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Performance Modeling Bending Pavement Layer Towards Geometric Variations of the Street

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Abstract

Buduan - Bondowoso link 216 is a provincial primary collector road that connects Probolinggo Regency with Bondowoso Regency which has a length of about 31 kilometers. Slope of the road that has a width of 6 to 7 meters is very varied because this road passes through the hills. This road also has many double bends which are small enough to bend the fingers because of the limited topography that is traversed. When passing a double bend in the incline or a derivative vehicle tends to reduce speed so that the impact on road pavement conditions due to the friction of the wheel with the pavement surface. On the other hand, the thickness and type of pavement are planned to be the same for each field condition so it is certain that the segment will suffer faster damage than the other segments. Researches related to road performance with various methods have been carried out including evaluation of road conditions and its handling by Hendrick S and his colleagues (2014) and Daryoto and his colleagues (2014). The purpose of writing this article is to look for relationships between terrain conditions and the level of road pavement damage that not many people do, assisted using the PCI method in classifying road damage and then PCI data is processed with Microsoft Excel using polynomial regression so that a graph appears to determine whether there is a relationship between terrain conditions with the degree of damage to the road pavement. From the results of the analysis obtained values for PCI and Slope of the length of the road obtained values R^2= 0.068 and Y = 1,7005x + 79.40 which shows that the PCI affects the slope of the road length is only 6.8% while 93.2% is influenced by other factors.

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Then for PCI and radius get the value of R^2 = 0.0243 and Y = -0,002x^2+0,2955x+82,271 which shows PCI affects the radius of only 2.4% while 97.6% is influenced by another factor. Then for PCI and the degree of arcing get the value R^2= 0.0041 and Y = -0.0278x +90.718 which shows the PCI affects the degree of arcing is only 0.41% while 99.59% is influenced by other factors.

Keywords: PCI; Road Damage; Regression.

1. Introduction

Buduan Street - Bondowoso link 216 is a provincial primary collector road which connects Probolinggo Regency with Bondowoso Regency which has a length of about 31 kilometers. This road can also be an alternative route for Probolinggo - Jember vehicles. Slope of the road that has a width of 6 to 7 meters is very varied because this road passes through the hills. This road also has many double bends which are small enough to bend the fingers because of the limited topography that is traversed. When passing a double bend in the incline or derivative area, vehicles tend to decrease their speed by braking. This braking affects the pavement conditions because the friction force of the vehicle wheels with pavement surface becomes larger so that the surface of the road under these terrain conditions experience greater friction than the road on flat terrain conditions. On the other hand, thickness and type of pavement are planned to be the same for each field condition. So it's likely that the road segment will experience damage faster than other segments.

2. Methods

First we look for the PCI value of each section of the road with the steps as below :

- Determine the level of damage according to the form (low, medium, high)
- Determine the damage density
- Determine the value of deduct value
- Calculate the total of deduct value (TDV)
- Determine the correct deduct value
- Calculate PCI using PCI = 100 – CDV

After we get the PCI value of each segment then we use the PCI value to find the connection that will later be used in the polynomial regression and then we will get the connection graph as the result.

