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Road Geometry vs. PCI in Different Pavement Surface Types

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Abstract

Previous studies on the correlation between road geometry and pavement condition index have focused on flexible pavement types, which assume constant traffic volume in their modeling approaches. This creates limitations in understanding the behavior of different pavement types under varying traffic conditions and geometries. To address this gap, this study analyzes the relationship between road geometry and the Pavement Condition Index (PCI) across different surface types—specifically, flexible and rigid pavements—while including traffic volume as an independent variable. In Indonesia, road infrastructure is largely dominated by flexible pavements, with a total of 329,189 kilometers in 2024, compared to 218,908 kilometers of other pavement types, including rigid pavements. Reflecting this distribution, the study was conducted on six urban road sections, consisting of four flexible pavement roads and two rigid pavement roads. A non-linear regression approach was applied to develop separate models for each pavement type. The flexible pavement model achieved a coefficient of determination (R^2) of 0.570, while the rigid pavement model produced an R^2 of 0.561. Among the geometry parameters evaluated, road gradient was found to be the most significant factor affecting PCI in both pavement types. Rigid pavement is recommended for roads with varying alignments to minimize geometry effects on pavement conditions, extending maintenance intervals and improving safety.

Keywords

road geometry, pavement condition index, urban road

1 Introduction

Road infrastructure plays an important role by providing mobility for the efficient movements of people and goods, as well as providing accessibility to a wide variety of commercial and social activities (Astuti et al., 2021; Ji and Huang, 2023; Nawir et al., 2023; Ng et al., 2019; Oktarina, 2016). Roads need to be designed in accordance with applicable technical regulations so that the safety of road users is guaranteed. Roads must be designed according to both geometry and pavement requirements (Wibowo et al., 2022). Both road geometry and pavement condition have a significant impact on road safety, as poor geometry design and deteriorating pavement can increase the risk of accidents and reduce overall driving comfort (Al'Adilah et al., 2021; Barman and Bandyopadhyaya, 2020; Bobermin et al., 2021; Chen et al., 2016; Hussein et al., 2021; Mkwata and Chong, 2022).

Road geometry refers to the shape of the road, encompassing its cross-section, longitudinal section, and other physical aspects related to the road's form (Lawalata et al., 2022; Sinaga et al., 2019). Meanwhile, pavement design includes the thickness of the pavement (Isnaini et al., 2019). There are two main types of road pavement commonly used worldwide: flexible pavement and rigid pavement (Wardani and Agustanti, 2021). Among these two types, flexible pavement is more widely used in Indonesia. According to data from the Central Statistics Agency, in 2024, the total length of roads with flexible pavement reached 329,189 kilometers, while roads with other types of pavement measured 218,908 kilometers (Badan Pusat Statistik, 2024).

All these roads have been constructed across Indonesia's diverse topography, as the country is characterized by varying topography, including mountainous areas, plains, and coastal regions (Sunarsih and Bernadi, 2022; Widhaningtyas et al., 2020). Indonesia's varied topography necessitates roads that conform to existing land contours, resulting in roads with diverse shapes that follow the natural landscape. This approach helps reduce road construction costs compared to the

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more expensive methods of cutting and filling to achieve a flat alignment.

The shape of the road has an influence on driver behavior (Bobermin et al., 2021; Mussone, 2023; Ukam and Aniekan Emiri, 2019). For example, the driver will reduce speed on uphill or downhill roads. This behavior has an influence on the pavement because reducing vehicle speed will increase the bearing load on the road surface, which will make the area susceptible to damage (Anggreana, 2021). Apart from geometry shape, other factors that can influence road pavement conditions are vehicle load, inadequate road maintenance, temperature fluctuations, material quality, and insufficient drainage (Astor et al., 2023a; Astor et al., 2023b; Bhandari et al., 2023; Hatmoko et al., 2019; Manurung et al., 2022; Marsyanda et al., 2022; Prawesthi et al., 2022; Rizky et al., 2023; Sihombing et al., 2021; Zahra et al., 2025).

However, there is still little discussion of the influence of geometry shapes on road pavement conditions. The results of previous research suggest that the PCI value is directly proportional to the road width, bend radius, and inversely proportional to the transverse slope and longitudinal slope (Solatiyan, 2012). This can be influenced by a decrease in the resilience modulus value of the subgrade on roads that have slopes and high shear strain values on narrow road shoulders (Forghani et al., 2020). However, this research only analyzed flexible pavement, so the relationship between PCI and geometry aspects of rigid pavement is not yet known. Understanding how road geometry influences PCI on rigid pavements is equally essential, especially considering that rigid pavements have different structural behavior and load transfer mechanisms compared to flexible pavements. Rigid pavements distribute loads over a wider area and typically have higher stiffness, which could result in different performance patterns when influenced by geometry factors.

This research analyzes and compares the relationship between road geometry and PCI on flexible and rigid pavement on urban roads with similar conditions (traffic, geometry, and classification). The results of this research can later become input for planners and policymakers in developing and maintaining safe roads so that resource allocation can be effective and efficient.

