

Comparison of Pavement Performance Models for Urban Road Damage

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Abstract

The Road Condition Value determines the functional condition analysis of road pavements in managing flexible and rigid pavements for urban roads in Indonesia. The assessment is to obtain the pavement condition based on unevenness, rutting, and the primary damage to the pavement surface. This study aimed to determine the value of road damage on flexible and rigid pavements and the specific relationship between the Present Serviceability Index, International Roughness Index, and Pavement Condition Index. The method used is direct observation in the field to collect data on the types of damage that occur in both flexible and rigid pavements. The field survey results showed that the most common types of damage on flexible pavements were fillings and longitudinal cracks in rigid pavements, as many as 56 and 18, respectively. There is a strong relationship between PSI with IRI and PCI modeling with R^2 values above 90%, which are acceptable for good, medium, and poor-quality roads. The obtained equations develop a good relationship between IRI and PCI. Furthermore, the validation results show that the model has high accuracy.

Keywords

Road condition, Serviceability of pavement, Road maintenance, international roughness index and Pavement condition index

1. Introduction

One of the fundamental aspects in the design and maintenance of roads is the evaluation of the functional performance of the condition of the road infrastructure until the service level reaches the design life (Solminihac et al. 2003).

Damage that often occurs will certainly affect safety and comfort. Assessing surface conditions is one step to determining the correct appraisalment plan (Suryoto et al. 2017).

Roads are a vital means of transportation in life. It facilitates the economy, culture, and the flow of distribution of goods and services. It also connects regions to improve the economy and standard of living (Firdaus et al. 2022). It must be monitored on a timely basis, both structural and non-structural. The road condition value will later be used as a guide to decide if it is an improvement, periodic, or routine maintenance (Pérez-Acebo et al. 2020), (Tho'atin and Suprpto 2016), (Isradi et al. 2020).

Jalan Daan Mogot, West Jakarta, is a Class 3 road. It is a secondary, collector, local arterial road with a width of 8 meters in the capital of Indonesia. It serves as connecting access to the next city in Banten Province. An assessment of the surface condition is required by conducting a direct visual survey or software to avoid damage in the form of cracks, ruts, and holes (Shrestha and Khadka 2021). Several assessment techniques in road maintenance are direct visual observation in the field using the Surface Distress Index (SDI) and Pavement Condition Index (PCI) methods. It can also use road surface measurements using the International Roughness Index (IRI) method (Abaza 2006).

This research aimed to predict surface structure conditions, determine the relationship between the damage prediction and the value of the Present Serviceability Index on flexible and stiff pavements, and obtain the impact of the relationship between PCI and IRI values.

2. Method and Data Collection

Data collection techniques include direct observation, interviews, primary data processing from field surveys, and secondary data collection (Isradi et al. 2021). This research was implemented on Jalan Daan Mogot with a length of 12 km see Figure 1, whose pavement uses flexible and rigid pavements.