2.1. Flowchart research

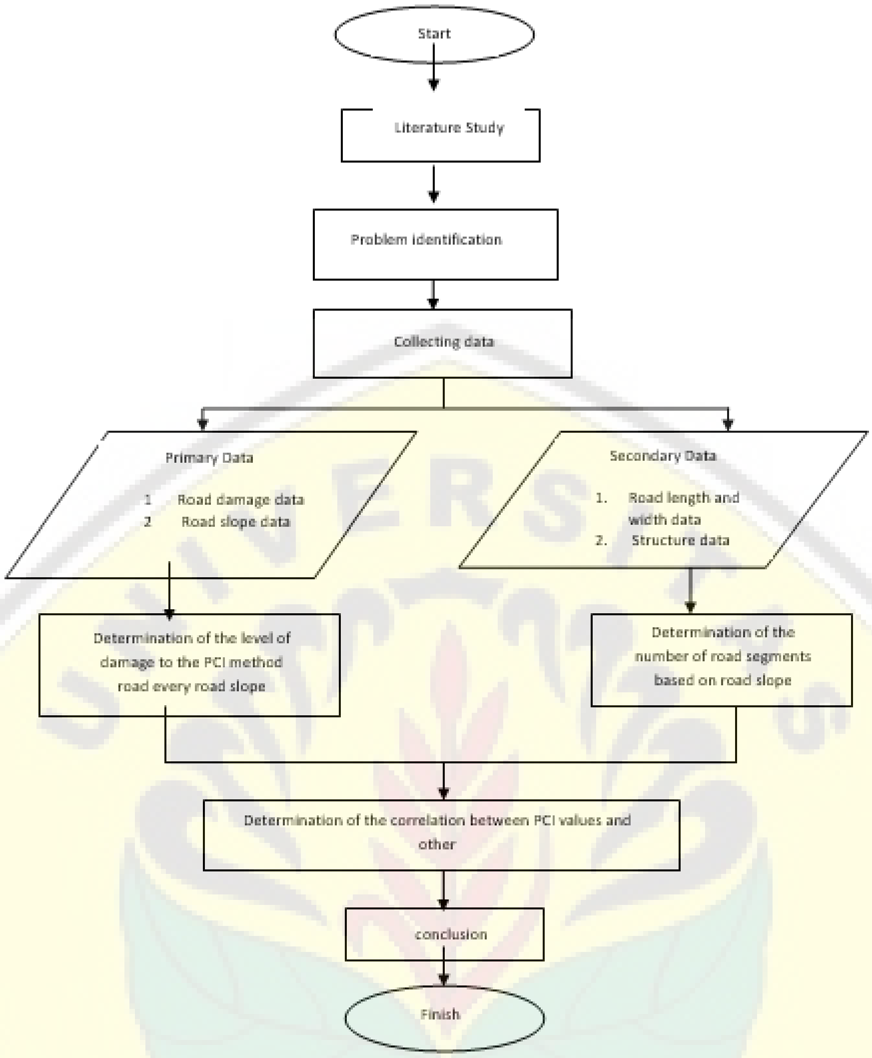

Figure 1: Flowchart Research

3. Result and Discussion

3.1. Collecting damage data from the road

The road damage survey is carried out visually or directly on the field survey on the Arak-arak Wringin Street, Situbondo – Bondowoso Regency. Damage data collection using predetermined forms according to the Pavement Conditions Index (PCI) method. In the PCI method itself there are 19 type of damage, but from the survey results not all types of damage occur in the field. The survey was conducted by dividing locations into several segments, each segment has a different value or condition of damage accordingly guidelines of the [1] PCI method. Teh pavement condition rating starts from the condition failed until condition is perfect (excellent). Conduct a survey segmentation aims to facilitate researches for data retrieval and calculation of handling costs.

Table 1: recapitulation of road damage for all road sections

NO	STA	Extensive Damage (M2)								Total
		1	3	4	5	6	7	10	13	
1	167+000 – 167+100	50,3	-	-	6,9993	-	-	-	-	57,293
2	100-200	22,25	-	-	29,92	-	-	-	-	52,17
3	200-300	-	-	-	12,25	-	-	-	-	12,25
4	300-400	-	-	-	12,39	-	-	-	-	12,39
5	400-500	-	-	-	-	-	-	-	-	-
6	500-600	-	-	-	-	-	-	-	-	-
7	600-700	-	-	5,6	-	-	-	-	-	5,6
8	700-800	75,6	-	2,24	-	-	-	-	-	77,84
9	800-900	8,75	-	4,95	-	-	-	-	-	13,7
10	900-168+000	-	-	-	-	-	-	-	3,75	3,75
11	168+000-168+100	32,5	-	-	-	-	1,5	-	-	34
12	100-200	12,3	-	-	-	-	-	-	-	12,3
13	200-300	17,1	-	-	-	-	-	-	-	17,1
14	300-400	-	-	-	-	-	-	-	-	-
15	400-500	-	-	6	24,45	-	-	-	-	30,45
16	500-600	-	-	-	-	-	-	-	-	-
17	600-700	32,55	-	-	32,55	-	-	-	-	65,1
18	700-800	-	-	4,95	-	0,-7	-	-	-	5,65
19	800-900	-	-	-	156,5	-	-	-	-	156,5
20	900-169+000	-	-	-	5,25	-	-	-	-	5,25
21	169+000-169+100	-	-	-	20,072	-	-	-	1	21,072
22	100-200	-	-	-	11	-	-	-	-	11
23	200-300	-	-	-	-	-	-	-	-	-
24	300-400	-	-	-	-	-	-	-	-	-
25	400-500	-	-	-	-	-	-	-	-	-
26	500-600	-	-	-	-	-	-	-	-	-
27	600-700	-	-	2,45	-	-	-	-	-	2,45
28	700-800	-	-	-	-	-	-	-	-	-
29	800-900	-	-	-	-	-	-	-	-	-
30	900-170+000	-	-	-	-	-	-	-	-	-
31	170+000-170+100	-	-	-	-	-	-	-	-	-
32	100-200	-	-	-	-	-	-	-	-	-
33	200-300	-	1	-	-	-	-	56	-	57
34	300-400	-	-	-	-	-	-	-	-	-
35	400-500	-	-	-	-	-	-	-	-	-
36	500-600	-	-	-	-	-	-	-	-	-
37	600-700	-	-	-	-	-	-	-	-	-

