Evaluation of functional and structural conditions on flexible pavements using pavement condition index (PCI) and international roughness index (IRI) methods

Muji Mujirifai, Ary Sri Handayani, Fajar Sri Setyawan, Antonius Dipta

Abstract. This study contains an evaluation of the conditional value of the national road pavement using the PCI and IRI methods on Kudus East Ring Road Section, Pati Ring Road Section, and Wangon-Menganti Road Section. This road pavement infrastructure that is burdened with relatively high and repeated traffic volumes will experience a decrease in quality. Indicators of road quality degradation can be identified from the condition of the road surface, both structural and functional conditions that are damaged. The condition of the road surface and other parts needs to be monitored to determine the condition of the damaged road surface [3].

Evaluation for the value of the condition of the highway pavement can be obtained by finding the Pavement Condition Index (PCI) value, namely by finding out the types of damage that occur according to the damage level index [3]. The PCI method is a method of assessing road pavement conditions based on the type, level, and extent of the damage [4]. The range of values used in the PCI method is 0 to 100, where a value of 0 indicates a very damaged pavement and a value of 100 indicates a very good pavement condition [6]. In addition, the value of the condition of the highway pavement can also be obtained using the International Roughness Index (IRI) method. The IRI method is a method used to measure the level of road surface roughness, the roughness measured at one location assumes the physical condition of the pavement at that location [6].

This study contains an evaluation of the conditional value of the national road pavement using the PCI and IRI methods on Kudus East Ring Road Section, Pati Ring Road Section, and Wangon-Menganti Road Section.

2 Research method

The purpose of this research is to evaluate the functional condition of the road pavement using the PCI method and the IRI method, as well as to correlate the results of the analysis of the two methods. This road pavement condition evaluation research uses an analytical descriptive method, which is a research method by describing a research object studied through samples that have been collected and draw conclusions that are generally accepted.
In this study there are 2 types of data, namely primary data and secondary data. Primary data was obtained through a field survey conducted to determine the physical condition of the road sections studied including documentation and observation of the functional condition of the pavement including the type of damage, size and level of damage [7]. Meanwhile, secondary data was obtained from the Highways Office of Central Java Province in the form of road maps. And from the VII National Road Implementation Center (Central Java and DIY) in the form of average daily traffic (LHR), IRI data and PCI for Kudus East Ring Road Section, the Pati Ring Road Section, and the Wangon-Menganti Road Section.

Analysis of road pavement surface conditions with the PCI method with the following steps:

1. Recapitulate the data obtained using the Hawkeye 2000 car.
2. Calculating the PCI value for each unit of the research object road section (Equation 1).
3. Calculating the average PCI value of all road units on a road under study to obtain the PCI value of that road segment (Equation 2).

\[
PCI_s = 100 - CDV \quad (1)
\]
\[
PCI_f = \frac{\sum PCI_s}{N} \quad (2)
\]

- \( PCI_s \): Pavement Condition Index for each unit.
- \( CDV \): Corrected Deduct Value for each unit.
- \( PCI_f \): Overall pavement PCI value.
- \( N \): Number of units.

Meanwhile, the IRI value was obtained from the secondary data above using Hawkeye 2000. Then after the PCI and IRI values are known, the correlation value of the two is sought using the following Equations 3-4.

\[
r^2 = \frac{\Sigma(Y_{est} - \bar{Y})^2}{\Sigma(Y - \bar{Y})^2} \quad (3)
\]
\[
r = \pm \sqrt{\frac{\Sigma(Y_{est} - \bar{Y})^2}{\Sigma(Y - \bar{Y})^2}} \quad (4)
\]

- \( r^2 \) = coefficient of determination
- \( r \) = correlation coefficient
- \( \Sigma(Y_{est} - \bar{Y})^2 \) = explained variation
- \( \Sigma(Y - \bar{Y})^2 \) = total variations

3 Result and discussion

Technical data:

- Kudus East Ring Road section is located in Pati Regency and Kudus Regency, is a primary arterial road with a length of 10,360 m and a road width of 7 m.
- Pati Ring Road section, located in Pati Regency, is a primary arterial road with a length of 12,270 m and a road width of 7 m.
- Wangon-Menganti Road section is located in Banyumas Regency, is a primary collector road with a length of 11,600 m and a road width of 7 m.

