Relationship of present serviceability index for flexible and rigid pavement in urban road damage assessment using pavement condition index and international roughness index

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Abstract. Functional and structural failures in the pavement structure can be distinguished. The Road state Value measures the functional state of road pavements in managing flexible and stiff pavements for urban roadways in Indonesia. The pavement condition assessment is based on the unevenness of the pavement surface, rutting, and direct surface damage. This research aims to assess the worth of road damage on flexible and rigid pavements and establish a special relationship between Present Serviceability, International Roughness, and Pavement Condition Index. Direct observation in the field is utilized to obtain data on the different types of damage. According to the field survey data, the most common types of damage for flexible pavements were filled (56), followed by longitudinal cracks (18) for rigid pavements. PSI, IRI, and PCI models have a strong association, with the $R^2$ value found to be acceptable. It shows a high correlation with scores above 90% for good, medium, and inferior roads. The resulting equations establish a strong link between IRI and PCI. Furthermore, the validation findings demonstrate that the model is entirely accurate.

1 Introduction

The first roughness of newly laid pavement is good. However, the surface roughness of the pavement reduces over time due to traffic movements and environmental conditions [1-2]. The fluctuation in surface elevation that creates vibrations in crossing cars at a specific period is called pavement roughness [3]. Evaluating road infrastructure conditions’ functional performance until the service level is achieved up to the design life is a vital part of road design and maintenance [4]. One of the processes in determining the type of evaluation program that needs to be carried out is to assess the road surface conditions. Damage that occurs frequently would indeed impact the safety and comfort of road users, as well as cause congestion and accidents [5-6].

Because it cracks readily and fast, pavement is a consumable material that must be replenished. So, to take appropriate maintenance steps, it is vital to understand what causes the damage. Pavement conditions should be monitored and assessed annually to maintain their efficiency in the maintenance and management of the road network [7-8]. The road is a vital mode of transportation in everyday life. It improves the economy and people's living standards by facilitating the flow of commodities and services, connecting access between regions, and boosting the economy and people's living standards [9]. Road structural and non-structural functions necessitate regular road condition inspections. The road condition value will eventually be used as a reference to identify the type of evaluation program required [10], whether it is an improvement program, periodic maintenance, or routine maintenance [11-12].

Jalan Daan Mogot in West Jakarta is a major thoroughfare and one of the main highways in DKI Jakarta Province. It provides access to the following outside city: Banten Province. This road section's pavement construction comprises flexible, stiff pavement with relatively high vehicle loading. It harms the road's surface; hence knowing the sort of damage is required to calculate the road condition value. Road pavement conditions must be assessed to determine road maintenance and repair activities. There are numerous approaches to evaluate pavement conditions, including the Bina Marga, Asphalt Institute, and PCI methods [11, 13]. Direct visual observation in the field utilizing the Surface Distress Index (SDI), Pavement Condition Index (PCI), and International Roughness Index (IRI)
approaches [2, 14-15] is one of several road maintenance assessment procedures.

The road surface flatness score (IRI/International Roughness Index), performed every semester, is widely available at the Directorate General of Highways. As a result, decision-makers prefer to rely on data from metropolitan roads and freeways. This study aimed to investigate the link between PCI and IRI values on urban roadways and their correlation with PSI values on flexible and stiff pavements.

2 Method and data collection

The data was collected directly through direct observation by separating the roadways into observation segments. The segment length for flexible pavements is 100 meters, whereas it is 50 meters for rigid pavements. IRI values collected secondary data from the Bina Marga agency [16]. This study was conducted on Jalan Daan Mogot, a 10-kilometer-long national road stretch in the DKI Jakarta area that uses both flexible and rigid pavement (Fig. 1).

Fig. 1. Research location.

The research planning process necessitates proper and solid analysis, complete and correct data, and developed basic notions [17]. The research findings are given in tables and figures to finish. Field surveys were used to collect data on the types and dimensions of road damage and traffic, road damage, and road geometry data [18].