2 Materials

The primary data required for this study includes road geometry, road condition, and traffic volume from six locations, consisting of four roads with flexible pavement and two roads with rigid pavement. The selected study location is a road that has an average vertical alignment of 6% and has variations in horizontal alignment. The traffic volume at the study location has a relatively similar amount. The geometry data required in this study are road gradient, bend radius, and road width. Furthermore, the road conditions are based on the pavement conditions index (PCI). The traffic volume is the traffic volume during rush/peak hour. Table 1 presents the data collected at each study location.

3 Methodology

The steps required to achieve the objectives of this research are literature review, preparation, data collection and processing, research analysis, and product development (Fig. 1). Data collection was conducted at close intervals to minimize significant differences in pavement conditions. All data were collected by direct survey in the field. The process of collecting geometry data at the study location was performed using a water pass with the double stand method. Other measurements used a measuring tape and an odometer. The geometry data obtained were analyzed as independent variables (x) in the correlation analysis. The road gradient is x_1, the bend radius is x_2, and the road width is x_3.

Pavement condition index data collection was carried out twice at each study location with a time span of 6 months. This was done to see the differences in the pavement condition index. The pavement condition survey was initiated by segmenting the road section into several sample units, each with a length of 50 meters. In accordance with the specifications outlined in Pd-01-2016-B, the area of each sample unit is required to be approximately 225 ± 90 m^2. In the correlation analysis, the pavement condition index is the dependent variable (y).

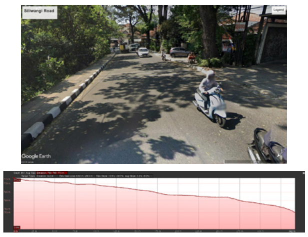
To obtain the traffic volume of each location, traffic counting is done directly in the field and using CCTV. Table 2 gives details of the data collection of the traffic volume survey. Traffic volume is an independent variable (x_4) in the correlation analysis.

After all data from each research location are collected, the next step is data processing and statistical analysis. Details of the statistical analysis flow can be seen in Fig. 2.

Statistical analysis begins with conducting data adequacy and uniformity test. If the data adequacy and uniformity test has met the expected level, then the next step is to analyze the probability distribution and normality of each data.

In this study, the confidence level used is 95% (k = 2) and the accuracy level is 80% (s = 0.2). Data Adequacy is calculated using the formula Eq. 1. The amount of data needed (N') for each variable can be seen in Table 3.

Table 1 Study location – Specific data

No	Study location	Surface type	Road length (m)	Road width (m)	Geometry data Gradient max. (%)	Bend radius (m)	PCI First survey	PCI Second survey	Traffic volume pcu/hour
1	 Lemahneundeut road	Rigid pavement	432	7	8.79	80 20 15	86.21	78.49	3,602.30
2	 Gegerkalong Hilir Road	Rigid pavement	338	6	10.17	30 58 32	80.00	66.86	3,528.50
3	 Pacuan Kuda Road	Flexible pavement	400	7	5.60	20 90	89.44	61.50	1,920.80
4	 Siliwangi Road	Flexible pavement	350	10	5.21	55 110 50	62.50	69.93	4,717.90
5	 Prof. Sutami Road	Flexible pavement	350	6.5	14.43	11 7	86.07	80.96	3,849.40
6	 Trs. Prof Sutami Road	Flexible pavement	350	8.3	6.04	25	95.14	93.00	2,480.10

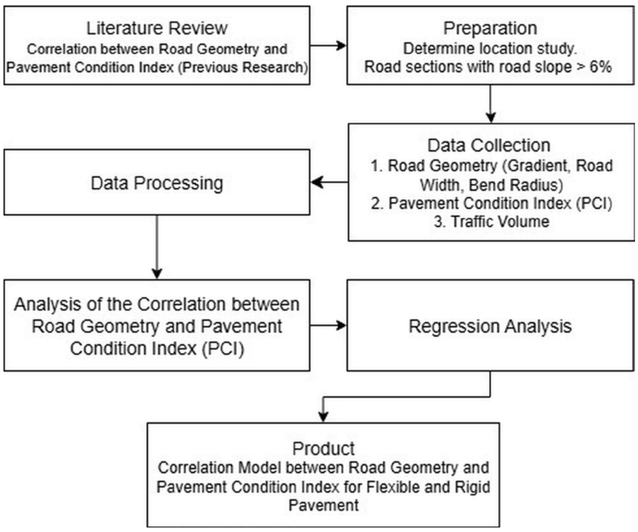


Fig. 1 Methodology

Table 2 Traffic counting survey

No.	Study location	Data collection
1.	Jalan Lemahneundeut (Rigid pavement)	Direct survey
2.	Jalan Gegerkalong Hilir (Rigid pavement)	Direct survey
3.	Jalan Pacuan Kuda (Flexible pavement)	CCTV
4.	Jalan Siliwangi (Flexible pavement)	CCTV
5.	Jalan Prof. Sutami (Flexible pavement)	Direct survey
6.	Jalan Trs. Prof. Sutami (Flexible pavement)	CCTV

$$N' = \left(\frac{\frac{k}{s}\sqrt{N\sum x^2 - \left(\sum x\right)^2}}{\sum x} \right)^2 . \quad (1)$$