Information :

1. Alligator Cracking
5. Longitudinal Cracking
3. Depression
6. Patching
4. Edge Cracking
7. Pothole
10. Raveling
13. Bump and Sag

From the data above we get the largest damage area value in the segment (186+800 – 168+900) with an area value of 156 m^2. For kind damage that is often found in the field is elongate cracks by 29.4% of all damage that occurs in the field. To recapitulate according to the type of damage namely alligator crack 23.5%, depression 5.8%, edge cracking 26.5%, longitudinal cracking 29.4%, patching 3%, pothole 3%, raveling 3%, bump and sag 5.8% of the total damage.

3.2. Calculations using PCI method

- Calculate the value of density

Density (%) $= \frac{Ad}{As}$ x 100 %

Or,

Density (%) $= \frac{Ld}{As}$ x 100 %

Ad = The total area of the type damage per level of damage (m^2)

Ld = Total length of damage per damage level (m)

As = Total area of one road segment (m^2)

- Calculate the deduct value

The deduction value is obtained from the density curve according to the severity that obtained.

- Calculate the total deduct value

The total deduction value is the sum of the total subtraction values in each segment.

- Calculate the corrected deduct value

From the results of deduct value (DV) to get a CDV by entering a DV that is more than CDV curve by drawing a vertical line on the DV until it crosses the q line then drawn on the horizontal line.

- Calculate the pavement condition index

PCI = 100 –*CDV*

It can be concluded that the surface condition of road pavement with a percentage of 72.97% perfect condition, 18.91% very good, 8.11% good. From the data obtained there are some damage that occurred according to the type of damage is alligator cracks, depressions, edge cracks, longitudinal cracks, patching, pothole, raveling, and bump and sag.

Table 2: recapitulation of overall PCI values

NO	STA	Area of Damage	PCI Value	Condition
1	167+000 - 167+100	57,293	60	GOOD
2	100 - 200	52,17	74	VERY GOOD
3	200 - 300	12,25	86	PERFECT
4	300 - 400	12,39	86	PERFECT
5	400- 500	6,3	96	PERFECT
6	500 - 600	-	100	PERFECT
7	600 - 700	5,6	96	PERFECT
8	700 - 800	77,84	58	GOOD
9	800 - 900	13,7	74,5	VERY GOOD
10	900 - 168 +000	3,75	95	PERFECT
11	168+000 - 168+100	25,75	79	VERY GOOD
12	100 - 200	12,3	85	VERY GOOD
13	200 - 300	17,1	70	GOOD
14	300 - 400	-	100	PERFECT
15	400- 500	24,45	87	PERFECT
16	500 - 600	-	100	PERFECT
17	600 - 700	65,1	75	VERY GOOD
18	700 - 800	5,65	95,5	PERFECT
19	800 - 900	156,5	73	VERY GOOD
20	900 - 169 +000	5,25	94	PERFECT
21	169+000 - 169+100	10,072	94,5	PERFECT
22	100 - 200	11	85	VERY GOOD
23	200 - 300	-	100	PERFECT
24	300 - 400	-	100	PERFECT
25	400- 500	-	100	PERFECT
26	500 - 600	-	100	PERFECT
27	600 - 700	2,45	97,5	PERFECT
28	700 - 800	-	100	PERFECT
29	800 - 900	-	100	PERFECT
30	900 - 170 +000	-	100	PERFECT
31	170+000 - 170+100	-	100	PERFECT
32	100 - 200	-	100	PERFECT
33	200 - 300	57	93	PERFECT
34	300 - 400	-	100	PERFECT
35	400- 500	-	100	PERFECT
36	500 - 600	-	100	PERFECT
37	600 - 700	-	100	PERFECT

3.3. Slope on the road

From the data obtained there are some slopes of the bend in Wringin street – Bondowoso Regency which can be seen in Table 3.

