengguli-Welahan, if the damage percentage on the road segment is high, the PCI value is low. The low PCI value means that the pavement in the middle of the road currently experiences poor conditions. In contrast, if the percentage of damage on the road segment is low, the PCI value will be high. It means the pavement on the road segment is in very good condition. The cause of the damage on the road needs further research to find out the causes of damage to the road segment, as discussed.

5. Conclusion

Here are the conclusions based on the results of data analysis and discussions:

1. Types of damage in the road segment of Trengguli – Welahan include: Patches, longitudinal/transverse cracks, potholes, and joint cracks
2. The road Pavement Condition Index (PCI) with flexible pavement on the segment of Trengguli – Welahan is 54.36. The figures, the condition of the road segment is in the medium category. The percentage of road damage on the road segment includes 5.29% of joint cracks, 1.87% of longitudinal cracks, 6.27% of fillings, and 0.01% of potholes. The total percentage of road damage in the area is 13.41%.
3. The following is the conclusion of the relationship between the PCI (Pavement Condition Index) Value and the Percentage of Damage:
   a. The PCI (Pavement Condition Index) uses 3 categories: the type of damage, the severity of the damage, and the amount or density of damage.
   b. The Value of r_{count} with r_{table}, as the Value of r_{count} is smaller than r_{table}. It can be inferred that there is a relationship between the percentage of road damage and the PCI value. Looking at the results of the r_{count}, a negative number might explain there is an inverse comparison between the variables. The coefficient value is between 0.8 and 0.9, indicating a high correlation between variables

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