The results of this analysis will determine the correlation test to be conducted. Because the data used in this study are not normally distributed, the correlation test uses the Spearman correlation. Next, a non-linear regression test is conducted. The non-linear regression test is conducted by curve estimation, then the form that has the largest R adj. value is chosen. Then a non-linear regression test is conducted. If the R value obtained from the non-linear regression model is small, an iteration is performed by eliminating one of the independent variables with the smallest correlation with the dependent variable. If the R value remains small, then there is a possibility that there are other variables that affect the dependent variable but are not in the model. This condition is also reflected by the constant value contained in the model. Next, a regression assumption test is conducted to ensure that all assumptions have been met. Finally, a coefficient significance test is conducted on the model to determine the validity of the existing model. In this study, the model was created by referring to the model that was put forward in previous studies, as seen in Eq. (2):

$$PCI = 1.81W - 5.6C + 0.0002R - 0.09G + 86.9 . \quad (2)$$
$$R^2 = 0.67$$

Where:
- W = Road width
- C = Cross slope
- R = Bend radius
- G = Gradient

This model is intended for roads with flexible pavement. Based on the model, the relationship between PCI and all the calculated geometry aspects is linear. The model has an R^2 value of 0.67. This study will add one more independent variable, namely traffic volume and the cross slope was not calculated.

In this study, the model was changed from linear to non-linear following the correlation form obtained from the data. In this study, the model is made based on the following conditions:

A: On flexible pavement: gradient in the range of 1% – 6%, bend radius in the range of 10 – 120 m, road

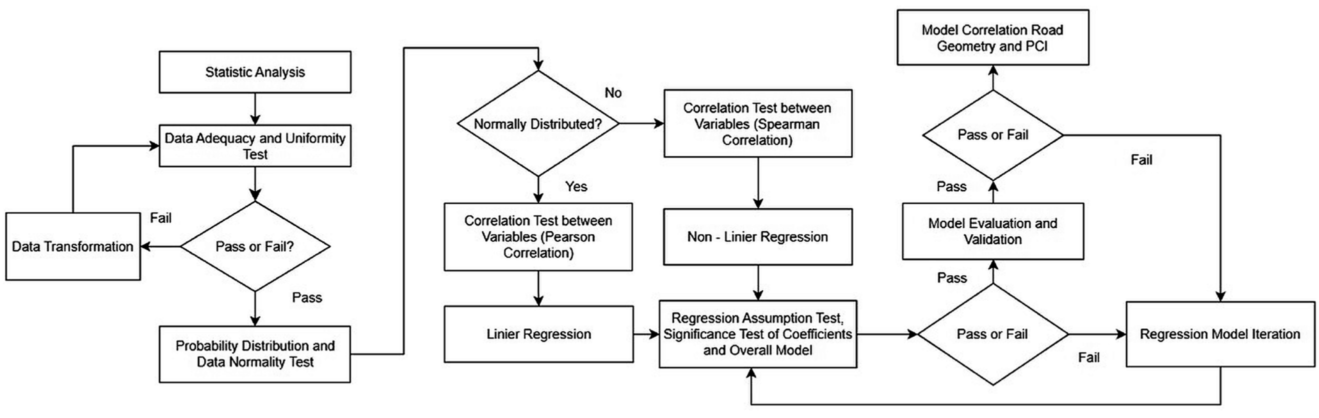


Fig. 2 Statistical analysis flow

Table 3 Data adequacy

Pavement type	Variable	$\sum x$	$\sum x^2$	N'
Flexible pavement	PCI	1,353.50	118,321.75	3.34
	Gradient	0.67	0.03	13.89
	ln (Bend radius)	59.19	229.05	4.60
	Road width	88.00	494.00	2.07
	Traffic volume	23,051	36,894,301	11.10
Rigid pavement	PCI	889.00	67,505.00	2.50
	ln (Gradient)	-39.79	141.14	6.97
	ln (Bend radius)	40.62	141.77	3.09
	Road width	76.00	484.00	0.55
	Traffic volume	21,064.79	37,130,390.14	0.41

width in the range of 3 – 8 m, and traffic volume in the range of 700 – 2,000 pcu/hour

B: On rigid pavement: gradient in the range of 1% – 13%, bend radius in the range of 10 – 60 m, road width in the range of 6 – 7 m, and traffic volume in the range of 1,600 – 1,900 pcu/hour

C: Other aspects are considered constant.