Table 3: slope on the road

No	Bend	Stationing (STA)	Slope %	Radius (R)	Degree of curve (D)	PCI
1	Bend 1	STA 166 + 600 - 166 + 700	10	25,56	78º	100
2	Bend 2	STA 167 + 100 - 167 + 200	9	55,77	47º	100
3	Bend 3	STA 167 + 200 - 166 + 300	5	25,2	37º	100
4	Bend 4	STA 167 + 500 - 167 + 600	4	13,99	142º	100
5	Bend 5	STA 167 + 700 - 167 + 800	6	27,94	63º	100
6	Bend 6	STA 167 + 900 - 168 + 000	7	23,11	40º	100
7	Bend 7	STA 168 + 100 - 168 + 200	5	60,54	66º	100
8	Bend 8	STA 168 + 200 - 168 + 300	7	27,16	104º	100
9	Bend 9	STA 168 + 300 - 168 + 400	5	19,82	61º	100
10	Bend 10	STA 168 + 400 - 168 + 500	9	25,49	42º	100
11	Bend 11	STA 168 + 400 - 168 + 500	3	16,77	50º	48
12	Bend 12	STA 168 + 500 - 168 + 600	6	23,52	33º	74
13	Bend 13	STA 168 + 600 - 168 + 700	5	12,76	92º	86
14	Bend 14	STA 168 + 600 - 168 + 700	5	11,7	90º	86
15	Bend 15	STA 168 + 700 - 168 + 800	10	28,48	68º	96
16	Bend 16	STA 168 + 800 - 168 + 900	3	21,65	33º	100
17	Bend 17	STA 168 + 900 - 169 + 000	7	52,74	19º	96
18	Bend 18	STA 169 + 100 - 169 + 200	7	45,71	47º	58
19	Bend 19	STA 169 + 200 - 169 + 300	7	22,38	66º	74,5
20	Bend 20	STA 169 + 200 - 169 + 300	7	50,98	28º	95
21	Bend 21	STA 169 + 400 - 169 + 500	4	15,33	103º	79
22	Bend 22	STA 169 + 400 - 169 + 500	5	13,34	109º	85
23	Bend 23	STA 169 + 400 - 169 + 500	3	19,02	42º	70
24	Bend 24	STA 169 + 500 - 169 + 600	4	24,46	29º	100
25	Bend 25	STA 169 + 600 - 169 + 700	3	54,34	51º	87
26	Bend 26	STA 170 + 000 - 170 + 100	3	46,74	34º	100
27	Bend 27	STA 170 + 200 - 170 + 300	8	35,05	134º	75
28	Bend 28	STA 170 + 200 - 170 + 301	3	33,62	67º	95,5
29	Bend 29	STA 170 + 500 - 170 + 600	3	39,61	63º	73

3.4. Multiple regression analysis

Multiple regression analysis is a method for predicting the value of the influence of two or more independent variables on one dependent variable. Easier to prove whether there is a relationship between two variables or more than two independent variables X1, X2, X3,….Xn with respect to one dependent variable Y. General equation of regression analysis :

$$Y = \beta_X + \varepsilon \tag{1}$$

Where :

Y = Dependent variable

β = Parameter

X = Independent Variable

E = Error

According to Draper and Smith [2] the relationship between one dependent variable and one or more independent variables can be expressed in multiple linear regression. The relationship can be stated in general as follows :

$$Y_i = _0 + \beta_i X_{i1} + \beta_2 X_{i2} + \ldots + \beta_k X_{ik} + \varepsilon_i \tag{2}$$

Where :

Yi : dependent variable for observation i = 1,2,...,n.

$\beta_{0}, _1, \ldots, \beta_k$: parameter

$X_{i1,2}, \ldots, X_{ik}$: independent variable

ε_i : the rest (ε) for observation -i

3.5. The relationship between PCI values, Road slope, Radius, and Degree of Curvature

Referring to Table 3 about the slope of the curve (bend) obtained the relationship between PCI with slope , PCI with radius, and PCI with degree of curve, each of which have R^2 values of their own. From Table 3 the graph of the relationship between each component is then made , to graph the relationship between PCI and slope using Excel software. The graph can be seen in Figure 2.

