Volume 4, No. 4 April 2025 (790-801)
p-ISSN 2980-4868 | e-ISSN 2980-4841
https://ajesh.ph/index.php/gp

Evaluation of Road Conditions and Maintenance Cost Estimation for the Durenan-Prigi Section (Link 006) Using the Pavement Condition Index (PCI) Method

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ABSTRACT:
The 30.4 km Durenan-Prigi road, managed by the East Java Provincial Government, serves as the primary route to key tourist attractions in Trenggalek Regency, including Prigi Beach and Mutiara Beach. To ensure user comfort and safety, maintaining the road's condition is essential. However, the road is prone to damage caused by factors such as heavy traffic loads, unstable soil conditions, extreme weather, and inadequate drainage systems. To comprehensively assess the road's condition, this study employs the Pavement Condition Index (PCI) method. The PCI method visually evaluates road damage by categorizing 20 types of damage into seven distinct categories based on severity and extent. The analysis revealed an average PCI value of 88.05 for the Durenan-Prigi road section, classifying it as "Perfect." Despite this classification, some sections require preventive maintenance to sustain optimal conditions. A detailed damage management plan has been developed, including patching, sealing cracks, and applying slurry seals. Patching is recommended for crocodile skin cracks, curling, vertical roadside cracks, longitudinal and transverse cracks, and localized depressions. Sealing is proposed for checkered cracks, while slurry seals are intended for addressing aggregate wear and granular disintegration. This study underscores the importance of routine maintenance to prolong the road's lifespan and enhance its serviceability. By employing the PCI method, road condition assessments are made more accurate and systematic, enabling efficient allocation of maintenance resources. The findings highlight the significance of integrating drainage system improvements alongside regular inspections to prevent further deterioration, particularly during the rainy season.

Keywords: Durenan-Prigi, PCI, Road Condition, Cost Estimation

INTRODUCTION

The road network is one of the important elements in the land transportation system that has a strategic role in the transportation sector, especially in terms of distribution of goods and services. The development of road infrastructure is closely related to the progress of human civilization, as roads are the main means of supporting various economic and social activities. The role of roads is not only limited to its function as a connector, but also as the main facilitator for the movement of goods and people, which is a basic need in daily life. Therefore, to ensure that roads remain capable of accommodating the increasing volume of movement with optimal service quality, there is a need for continuous efforts in road maintenance. Road maintenance is one of the important steps to keep the road in good and safe condition, and meet the service standards required by road users (Saputro, 2014).

For comfort and safety for drivers, roads must be supported by good pavement. Pavement is a mixture of aggregates and binding materials used to serve traffic loads. Road pavement is divided into two categories: flexible pavement and rigid pavement. Flexible pavement is a pavement that uses asphalt as a binder while rigid pavement is a type of pavement that uses concrete as the main material for the pavement (Rachman & Sari, 2020).

Road maintenance is important because every road has a certain service life that requires regular maintenance measures. Various factors, such as weather conditions, temperature changes, the presence of water, the quality of construction materials, increased vehicle volumes that exceed planning capacity, suboptimal compaction, and subgrade instability, can cause road damage. These conditions can hamper inter-regional mobility and social activities that support the country's economic development. Therefore, a thorough evaluation is needed to address these issues to ensure roads remain in good condition. The management and repair of road infrastructure is a strategic step to maintain road functionality, which must be done efficiently and effectively so that it can be used within its service life (Sandyna et al., 2022).

Road damage that occurs before reaching the planned life or what is often referred to as premature damage, is usually caused by various factors. Some of the main factors that play a role in the occurrence of this damage include improper treatment of subgrade soils that have weak bearing capacity, the presence of standing water on the road surface that cannot drain properly due to inadequate drainage systems, and vehicle tonnage loads that exceed the specified capacity. In addition, damage can also be triggered by inaccurate road planning, inadequate supervision during the construction process, and implementation that does not comply with established technical standards or specifications. All of these factors contribute to accelerating road deterioration prematurely. (Sutarno et al., 2015.)

Pavement maintenance management is an effort to maintain the condition of the road in accordance with the level of service and its ability when the road is completed and operated until the achievement of a predetermined plan life. Pavement maintenance management is seen from the type of damage that occurs on a road section (Ing & Riana, 2019). Road maintenance is important because it serves to ensure the safety, comfort, and reliability of infrastructure for users. A well-maintained road not only extends the life of the road itself but also prevents more severe damage that can increase repair costs in the future. Maintenance also facilitates traffic flow, reduces travel time, and supports the smooth distribution of goods and population mobility. As such, road maintenance directly contributes to economic growth and people's quality of life.