4 Results and discussion

4.1 Flexible pavement

Table 4 is the dataset used to model PCI (y) with independent variables (x) for the PCI model of flexible pavement. Table 5 contains the statistical properties of the dataset.

Table 4 Dataset for PCI model of flexible pavement

PCI	Gradient	ln (Bend radius)	Road width (m)	Traffic volume (pcu/hour)
53.0	0.054	4.007	5	1,983
57.0	0.048	3.912	5	1,235
66.5	0.048	3.912	5	1,235
70.0	0.054	4.007	5	1,983
72.0	0.052	4.700	5	1,235
86.0	0.052	4.700	5	1,983
88.0	0.048	3.912	5	1,983
88.0	0.052	4.700	5	1,235
88.5	0.037	2.303	6	789
95.5	0.052	3.135	8	1,815
100.0	0.048	3.912	5	1,983
100.0	0.052	4.700	5	1,983
100.0	0.037	2.303	6	789
89.0	0.011	2.996	6	1,020
100.0	0.011	2.996	6	900
100.0	0.011	2.996	6	900

Table 5 Statistical properties for PCI model of flexible pavement

Variable	N	Min	Max	Mean	Std. deviation
PCI	16	53.0	100.0	84.594	15.96
Gradient	16	0.011	0.054	0.04169	0.016
ln (Bend radius)	16	2.303	4.700	3.69953	0.81
Road width	16	5	8	5.50	0.81
Traffic volume	16	789	1983	1,440.81	495.71

Fig. 3 is a tornado plot of the sensitivity results obtained from the Spearman correlation analysis for each independent variable with the dependent variable in rigid pavements. The higher the correlation coefficient, the more relevant the input variable is in determining the results. Fig. 3 shows that the variable that has the most significant correlation is road width, followed by gradient, bend radius, and traffic volume. Correlation with a negative value means that for every increase in the gradient, bend radius, and traffic volume, the PCI value decreases. Conversely, if the road is wider, the PCI value increases.

The distribution of the dataset shows that the relationship between the independent and dependent variables is not linear, so the model is made non-linear following the shape of the dataset distribution. The non-linear regression model of PCI Flexible Pavement can be seen in Eq. (3). This model is obtained by iterating the shape of the model and also the variables involved. Model selection is based on the R^2 and AIC – SIC values. Eq. (3) is the model with the highest R^2 and the lowest AIC – SIC. Eq. (3) has a smaller R^2 value than Eq. (2), even though this model has taken traffic volume into account and can also be used as an initial step for developing a better model in further research.

The model is then evaluated by trying to apply it to another road case study. In this study, the model evaluation was conducted on Bandung – Subang Road, West Bandung Regency. The data used were secondary data from journals and also Google Earth. Table 6 shows the input data used in calculating PCI.

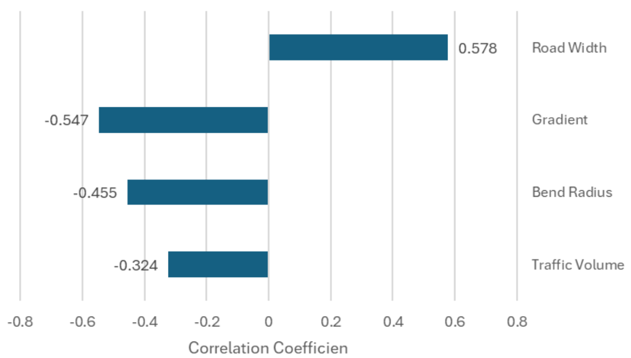


Fig. 3 Tornado diagram of correlation coefficient between variables and PCI for flexible pavement

Table 6 Data bandung – Subang road

No.	Stations	PCI	Gradient (%)	Bend radius (m)	Road width (m)	Traffic volume (pcu/hour)
1	0+200 – 0+500	47.67	13%	80	12	2,151
2	0+500 – 0+700	47	7%	42	8.2	2,151

$$y = -4448.762x_1 - 246.767x_2 + 5.024x_2^3 - 1387.095x_3 + 160.510x_3^2 - 0.272x_4 + 9.397E - 5x_4^2 + 5410.118 \quad (3)$$

$$R^2 = 0.570$$

Where:

- x_1 = Gradien
- x_2 = ln (Bend radius)
- x_3 = Width radius
- x_4 = Traffic volume

Table 7 shows the comparison of the PCI and PCI model, using this research model the accuracy obtained was 88% and 39%, respectively. While using the previous research model (Solatiyan, 2012), the PCI exceeded its maximum limit (>100). The small accuracy value (<80%) is caused by the lack of independent variables that affect the IKP in the model. The model created only considers geometry and traffic factors. The PCI model value is greater than the measured PCI value. This condition shows that the PCI value is not only influenced by geometry and traffic factors. This model needs to be improved by adding other independent variables and also other road case studies so that the model is more stable.

4.2 Rigid pavement

Table 8 is the dataset used to model PCI (y) with independent variables (x) for the PCI model of rigid pavement. Table 9 shows the statistical properties of the dataset.