2.1 Present serviceability index

The Present Serviceability Index assesses road pavement performance and can be used to predict timing and maintenance requirements. Road functional performance is evaluated as a user-opinion-based ranking. The PSI rating ranges from 0 to 5, according to an AASHTO Road Test concept. It combines subjective and objective evaluations and measurements of roughness, crack damage, patches, and grooves into a single equation [4]. The initial PSI value of the pavement at the time of construction is also known as initial serviceability, and it is advised that it be 4.2 for flexible pavements, with a minimum allowed limit of 2.0 [19].

For flexible pavement, the PSI value can be calculated using the AASHTO Equation 1 [20]:

\[ PSI_{\text{Average}} = \frac{5,671 - 1,714 \sqrt{IRI_{\text{average}}}}{1} \]  

(1)

Meanwhile, for rigid pavement, the value uses the following Equation 2.

\[ PSI_{\text{Average}} = \frac{5,769 - 1,589 \sqrt{IRI_{\text{average}}}}{1} \]  

(2)

The magnitude of the PSI value is shown in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Value</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Very Poor</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Fair</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>Very Good</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

2.2 International roughness index

The International Roughness Index (IRI) is an unevenness metric computed by dividing the total number of surface ups and downs in the direction of the longitudinal profile by the distance or length of the surface being measured. This test aims to determine the homogeneity and flatness of the road surface. The World Bank created IRI theoretically in the 1980s to depict the reaction of a single tire on a vehicle's suspension in determining the flatness of the pavement surface [22]. IRI is a road surface unevenness standard that describes a longitudinal profile of a road. Meters per kilometer (m/km) or millimeters per meter (mm/m) are often used units [22].

IRI data was received from the DKI Jakarta National Road Implementation Center along the observed road sections. The average IRI value is then used for each segment with a distance of every 100 m and many observation segments of 100 pieces.

IRI values have been developed for various pavement ages and speeds. Vehicles can move at 100 km/h on new roads with uneven surfaces (an IRI of 4 m/km) and 80 km/h on old roads with uneven surfaces (an IRI of 6 m/km). In other words, the IRI value for new routes ranges from 1.75 to 3.5 m/km, whereas the IRI value for existing pavement ranges from 2.5 to 6.00 m/km [23-24].

2.3 Pavement condition index

A field survey was used to collect PCI data. The value is determined by visually assessing road conditions and detecting different forms of road damage [25]. In this study, the following steps were taken to determine the PCI (Pavement Condition Index) value: measurement of the quantity of the type of damage, the level of damage, the level of road damage, the deduction value, the total deduct value, the corrected subtract value, the PCI value, which is then used to calculate the value of road conditions [13].
As illustrated in Fig. 2, this PCI score ranges from 0 to 100, with the criteria of good, satisfactory, fair, poor, very poor, serious, and failed [26].

<table>
<thead>
<tr>
<th>PCI</th>
<th>Rating</th>
<th>Colour</th>
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<tbody>
<tr>
<td>85-100</td>
<td>Excellent</td>
<td>Dark Green</td>
</tr>
<tr>
<td>70-85</td>
<td>Very Good</td>
<td>Light Green</td>
</tr>
<tr>
<td>55-70</td>
<td>Good</td>
<td>Yellow</td>
</tr>
<tr>
<td>40-55</td>
<td>Fair</td>
<td>Light Red</td>
</tr>
<tr>
<td>25-40</td>
<td>Poor</td>
<td>Medium Red</td>
</tr>
<tr>
<td>10-25</td>
<td>Very Poor</td>
<td>Dark Red</td>
</tr>
<tr>
<td>00-10</td>
<td>Failed</td>
<td>Dark Grey</td>
</tr>
</tbody>
</table>

Fig. 2. Recommended PCI value, damage scale, and color.

After finishing the survey, the researchers computed the area and percentage of damage based on the level and type. The next stage is calculating the PCI value for each sample unit of road sections—the steps are outlined below [27].