3.1 Average daily traffic conditions (LHR)

Fig. 1-2 show the condition of a road section can be determined by looking at the Average Daily Traffic (LHR).
Based on Fig. 1-2, it can be seen that the highest average daily traffic is on the Kudus East Ring Road Section with value of 25,051 vehicles (on the right lane) and 33,869 vehicles (on the left lane). While the smallest average daily traffic value is found on Wangon – Menganti road section with value of 12,142 vehicles (on the right lane) and 13,470 vehicles (on the left lane). It can also be seen that on the three segments the majority of vehicles passing through these roads are class 6b vehicles.

3.2 Pavement condition index (PCI)

The values used in this study were obtained from the VII National Road Implementation Center (Central Java and DIY) in 2020 using a Hawkeye 2000 car. Fig. 3 and Table 1 present the values and PCI recapitulation of Kudus East Ring Road Section.

Based on Fig. 3 and Table 1 it can be seen that the average Kudus East Ring Road Section is in the Poor category and it can be calculated the average PCI value on the roads with the following Equation 2.

\[ \text{PCI} = \frac{5876.17}{103} \]

\[ \text{PCI} = 57.05 \]

The results of the evaluation of functional conditions using the PCI method on Kudus East Ring Road Section found that the dominant condition was in the "Poor" category with a percentage of 34% of all segments. Meanwhile, the average PCI value was 57.05 which was
included in the "Fair" category. The results of the PCI value were due to the various damages that occurred on Kudus East Ring Road Section with the types of damage in the form of potholes, patching, polished aggregate, rutting, and bleeding. These damages are caused by several reasons, one of which is because the passing vehicles are heavy vehicles and many heavy vehicles stop on the shoulder of the road.

Fig. 4 and Table 2 present the value and PCI recapitulation of Pati Ring Road Section.

![Fig. 4. PCI value of the Pati Ring Road Section.](image)

<table>
<thead>
<tr>
<th>PCI conditions</th>
<th>Number of Segments</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>51</td>
<td>40%</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>5</td>
<td>4%</td>
</tr>
<tr>
<td>Fair</td>
<td>5</td>
<td>4%</td>
</tr>
<tr>
<td>Poor</td>
<td>14</td>
<td>11%</td>
</tr>
<tr>
<td>Very Poor</td>
<td>41</td>
<td>33%</td>
</tr>
<tr>
<td>Seriously</td>
<td>10</td>
<td>8%</td>
</tr>
<tr>
<td>Failed</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Amount</td>
<td>126</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2. PCI value summary for the Pati Ring Road section.

PCI = 7631.83/126
PCI = 60.57

The results of the evaluation of functional conditions using the PCI method on the Pati Ring Road Section found that the dominant condition was in the "Good" category with a percentage of 40% of all segments. While the average PCI value was 60.57 which was included in the "Fair" category. The results of the PCI value were due to the various damages that occurred on the Pati Ring Road section with several types of damage in the form of bleeding, alligator crack, shoving.

Fig. 5 and Table 3 present the value and PCI recapitulation of Wangon – Menganti Road Section.

![Fig. 5. PCI value of Wangon – Menganti Road Section.](image)
Table 3. PCI value summary for Wangon – Menganti Road Section.