Fig. 4 is a tornado plot of the sensitivity results obtained from the Spearman correlation analysis for each independent variable with the dependent variable in rigid pavements. The higher the correlation coefficient, the more relevant the input variable is in determining the results. Fig. 4 shows that the variable that has the most significant correlation is gradient, followed by traffic volume, road width and bend radius. Correlation with a negative value means that for every increase in the gradient, and traffic volume, the PCI value decreases. Conversely, if the road is wider and the bend radius is higher, the PCI value increases.

The distribution of the dataset shows that the relationship between the independent and dependent variables is not linear, so the model is made non-linear following the shape of the dataset distribution. The non-linear regression model of PCI in rigid pavements can be seen in Eq. (4). This model is obtained by iterating the shape of the model and also the variables involved. In this case, road width is not involved in the model because of the result of the R^2 and AIC – SIC values. Eq. (4) is the model with the highest R^2 and the lowest AIC – SIC.

$$y = -10.136x_1 - 199.281x_2 + 29.343x_2^2 - 3.617E - 9x_4^3 + 388.246 \quad (4)$$

$$R^2 = 0.561$$

Where:

- x_1 = ln (Gradient)
- x_2 = ln (Bend radius)
- x_4 = Traffic volume

The PCI model of rigid pavements in Eq. (4) shows a lower R^2 compared to flexible pavements. This indicates that the independent variables taken into model can only explain about 56% of the dependent variable. In addition, the constant value of 388.246 shows the shortcomings of this model and the existence of independent variables that have an influence on the PCI value but have not been included in this model. These variables can be the value of the resilient modulus of the subgrade, the strength of the material and the drainage conditions which in this study are considered constant. Although this model still needs improvement and refinement, this model can be used as an initial description of how geometry aspects affect the PCI of rigid pavement.

The model is then evaluated by trying to apply it to another road case study. In this study, the model evaluation was conducted on Cangkorah Road, West Bandung Regency. The data used were secondary data from both journals and Google Earth. Table 10 shows the input data and Table 11 contains the calculation results. As a result,

Table 7 Model evaluation

No.	Stations	PCI	PCI model (Zahra et al., 2025)	Accuracy	PCI model (Solatiyan, 2012)
1	0 + 200 – 0 + 500	47.67	53.20	88%	108.51
2	0 + 500 – 0 + 700	47	75.67	39%	101.63

Table 8 Dataset for PCI model of rigid pavement

PCI	ln (Gradient)	ln (Bend radius)	Road width (m)	Traffic volume (pcu/hour)
88	−4.92	3.00	7	1,627.82
84	−3.27	2.71	7	1,774.32
85	−4.92	3.00	7	1,774.32
71	−3.27	2.71	7	1,774.32
66	−2.62	2.83	6	1,894.30
76	−2.10	4.25	6	1,894.30
85	−3.49	4.06	6	1,634.20
85	−3.50	3.47	6	1,634.20
54	−2.62	2.83	6	1,894.30
61	−2.10	4.25	6	1,894.30
78	−3.49	4.06	6	1,634.20
56	−3.50	3.47	6	1,634.20

the measured PCI and the model PCI have an accuracy of 61% and 85%, respectively. The small accuracy value (<80%) is caused by the lack of independent variables that affect the IKP in the model. The model created only considers geometry and traffic factors. The PCI value of stations 0+400 – 0+450 based on the model is greater than the PCI value of stations 0 + 600 – 0 + 650 because the bend radius at stations 0 + 400 – 0 + 450 is greater than that of stations 0+600 – 0+650. This shows that the PCI value is not only influenced by geometry and traffic factors.

Although the model has a large intercept and the average accuracy of the measured PCI and calculated PCI is small (<80%), this model can be used as a reference in building a PCI model on rigid pavements in the future because this is the first correlation model between PCI and geometry on rigid pavements.

4.3 Discussion

Based on the analysis that has been done, a geometry aspects that have similar correlations both on flexible and rigid pavement is road gradient. This is caused by the decrease in the resilient modulus of the subgrade on uphill roads. So that the bearing capacity of the soil in this condition is also smaller than on flat roads. As a result, uphill roads are more easily damaged than flat roads. The decrease in vehicle speed on uphill roads also makes the load received greater than in flat conditions.

The distribution of loads concentrated on flexible pavements also makes this type of pavement have a greater correlation to other geometry aspects because variations in vertical and horizontal alignment greatly affect the distribution of loads. In addition, the type of material that is not stiffer and stronger than rigid pavement (Taher et al., 2020) also makes flexible pavements more correlated with geometry aspects.