3 Result and discussion

Survey data and damage identification along Jalan Daan Maogot have 100 observations. According to the Washington Department of Transportation, an IRI of 2.5 is high quality. Models were created for various ranges with good quality roads (2.5 < IRI < 3.5), medium quality roads (3.5 < IRI < 5), and lousy quality roads (5 < IRI < 8). IRI was the independent variable, while PCI was the dependent variable in an exponential regression analysis. According to the $R^2$ value, the link between PCI and IRI is excellent. However, PCI exceeds 100 in a small IRI range [28]. The association is as follows:

a. For $2.5 < IRI < 3.5$, $PCI = 4.915 - 0.1126 IRI$, $R^2 = 0.75$

b. For $3.5 < IRI < 5$, $R^2 = 0.76$

c. For $5 < IRI < 8$, $R^2 = 0.59$

3.1 Road damage identification

Several damages were discovered in each segment due to the survey and analysis. The wear ranged from mild to moderate. It can obstruct smooth driving and threaten other road users [29]. Fig. 3 depicts several types of damage to flexible and rigid pavements.

Jl. Daan Maogot has a 700-meter-long rigid impression structure, so the test is carried out by dividing seven segments on this pavement. Several types of damage can be found, as shown in Fig. 4, based on the survey results in the field directly and analysis.

Fig. 3. Identification of road damage on flexible and rigid pavement.

Fig. 4. Graph of damage types in rigid pavement.

Meanwhile, for 9.3 km long flexible pavement, the types of damage occurred more than those on the rigid pavement. It can be seen in Fig. 5.

Fig. 5. Graph of types of damage on flexible pavement.

PCI, IRI, and PSI are parameters that can assess a road's functional performance. Model development is carried out to determine the damaged relationship between PSI and IRI values for each road section.

The analysis of calculating the PCI value on Jalan Daan Mogot is shown in Fig. 6. The average PCI value for flexible pavements was 86.9. It signifies that the intermediate state of Jalan Daan Mogot is Excellent, with the lowest value of 50 found in segment 97 and the highest value of 100 found in segment 98. The average PCI value on rigid pavements is 96, indicating that the road conditions for rigid pavements are Excellent.

The average IRI value for flexible pavement is 4.47 mm/m, which means that the condition of Jalan Daan Mogot for flexible pavement is Fair. On the other hand, the IRI value on the rigid pavement is 4.25, with the road condition value being Fair. Each IRI value on this road section can be seen in Fig. 7.
3.2 Damage model development

IRI and PCI are two inversely proportional pavement quality measures. PCI falls, and IRI increases when the pavement deteriorates. At different pavement quality levels, the relationship between IRI and PCI values is variable [30]. The disparity in the magnitude of fluctuation between the IRI and PCI values necessitates a PCI to IRI value modification, as shown in Fig. 8 [26]. The corrected PCI values were then interpolated to the IRI by the researchers.

The relationship between IRI and PCI can be seen in Fig. 9.

3.3 Comparison of relationship models between PSI, IRI, and PCI

The investigation findings demonstrate that PSI and IRI have a strong link, which is explained by the similarity of their average functional conditions. Fig. 10 illustrates this link. The initial PSI value of the pavement at the time of construction, also known as initial serviceability, is advised to be 4.2 for flexible pavements and 2.0 for rigid pavements. The following relationship is derived from the results of the IRI-PCI relationship.

The graph above depicts a strong link between PSI levels and IRI. The association between Rigid PSI and PCI models has the most substantial relationship with $R^2$...
Meanwhile, the $R^2$ for the association between Rigid PSI and IRI values is 0.99. PSI and PCI modeling offers the most robust association for flexible pavement, with an $R^2$ of 0.998.

4 Conclusions

The results of road damage identification suggest that longitudinal fractures of 18 are the most damaging to firm pavements. Meanwhile, patches of 56 are the most typical sort of damage for flexible pavements. The research reveals that IRI and PCI values produce opposite consequences, necessitating modifications between PCI and IRI values. The results from road conditions obtained nearly the same condition values for stiff pavements. This modeling can be employed with an $R^2$ value of more than 90%.

The link between PSI and PCI modeling using IRI is substantial, especially for rigid pavements. PCI modeling yields $R^2 = 1$, whereas flexible pavement yields $R^2 = 0.998$.

Based on these findings, the $R^2$ value achieved is satisfactory. It shows a high correlation with scores above 90% for good, medium, and inferior roads. The resulting equation demonstrates a strong link between IRI and PCI. Furthermore, the validation findings indicate that the model is entirely accurate.

References