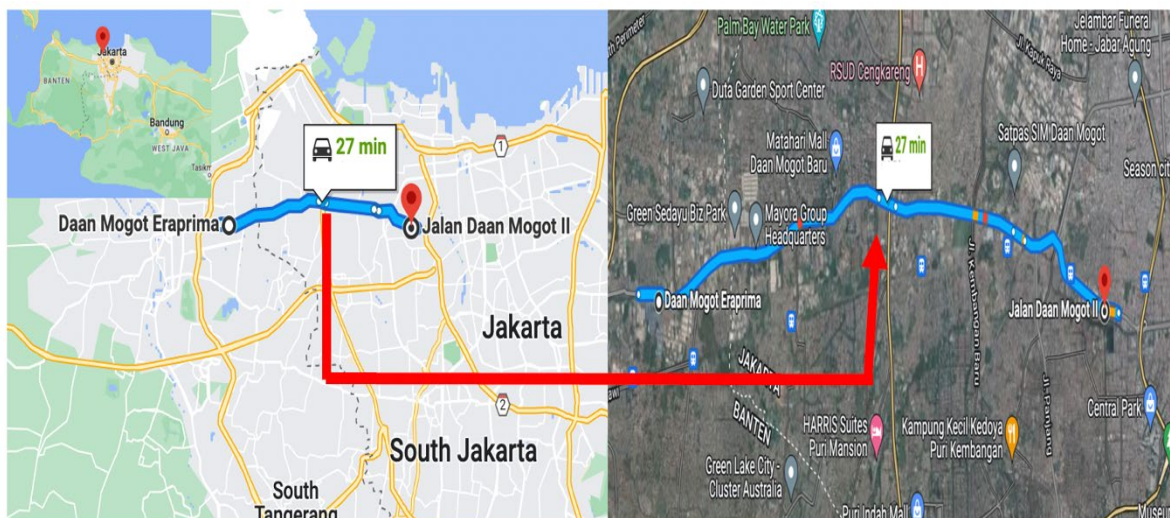


Figure 1. Research Location

The research planning process needs proper and sound analysis, which requires complete, accurate data and mature basic concepts (Rifai et al. 2015). After that, the research results are presented in tables and figures to conclude. Data on types and dimensions of road damage were obtained by conducting field surveys and getting traffic, road damage, and geometric road data (Prasetyo et al. 2021).

2.1. Average Daily Traffic Data

Traffic volume is calculated by calculating all motorized transportation modes that pass a spot on a road segment at certain time intervals expressed in vehicles or units of passenger cars (Prasetyo et al. 2020). In this study, the data was obtained by conducting a direct survey to determine the average daily traffic volume (Isradi et al. 2022).

2.2. Present Serviceability Index

The PSI value varies in the range from 0 to 5. AASHTO develops it through its Road Test, which correlates subjective and objective assessments with measurements of roughness, crack damage, fillings, and grooves into one equation (Solminihaç et al. 2003). The initial value after completion of construction is also called initial serviceability and is recommended at 4.2 for flexible pavements, with a minimum allowable limit of 2.0 (Bina Marga 2009).

For flexible pavement, the value can use the equation from AASHTO as follows (AASHTO 1993):

$$PSI_{Average} = 5,671 - 1,714\sqrt{IRI_{Average}}$$

Meanwhile, for rigid pavement, the value uses the following equation:

$$PSI_{Average} = 5,769 - 1,589\sqrt{IRI_{average}}$$

The PSI value is in Table 1 below:

Table 1. Serviceability Rating Value (Sukirman 1992)

No	Value	Rating
1	4 – 5	Very good
2	3 – 4	Good
3	3 – 2	Fair
4	2 – 1	Bad
5	0 – 1	Very bad

2.3. International Roughness Index

IRI data was from the DKI Jakarta National Road Implementation Center. The data along the observed roads are then calculated to find the average of each segment. The distance is every 100 m with 120 observations.

The World Bank in the 1980s developed an unevenness parameter of IRI. It is calculated from the cumulative surface elevation in the longitudinal profile direction divided by the surface distance/length (Direktorat Jendral Bina Marga, 2020). It is a standard for road surface unevenness that describes the longitudinal profile of a road, expressed in specific units (Direktorat Jendral Bina Marga 2020).

There are different IRI values for various pavement ages and speeds. IRI of less than 4 m/km for new roads can be reached at 100 km/hour, and less than 6 m/km for old roads at around 80 km/hour. In other words, the values range from 1.75-3.5 m/km for new courses and 2.5-6.00 m/km for old ones (Sayers and Karamihas 1998), (Paterson 1986).

2.4. Pavement Condition Index

PCI data, taken through a field survey, results from a visual inspection of road conditions by identifying various types of road damage (Isradi et al. 2020). The research stages of determining the value: defining and measuring the quantity of the type of damage, level of damage, level of damage, deduction value, total deduct value, corrected deduct value, PCI value, and then the value of road conditions (Nur et al. 2019).

PCI values have a range of 0-100 can be seen in Figure 2 below. The criteria are good, satisfactory, fair, poor, very poor, severe, and failed. (Shahin 2005).

PCI	Rating	Colour
85-100	Excellent	Dark Green
70-85	Very Good	Light Green
55-70	Good	Yellow
40-55	Fair	Light Red
25-40	Poor	Medium Red
10-25	Very Poor	Dark Red
00-10	Failed	Dark Grey

Figure 2. Recommended PCI Value, Damage Scale, and Color

After the survey, the researchers calculate the area and percentage of damage according to the level and its type. The next step is estimating the PCI value for each sample unit of the road sections. The following show how to determine the value (Hasibuan and Surbakti 2019).