<table>
<thead>
<tr>
<th>PCI conditions</th>
<th>Number of Segments</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>46</td>
<td>40%</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>46</td>
<td>40%</td>
</tr>
<tr>
<td>Fair</td>
<td>12</td>
<td>10%</td>
</tr>
<tr>
<td>Poor</td>
<td>8</td>
<td>7%</td>
</tr>
<tr>
<td>Very Poor</td>
<td>4</td>
<td>3%</td>
</tr>
<tr>
<td>Seriously</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Failed</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Amount</td>
<td>116</td>
<td>100%</td>
</tr>
</tbody>
</table>

Based on Fig. 5 and Table 3 it can be seen that the average Wangon Menganti Road Section is in the "Good" category and it can be calculated the average PCI value on the road using the following Equation 2.

\[ PCI = \frac{9088.24}{116} \]
\[ PCI = 78.35 \]

The results of the evaluation of functional conditions using the PCI method on Wangon - Menganti Road Section found that the dominant condition was in the "Good" category with a percentage of 46% of all segments. While the average PCI value was 78.35 which was included in the "Satisfactory" category. The results of the PCI value were due to the various damages that occurred on Wangon-Menganti Road Section with several types of damage in the form of potholes, patching, shoving, swell, bumps and sags, polished aggregate, and bleeding.

3.3 International roughness index (IRI)

The IRI values used in this study were obtained from the 2020 VII National Road Implementation Center (Central Java and DIY) using a Hawkeye 2000 car. Fig. 6 and Table 4 present the IRI values and recapitulation of Kudus East Ring Road Section.

![Fig. 6. IRI value of Kudus East Ring Road Section.](image)

Table 4. Summary of IRI values for Kudus East Ring Road section.

<table>
<thead>
<tr>
<th>IRI condition</th>
<th>Number of Segments</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>19</td>
<td>18%</td>
</tr>
<tr>
<td>Currently/Moderate</td>
<td>79</td>
<td>77%</td>
</tr>
<tr>
<td>Light Damage</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Heavily Damaged</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Amount</td>
<td>1.03</td>
<td>100%</td>
</tr>
</tbody>
</table>

Based on Fig. 6 and Table 4 it can be seen that the average Kudus East Ring Road Section is in the "Moderate" category and the IRI average value can be calculated using the following Equation 5.

\[ IRI = \frac{531.19}{103} \]
\[ IRI = 5.16 \]

The results of the evaluation of functional conditions using the IRI method on Kudus East Ring Road Section found that the dominant condition was in the "Medium" category with a percentage of 77% of all segments. Meanwhile, the average IRI value was 5.16 which was included in the "Moderate" category. The results of the IRI value were due to the various damages that occurred on Kudus East Ring Road Section which caused the condition of the road surface to become uneven.

Fig. 7 and Table 5 present the IRI value and recapitulation of Pati Ring Road Section.

Based on Fig. 7 and Table 5 it can be seen that the average Pati Ring Road is in the good category and the IRI average value can be calculated using the following Equation 5.

\[ IRI = \frac{621.85}{126} \]
\[ IRI = 4.94 \]

The results of the functional condition evaluation using the IRI method on the Jalan Likat Pati section found that the dominant condition was in the "Good" category with a percentage of 52% of all segments. Meanwhile, the average IRI value was 4.93 which was included in the "Moderate" damage category. The results of the IRI value were due to the various damages that occurred on the Pati Ring Road section with several types of damage in the form of bleeding, alligator crack,
shoving which caused the pavement surface to become uneven.

Table 5. Summary of IRI values for the Pati Ring Road section.

<table>
<thead>
<tr>
<th>IRI condition</th>
<th>Number of Segments</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>65</td>
<td>52%</td>
</tr>
<tr>
<td>Currently/Moderate</td>
<td>48</td>
<td>38%</td>
</tr>
<tr>
<td>Light Damage</td>
<td>13</td>
<td>10%</td>
</tr>
<tr>
<td>Heavily Damaged</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Amount</td>
<td>126</td>
<td>100%</td>
</tr>
</tbody>
</table>

The results of the evaluation of functional conditions using the IRI method on Wangon - Menganti Road Section found that the dominant condition was in the "Moderate" category with a percentage of 72% of all segments. Meanwhile, the average IRI value was 4.64 which was included in the "Moderate" category. The results of the IRI value are due to the various damages that occur on the Wangon -Menganti Road Section with several types of damage in the form of potholes, patching, shoving, swells, bumps and sags, polished aggregate, and bleeding which causes the pavement surface to become uneven.
Table 6. Summary of IRI values for Wangon – Menganti Road section.