Compared to previous studies, the findings of this research support previous results. Existing research highlights a correlation between road geometry and road damage, with the Pavement Condition Index (PCI) directly correlating with road and shoulder width, and inversely correlating with gradient on flexible pavements (Zahra et al., 2024). In this study,

Table 9 Statistical properties for PCI model of rigid pavement

Variable	*N*	Min	Max	Mean	Std. deviation
PCI	12	54.00	88.00	74.08	12.22
ln (Gradien)	12	−4.92	−2.10	−3.31	0.91
ln (Bend radius)	12	2.70	4.24	3.38	0.62
Road width	12	6.00	7.00	6.33	0.49
Traffic volume	12	1,627.819	1,894.300	1,755.39902	118.045325

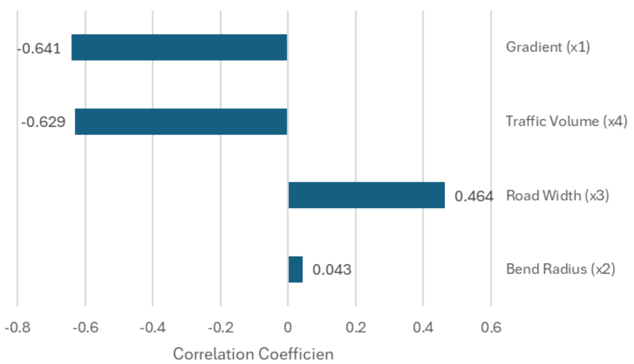


Fig. 4 Tornado diagram of correlation coefficient between variables and PCI for rigid pavement

Table 10 Data cangkorah road

No.	Stations	PCI	Gradient (%)	Bend radius (m)	Road width (m)	Traffic volume (pcu/hour)
1	0+400–0+450	67	4%	102	7	987.608333
2	0+600–0+650	70	4%	84	7	987.608333

Table 11 Model evaluation

No.	Stations	PCI existing	PCI model	Accuracy
1	0+400 – 0+450	67	93.37685	61%
2	0+600 – 0+650	70	80.47654	85%

it was also found that rigid pavements have the same correlation in these aspects. However, the correlation with bend radius and traffic volume is not as large as road width and gradient. On rigid pavements, traffic volume is more correlated than bend radius and road width. The rigid pavement has better ability and durability to hold a shape against traffic and difficult environmental conditions than flexible pavements (Taher et al., 2020).

5 Conclusion

Based on the discussion that has been presented, on roads with flexible pavement, the PCI value has a stronger correlation with geometry aspects. While on rigid pavement, the PCI value has a strong correlation only with the gradient and traffic volume.

The correlation model that has been explained in the previous section can be used in road maintenance planning to make it easier for stakeholders to carry out preventive maintenance. On roads with various horizontal and vertical alignments, rigid pavement can be used to reduce the influence of geometry shapes on road pavement conditions. The risk of traffic accidents can be more controlled due to the minimal influence of geometry shapes on the pavement. Rigid pavement requires less maintenance and has a good design life (Skrzypczak et al., 2018).

In order to improve the PCI model, both in rigid and flexible pavements, further research can add other independent variables such as material strength, micro – macro structure pavement, resilient modulus, drainage conditions and add more diverse data variations. Model design for other commonly used pavement surface types can be done in further research.

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References

Al'Adilah, Hasanuddin, A., Kriswardhana, W. (2021) "Analisis Hubungan Geometrik Jalan terhadap Keselamatan Jalan Bypass Mojokerto Km Sby 51–63" (Analysis of Relationship of Road Geometry and Road Safety on the Mojokerto Bypass Sby Km 51–63), Paduraksa: Jurnal Teknik Sipil Universitas Warmadewa, 10(2), pp. 253–265. (in Indonesian) https://doi.org/10.22225/pd.10.2.2770.253-265

Anggreana, V. (2021) "Analisa Tebal Perkerasan Jalan di Tanjakan Menggunakan Metode AASHTO 1993" (Analysis of Road Pavement Thickness on Inclines Using the 1993 AASHTO method), Akselerasi Jurnal Ilmiah Teknik Sipil, 2(2), pp. 1–8. (in Indonesian) https://doi.org/10.37058/aks.v2i2.2756

Astor, Y., Utami, R., Nabesima, Y., Sihombing, A. V. R. (2023a) "Implementation of UAV for Pavement Functional Performance Assesment", International Journal of Sustainable Construction Engineering and Technology, 14(1), pp. 270–278. https://doi.org/10.30880/ijscet.2023.14.01.024

Astor, Y., Nabesima, Y., Utami, R., Sihombing, A. V. R., Adli, M. (2023b) "Unmanned aerial vehicle implementation for pavement condition survey", Transportation Engineering, 12, 100168. https://doi.org/10.1016/j.treng.2023.100168

Astuti, S., Yusmania, R., Jauzi, N. A., Panorama, M. (2021) "The Effect of Road Infrastructure Development on the Welfare of the Community in Kayu Ara Village, Tulung Selapan Regency, Oki Regency, Selatan Sumatra", Berajah Journal, 2(1), pp. 123–132. https://doi.org/10.47353/bj.v2i1.65