3. Result and Discussion

The researchers conducted a daily average traffic data survey for three days, as shown Table 2 below:

Table 2. Average Number of Vehicles per Hour

Time	Average Vehicle (PCU) per Hour			
	Heavy Vehicle (HV)	Light Vehicle (LV)	Motorcycle (MC)	Total Vehicle
Day-1	78	1,922	5,994	7,994
Day-2	81	1,872	5,706	7,659
Day-3	66	1,854	6,361	8,280

The following is a Figure of 3 graphs of the average daily traffic observed for three days:

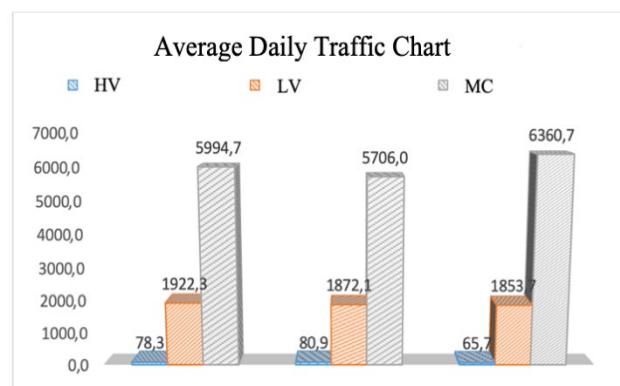


Figure 3. Average Daily Traffic Chart

3.1. Road Damage Identification

The survey and analysis results showed some damage in each segment, from minor damage to quite heavy damage. It can disrupt the smooth running and endanger the surrounding road users (Isradi et al. 2021). Figure 4 below exhibits several types of damage to both flexible and rigid pavements.



Figure 4. Identification of Road Damage on Flexible and Rigid Pavement

The survey and analysis results show several types of damage, as shown in Figure 5 below, to identify the amount of wear.

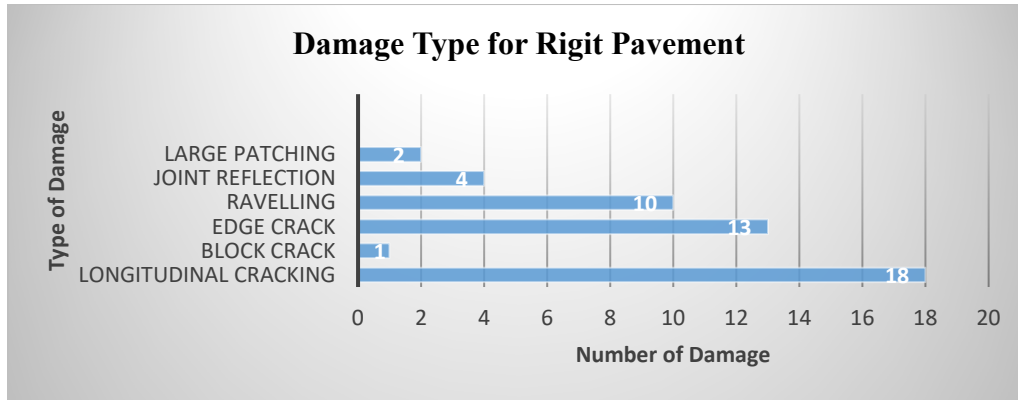


Figure 5. Chart of Damage Types in Rigid Pavement.

More types of damage occur on flexible pavements than those on rigid ones, as shown in Figure 6 below:

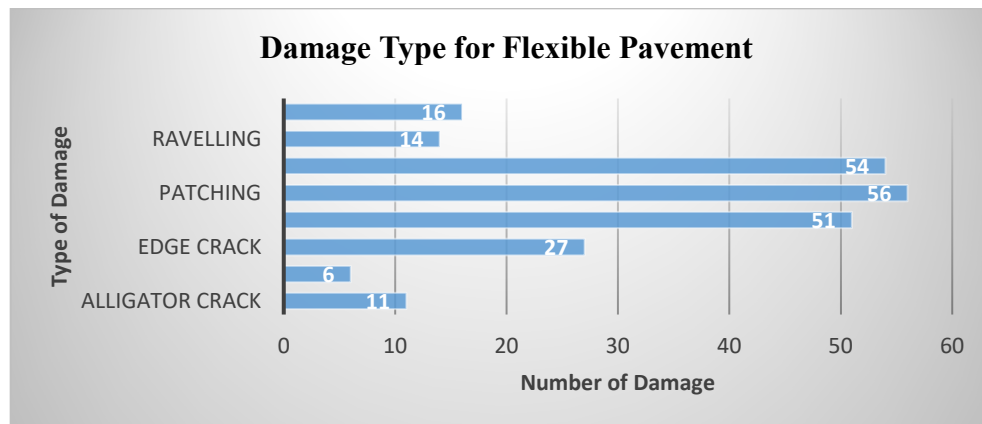


Figure 6. Chart of Damage Types in Flexible Pavement

For flexible pavements, the PCI average value is 87, which means that the average condition is excellent, with the lowest value of 50 and the highest value of 100 in segment 97. In rigid pavements, the average PCI value is 96, which means that road condition is Excellent. The Figure 7 below exhibits the PCI score.