<table>
<thead>
<tr>
<th>IRI condition</th>
<th>Number of Segments</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>31</td>
<td>27%</td>
</tr>
<tr>
<td>Currently/Moderate</td>
<td>84</td>
<td>72%</td>
</tr>
<tr>
<td>Light Damage</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Heavily Damaged</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Amount</td>
<td>116</td>
<td>100%</td>
</tr>
</tbody>
</table>

3.4 Correlation of road conditions based on IRI and PCI methods

The level of closeness of the variable is determined based on the value of r using the Pearson method [8].

Based on Fig. 9 it is known that the linear regression equation on Kudus East Ring Road Section is $y = -3.098x + 73.027$. The R value for Kudus East Ring Road Section can be calculated by Equations 3-4.

$$ r = \pm \sqrt{\frac{1638.56}{21600.41}} $$

$$ r = 0.2754 $$

$$ r^2 = 0.0758 $$

From the results of these calculations, the value of r for Kudus East Ring Road Section is 0.2754 in the "Weak" category and $r^2$ is 0.0758.

Based on Fig. 10 it is known that the linear regression equation on Wangon – Menganti Road section is $y = -8.7014x + 103.51$. The r value for the Pati Ring Road section can be calculated by Equation 3-4.

$$ r = \pm \sqrt{\frac{33162.56}{108282.64}} $$

$$ r = 0.5534 $$

$$ r^2 = 0.3063 $$

From the results of these calculations, the r value for the Pati Ring Road section is 0.5534 in the "Medium" category and $r^2$ is 0.3063.

Based on Fig. 11 it is known that the linear regression equation on Wangon – Menganti Road Section is $y = 0.6926x + 75.134$. The r value for Wangon-Menganti Road Section can be calculated by Equation 3-4.

$$ r = \pm \sqrt{\frac{48.69}{25687.95}} $$

$$ r = 0.0435 $$

$$ r^2 = 0.0019 $$

From the results of these calculations, the r value for Wangon – Menganti Road Section is 0.0435 in the "No Correlation" category and $r^2$ is 0.0019.

4 Conclusion

The conclusions of this study are:

- The functional condition of the road pavement with the PCI method on Kudus East Ring Road Section is 57.05 “Fair”, the Pati Ring Road section is 60.57 “Fair”, and the Wangon – Menganti Road section is 78.35 “Satisfactory”.

- The functional condition of the road pavement using the IRI method on the Kudus East Ring Road Section is 5.16 “Medium”, the Pati Ring Road section is 4.94 “Moderate”, and the Wangon – Menganti Road section is 4.64 “Medium”.


![Fig. 9](image_url)

![Fig. 10](image_url)

![Fig. 11](image_url)
Correlation of the functional condition of the road pavement with the PCI method and the IRI method on the Kudus East Ring Road Section has a “weak” correlation with a value of 0.2754 and an $r^2$ value = 0.0758, then for the Pati Ring Road section it has a “moderate” correlation with a value of 0.5534 and $r^2 = 0.3063$, and the Wangon–Menganti Road section “no correlation” with a value of 0.0435 and $r^2 = 0.0019$.

References

1. Indonesian Central Government, Law (UU) number 38 of 2004 concerning roads (UU No. 38, 2004)

2. Indonesian Central Government, Government regulation (PP) number 34 of 2006 concerning roads (PP No. 34 of 2006)


7. Director General of Highways, Road pavement manual, revision June 2017 (No. 04/SE/Db/2017)