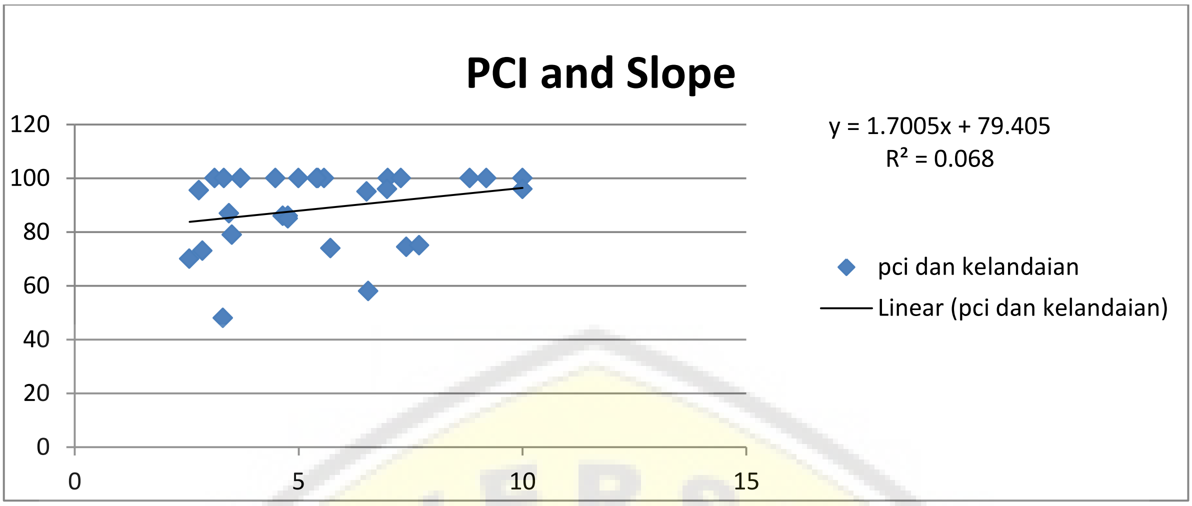

Figure 2: Relationship between PCI and Slope

From Figure 2 it is explained that the relationship between PCI and slope is obtained R^2 value of 0.068 with the type of polynomial regression. This value indicates that PCI affects the road slope of 6.8% while 93.2% is influenced by other factors.

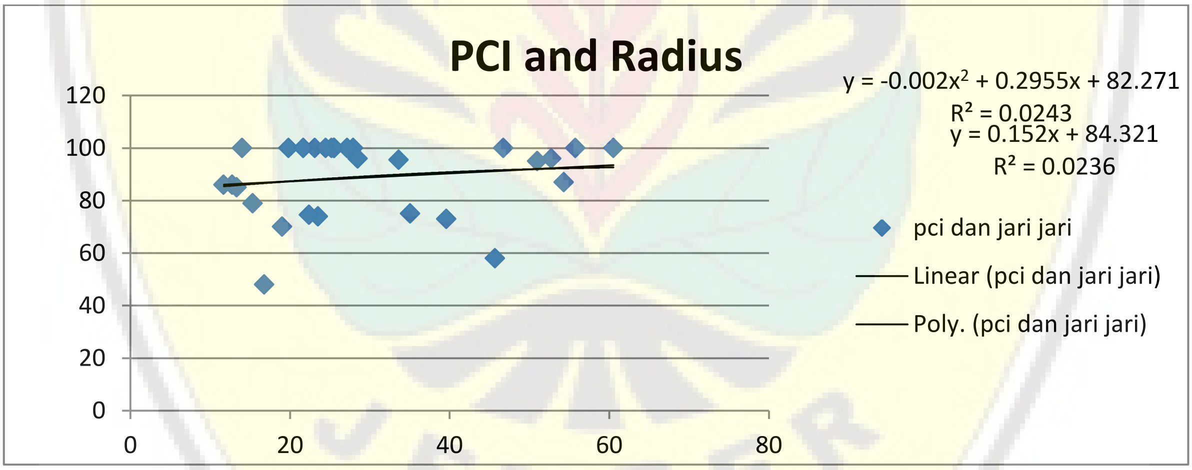

Figure 3: Relationship between PCI and Radius

From Figure 3 it is explained that the relationship between PCI and radius is obtained R^2 value of 0.0243 with the type of polynomial regression. This value indicates that PCI affects the radius of 2.4% while 97.6% is influenced by other factors.