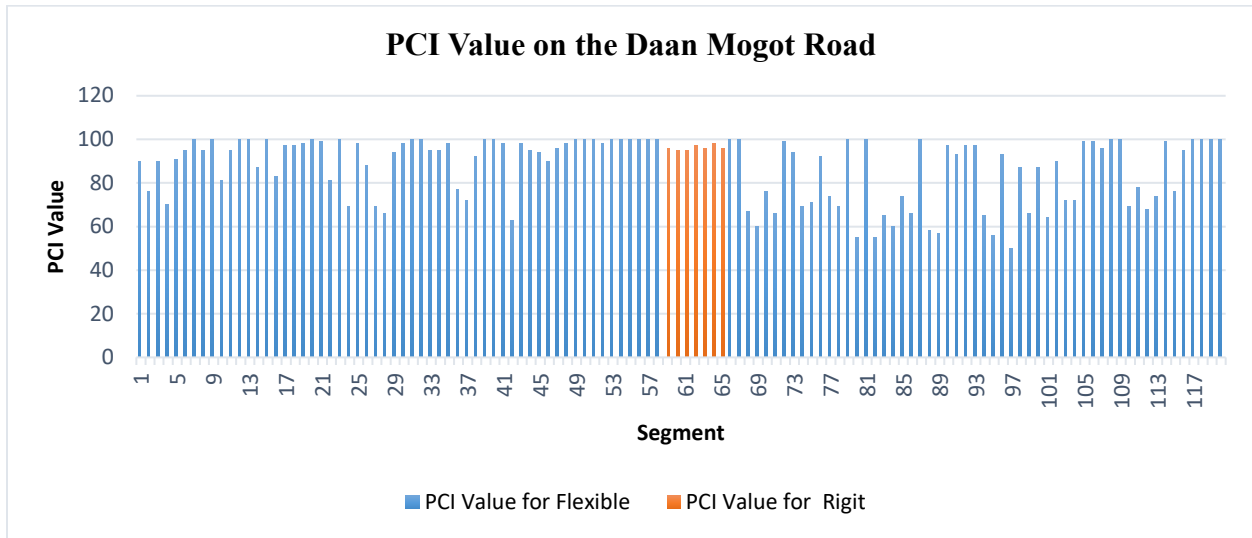


Figure 7. PCI values for sections of flexible and rigid pavement

The average value of IRI for flexible pavement is 4.47 mm/m, which means moderate condition. The average value of IRI on the rigid pavement is 4.25 with a fair condition. Each IRI value can be seen in Figure 8 below:

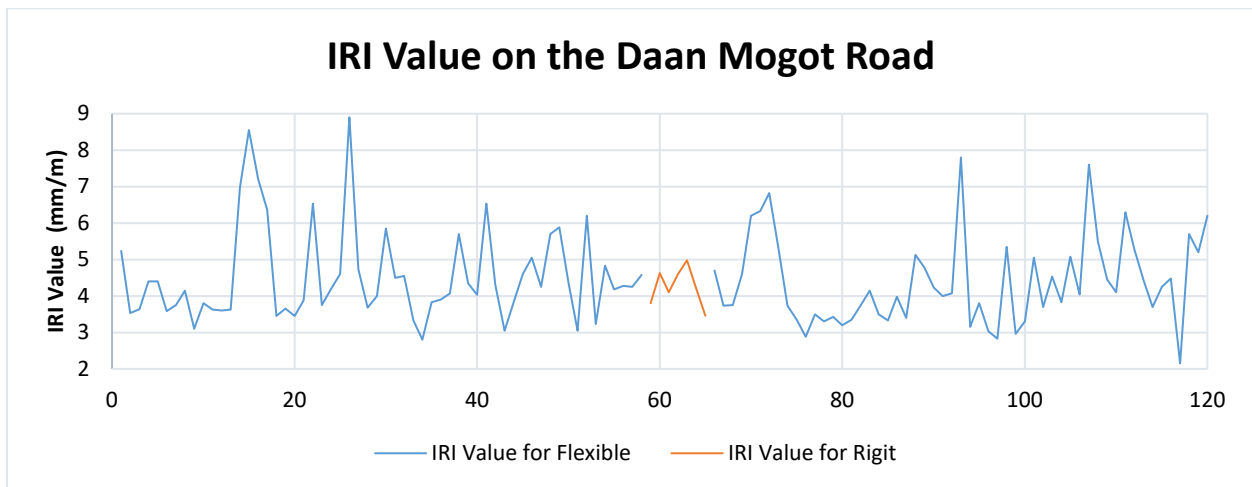


Figure 8. IRI value on the flexible and rigid pavement (mm/m)

3.2. Damage Model Development

IRI and PCI are two inversely related indices. As the structure worsens, PCI goes down, and IRI moves up. They are associated with pavement grades (Adeli et al. 2021). The difference in the level of variation between the IRI and PCI values requires an adjustment of the PCI to IRI values, which refer to the following Figure 9 (Shahin 2006), It is then interpolated to adjust the PCI to IRI values.

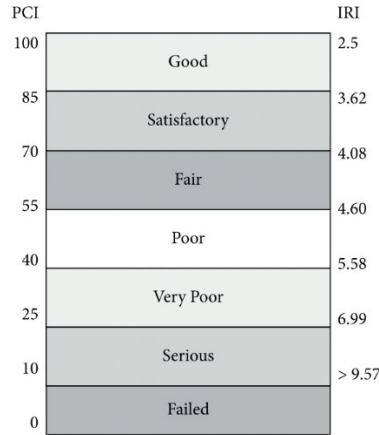


Figure 9. Pavement quality for a given IRI and PCI grade

As mentioned in the model development, the relationship between IRI and PCI can be seen in Figure 10 below:

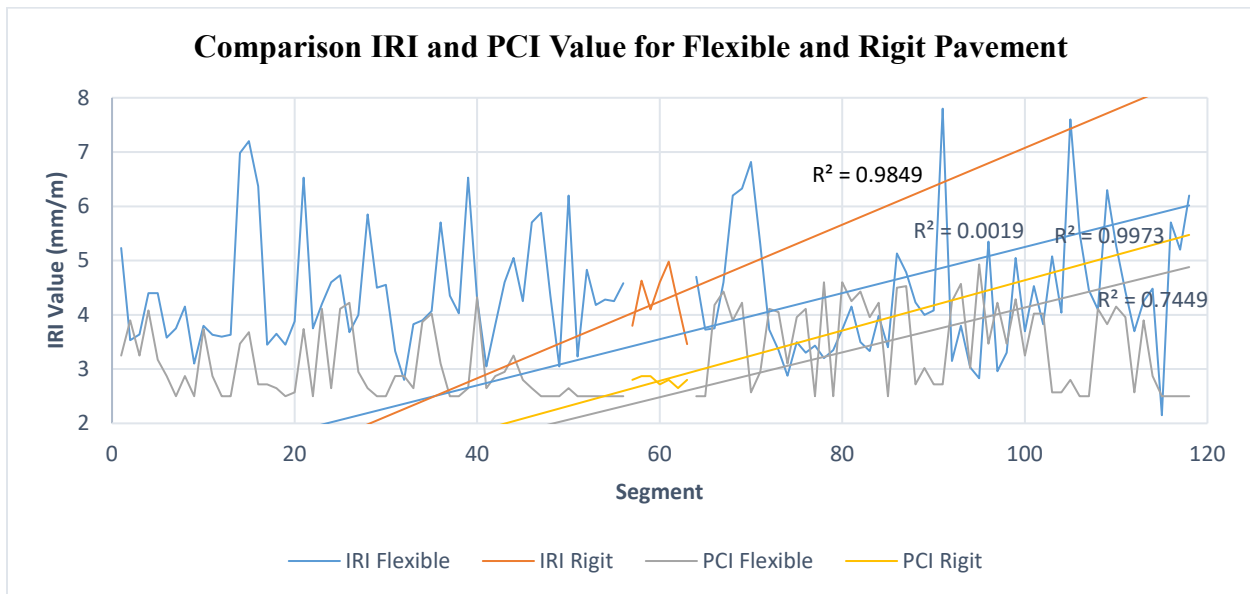


Figure 10. Relationship between IRI and PCI values for flexible and rigid pavement

The picture above proves that IRI and PCI for rigid pavements score better at the condition values adjacent to the R^2 value above 90%. Meanwhile, the flexible pavement has a less intense relationship with the lowest variation of R^2 value below 10%.