Badan Pusat Statistik (2024) "Panjang Jalan Menurut Jenis Permukaan (km), 2020–2022" (Road length by surface type (km), 2020–2022) [online] Available at: https://www.bps.go.id/id/statistics-table/2/NTEjMg==/panjang-jalan-menurut-jenis-permukaan--km-.html [Accessed: 5 May 2025]

Barman, S., Bandyopadhyaya, R. (2020) "Crash Severity Analysis for Low-Speed Roads Using Structural Equation Modeling Considering Shoulder- and Pavement-Distress Conditions", Journal of Transportation Engineering, Part A: Systems, 146(7), 04020065. https://doi.org/10.1061/jtepbs.0000373

Bhandari, S., Luo, X., Wang, F. (2023) "Understanding the effects of structural factors and traffic loading on flexible pavement performance", International Journal of Transportation Science and Technology, 12(1), pp. 258–272. https://doi.org/10.1016/j.ijtst.2022.02.004

Bobermin, M. P., Silva, M. M., Ferreira, S. (2021) "Driving simulators to evaluate road geometric design effects on driver behaviour: A systematic review", Accident Analysis & Prevention, 150, 105923. https://doi.org/10.1016/j.aap.2020.105923

Chen, C., Wang, Y., Ma, C., Zhang, W. (2016) "How Expressway Geometry Factors Contribute to Accident Occurrence? A Binary Logistic Regression Study", Periodica Polytechnica Transportation Engineering, 44(4), pp. 215–221. https://doi.org/10.3311/PPtr.8795

Forghani, F., Tighe, S., Henderson, V., Becke, M., Soares, R., Haichert, R. (2020) "Impact of Road Geometry and Thickness on Pavement Behaviour using PSIPave 3DTM", [online] presented at: 2020 TAC Conference & Exhibition, Innovations in Pavement Management, Engineering and Technologies Session, Canada, Sept 21 – Oct 08 2020. Available at: https://trid.trb.org/View/1754893 [Accessed: 11 November 2025]

Hatmoko, J. U. D., Setiadji, B. H., Wibowo, M. A. (2019) "Investigating causal factors of road damage: a case study", MATEC Web of Conferences, 258, 02007. https://doi.org/10.1051/matecconf/201925802007

Hussein, N., Hassan, R., Fahey, M. T. (2021) "Effect of pavement condition and geometrics at signalised intersections on casualty crashes", Journal of Safety Research, 76, pp. 276–288. https://doi.org/10.1016/j.jsr.2020.12.021

Isnaini, A. Y., Suparma, L. B., Utomo, S. H. T. (2019) "Perancangan Perkerasan Jalan Lingkar Kota Kabupaten Wonogiri" (Pavement Design for the Wonogiri Regency Capital City Ring Road), Jurnal Himpunan Pergembangan Jalan Indonesia, 5(2), pp. 119–128. (in Indonesian) https://doi.org/10.26593/jh.v5i2.3372.119-128

Ji, Z., Huang, Y. (2023) "The Impact of Highway Infrastructure on Population Mobility: Evidence from a Sample of 800 Counties and Districts (2000–2019) in China", Sustainability, 15(20), 14834. https://doi.org/10.3390/su152014834

Lawalata, G. M., Cahyadi, U., Rustijan, Amelia, S. (2022) "Desain Jalan Kelandaian Curam" (Steep-Grade Road Design), [online] KRTJ-HPJI. Available at: https://www.scribd.com/document/669760824/163-KTI-KRTJ-landai-tinggi-2022-Greece-M-Lawalata-Greece-Maria-Lawalata-docx-compressed [Accessed: 11 November 2025]

Manurung, E. H., Sawito, K., Satoto, A., Tuanany, N. (2022) "Analysis of the Causes of Road Damage", Civilla: Jurnal Teknik Sipil Universitas Islam Lamongan, 7(1), pp. 87–96. https://doi.org/10.30736/cvl.v7i1.793

Marsyanda, U. A., Januar, I. Y. D., Said, L. B., Idrus, Y., Alkam, R. B. (2022) "Analisis Kerusakan Jalan dan Cara Penanggulangannya" (Analysis of Road Damage and Remedial Measures), Jurnal Teknik Sipil MACCA, 7(1), pp. 8–17. (in Indonesian) https://doi.org/10.33096/jtsm.v7i1.536

Mkwata, R., Chong, E. E. M. (2022) "Effect of pavement surface conditions on road traffic accident - A Review", E3S Web of Conferences, 347, 01017. https://doi.org/10.1051/e3sconf/202234701017

Mussone, L. (2023) "Assessing the effects of road geometry and fidelity on driver behaviour in driving simulator experiments", Transportation Research Interdisciplinary Perspectives, 20, 100835. https://doi.org/10.1016/j.trip.2023.100835

Nawir, D., Bakri, M. D., Syarif, I. A. (2023) "Central government role in road infrastructure development and economic growth in the form of future study: the case of Indonesia", City, Territory and Architecture, 10(1), 12. https://doi.org/10.1186/s40410-022-00188-9