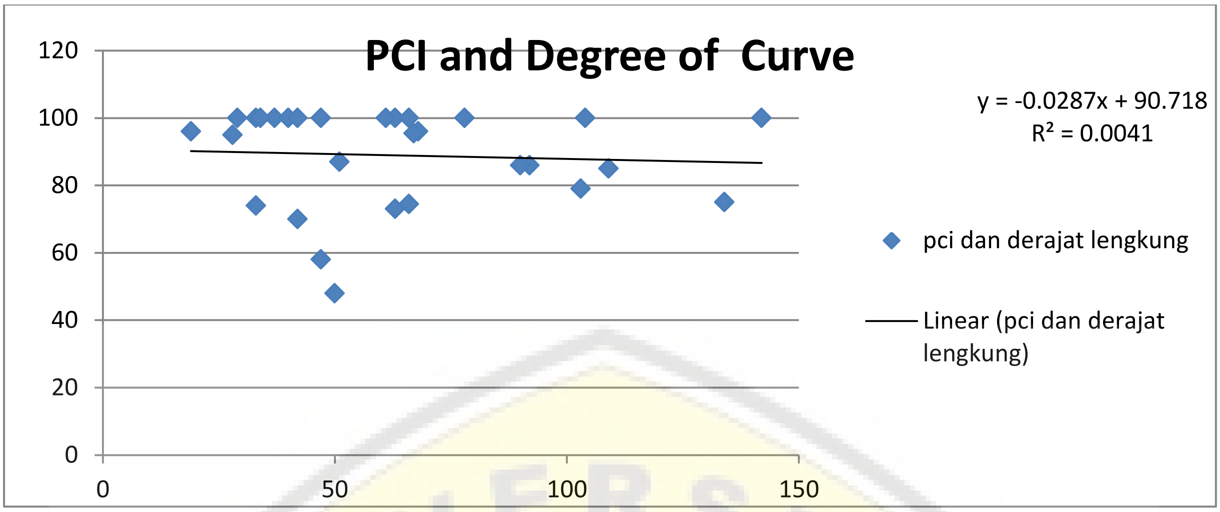

Figure 4: Relationship between PCI and Degree of Curve

From Figure 4 it is explained that the relationship between PCI and Degree of Curve is obtained R^2 value of 0.0041 with the type of polynomial regression. This value indicates that PCI affects the Degree of Curve 0.41% while 99.59% is influenced by other factors. The following results of the relationship between PCI with slope, PCI with radius, and PCI with degree of curve can be seen in Table 4.

Table 4: recapitulation of the equation and the connection model of PCI, slope, radius, and degree of curve

No	connection	Determination coefficient (R^2)	equation	Type of regression
1	PCI with Slope	0,068	Y = 1,7005x + 79,40	Polynomial Regression
2	PCI with Radius	0,0243	Y = -0,002x^2+0,2955x+82,271	Polynomial Regression
3	PCI with Degree of Curve	0,0041	Y = -0,0278x + 90,718	Polynomial Regression

4. Conclusion

From the calculation results and regression analysis of PCI relationship, radius, degree of curvature, and slope lengthwise on the Wringin street - Bondowoso Regency, it is concluded that for PCI and slope lengthening the road gets a value of R^2= 0.068 and Y = 1,7005x + 79,40 using the polynomial regression model. This value shows that PCI affects the length of slope only 6.8% while 93.2% is influenced by other factors. For PCI and radius get the value R^2= 0.0243 and Y = -0.002$\mathbf{x}^2$+ 0.2955x + 82.271 by using the polynomial regression model. This value indicates that the PCI affects the radius of only 2.4% while 97.6% is influenced by other factors. Then for PCI and the degree of arcs get values R^2= 0.0041 and Y = -0.0278x + 90.718 using the polynomial regression model. This value shows that PCI affects the degree of arcing of only 0.41% while 99.59% is influenced by other factors. So the relationship between PCI, radius, degree of arcing, and longitudinal slope there is no relationship if juxtaposed with the value of the PCI itself.

Acknowledgements

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