3.3. Comparison of Relationship Models between PSI, IRI, and PCI

The analysis results explain that PSI and IRI have a robust connection, defined by the resemblance of the average functional conditions as depicted below.

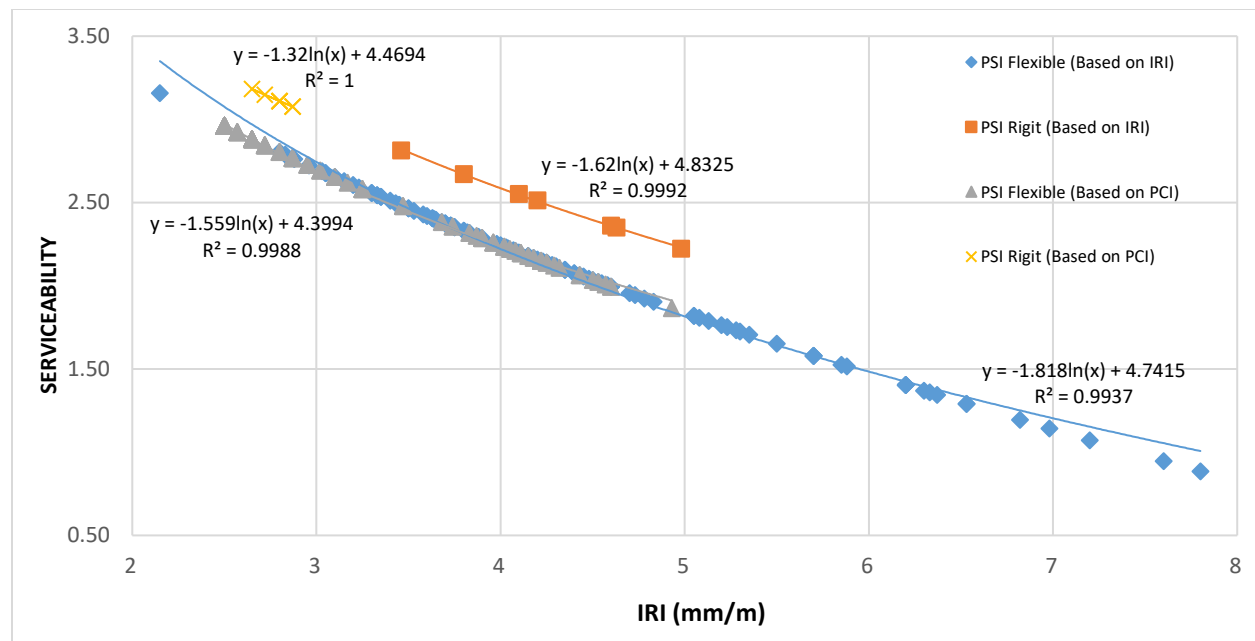


Figure 11. Comparison of the Relationship Model between PSI with IRI and PCI in Flexible and Rigid Pavement

The Figure 11 above proves the relationship between Rigid PSI and PCI modeling, which has the most substantial relationship with $R^2 = 1$. On the other hand, the relationship between Rigid PSI and IRI has an R^2 value of 0.99. For flexible pavement, PSI modeling with PCI has the most robust association with $R^2 = 0.9988$.

4. Conclusions

Results of the damage identification, the most types of damage for rigid pavements are longitudinal cracks (18) and fillings (56) for flexible pavements. The analysis shows that IRI and PCI have inverse results, so adjusting the pavement quality values from PCI to IRI is necessary. Road conditions for rigid pavements show almost the same values, meaning this modeling can be used with R^2 values above 90%.

The value of the relationship between PSI using IRI and PCI modeling has a strong relationship, especially for rigid pavements with a value of $R^2 = 1$ and 0.998 for flexible pavements.

Based on these results, the R^2 value obtained is acceptable because it has a strong relationship with values above 90% for roads with good, medium, and awful quality. The obtained equations develop a good relationship between IRI and PCI. Furthermore, the validation results show that the model has high accuracy.

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Biography

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