Ng, C. P., Law, T. H., Jakarni, F. M., Kulanthayan, S. (2019) "Road infrastructure development and economic growth", IOP Conference Series: Materials Science and Engineering, 512(1), 012045. https://doi.org/10.1088/1757-899X/512/1/012045

Oktarina, V. V. (2016) "Pengaruh Infrastruktur Jalan Dalam Menunjang Pengembangan Potensi Kabupaten Bengkayang" (The Influence of Road Infrastructure on the Development of Bengkayang Regency's Regional Potential), Jurnal Teknik Sipil, 16(2), pp. 449–454. https://doi.org/10.26418/jtst.v16i2.27098

Prawesthi, W. A., Mudiyono, R., Poedjiastoeti, H. (2022) "Road Damaged Factor Analysis at Signalized Intersection" (Case Study: The Traffic Light in Front of UNISSULA, Jl. Raya Kaligawe KM 4, Semarang), Pondasi, 27(2), pp. 234–239. https://doi.org/10.30659/pondasi.v27i2.24345

Rizky, A. M., Zahra, A. A., Astor, Y., Septian, R., Munawar, G., Sihombing, A. V., Fauzi, C. (2023) "Road Maintenance Management Based on Geographic Information System (GIS)", International Journal on Advanced Science Engineering Information Technology, 13(6), pp. 2418–2426. https://doi.org/10.18517/ijaseit.13.6.19390

Sinaga, L., Sendow, T. K., Waani, J. E. (2019) "Evaluasi Geometrik Jalan Berdasarkan Standar Perencanaan Bina Marga" (Assessment of Road Geometric Design Based on Bina Marga Planning Standards), Jurnal Sipil Statik, 7(7), pp. 819–826. (in Indonesian)

Skrzypczak, I., Radwański, W., Pytlowany, T. (2018) "Durability vs technical - the usage properties of road pavements", E3S Web of Conferences, 45, 00082. https://doi.org/10.1051/e3sconf/20184500082

Solatiyan, E. (2012) "Performance Modeling the Geometric Characteristic of Curved Sections in the Two-Way Two-Lane Rural Roads on the Pavement Distress", 6(1), pp. 45–50.

Sunarsih, S., Benardi, A. I. (2022) "Kajian Tingkat Kesadaran Masyarakat Kecamatan Bantarkawung Dalam Mengelola Lahan Di Wilayah Rawan Bencana Tanah Longsor" (Analysis of Community Awareness in Managing Land in Landslide-Prone Areas, Bantarkawung Subdistrict), Edu Geography, 10(1), pp. 59–65. (in Indonesian) https://doi.org/10.15294/edugeo.v10i1.56435

Taher, S. A., Alyousify, S., Hassan, H. J. A. (2020) "Comparative Study of Using Flexible and Rigid Pavements for Roads: A Review Study", The Journal of the University of Duhok, 23(2), pp. 222–234. https://doi.org/10.26682/csjuod.2020.23.2.18

Ukam, G., Aniekan Emiri, D. (2019) "Investigating the Effect of Highway Geometric Design on Safety, Using a Safety Indicator within the Design Manual", International Journal of Engineering Science Invention (IJESI), 8(08), pp. 58–63. Available at: https://www.researchgate.net/publication/338019503 [Accessed: 11 November 2025]

Wardani, W., Agustanti, Y. N. (2021) "Study The Difference Between Flexible Pavement and Rigid Pavement Construction", Undergraduate thesis, Universitas Islam Sultan Agung Semarang.

Wibowo, D. E., Putra, Y. P., Ma'arif, F. (2022) "Evaluation and Redesign Based on Highway Geometric Design Guidelines 2021" (Case Study of Sampakan – Singosaren Road KM 13.8, Bantul Regency), INERSIA Informasi dan Ekspose Hasil Riset Teknik Sipil dan Arsitektur, 18(2), pp. 186–195. https://doi.org/10.21831/inersia.v18i2.54664

Widhaningtyas, T. U., Putra, A. C. P., Fariz, T. R. (2020) "Perbandingan Metode Koreksi Topografi Pada Citra Satelit Landsat 8 Di Wilayah Gunung Telomoyo, Jawa Tengah" (Comparison of Topographic Correction Methods for Landsat-8 Satellite Imagery in the Mount Telomoyo Region, Central Java), Jurnal Geografi: Media Informasi Pengembangan dan Profesi Kegeografian, 17(2), pp. 32–38. (in Indonesian) https://doi.org/10.15294/jg.v17i2.22863

Zahra, A. A., Astor, Y., Sihombing, A. V. (2024) "Correlation Road Geometric on Road Damage", Journal of Green Science and Technology, 8(1), pp. 11–17. https://doi.org/10.33603/jgst.v8i1.124

Zahra, A. A., Astor, Y., Sihombing, A. V. R. (2025) "Tls implementation for urban road evaluation", International Journal of GEOMATE, 29(134), pp. 133–140.