Roads can deteriorate due to a number of natural and man-made factors. One of the main causes is traffic loads, especially from heavy vehicles, which put pressure on the road surface resulting in cracks or deformations, extreme weather, such as heavy rainfall, also accelerates damage by causing material erosion and resulting in potholes (Nugroho & Marleno, 2020). In addition, inadequate drainage systems exacerbate waterlogging damage, while low-quality materials and construction make roads deteriorate faster (Sandyna et al., 2022). Lack of regular maintenance also shortens the technical life of roads.

Road surface condition assessment is one of the stages to determine the type of revaluation program that needs to be carried out. One of the stages in evaluating the condition of the road surface is to assess the condition of the road surface layer (Gusnilawati et al., 2021). The development of the road system is in line with the evolution of human history, requiring optimal pavement design to meet transportation needs. Road damage, especially to flexible pavements, can significantly affect traffic flow and requires condition evaluation using methods such as the Pavement Condition Index (PCI) (Wibowo et al., 2023).

Pavement Condition Index (PCI) is a road condition survey method by assessing the condition of road pavement with visual data based on the level of damage, type of damage and extent of damage so that it can be used as reference data for road preservation (Sandyna et al., 2022).

Based on the data, the topic of Road Condition Evaluation and Road Damage Handling Plan on Durenan-Prigi Section (Link 006) Using Pavement Condition Index (PCI) Method. very worthy of research. This road section is the main access to the Prigi Beach tourist area, so its maintenance is important for the mobility of the community and tourists. Several points of damage found on this road section, such as potholes and cracks, indicate the need for a thorough evaluation using the SDI and PCI methods. Both methods are efficient and economical methods to visually and systematically identify the type of damage, which allows for proper cost and maintenance planning. By knowing the detailed condition of the road, the government can determine the optimal treatment plan and extend the technical life of the road

The Pavement Condition Index (PCI) method offers a more complex approach to road condition assessment as it uses various evaluation criteria to identify different types of defects. As such, the PCI method can provide a more detailed and varied picture of road condition. PCI not only identifies more types of defects, but also provides a more comprehensive assessment of the overall quality of the road structure. This can provide more complete information for policy makers in planning road repairs or maintenance, so that budget allocations can be made more precisely and efficiently. The research focus on the Durenan-Prigi road section (Link 006) is particularly relevant, given that this road is an important route that connects various regions, including tourist destinations. By ensuring the road is in good condition, the quality of road services can be maintained, which will certainly increase comfort and safety for both local communities and tourists. Thus, the objectives of this research are divided into two types including the following.

1. Determine the type of road damage and road condition assessment using the PCI method on the Durenan - Prigi Road Section (Link 006)
2. Determine the road damage handling plan on the Durenan - Prigi Road Section

METHODS

Research Location

The location of this research takes place in the Durenan - Prigi road section which passes through 2 (two) districts, namely Trenggalek Regency and Tulungagung Regency and passes through 3 sub-districts, namely Durenan District (Trennggalek Regency), Bandung District

(Tulungagung Regency) and Watulimo District (Trenggalek Regency). The picture of this research location is specifically shown in Figure 2.

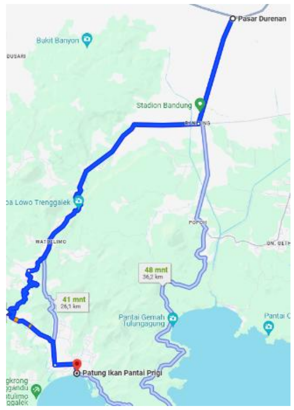

Figure 1. Road Section Durenan - Prigi (Link 006)

Data

This research utilizes primary and secondary data as sources of information. Primary data in this study took data in the form of direct collection to the field. Meanwhile, secondary data is taken from related agencies, journals, books, and other scientific works.

Survey Method

This study used several pieces of equipment to support the survey activities. The equipment includes 4-wheeled vehicles, cameras to record road conditions with good resolution, road damage record forms, pull meters, GPS, Smartphones. Then, the survey was carried out by observing from a 4-wheeled vehicle slowly while filling out the prepared form. Observations were made from the beginning of the section to the end of the section. Then, direct measurement is also carried out on the road section if necessary by also taking documentation of the survey implementation.

Cost Budget Plan

The cost budget plan is calculated based on the handling plan that has been prepared. The cost budget plan is calculated using unit price analysis from the PUPR ministry with the price of wages, materials, tools following the Basic Unit Price of the Trenggalek Regency Government. The RAB calculation is calculated using the formula:

$$Volume\ x\ Harga\ Satuan\ =\ Jumlah\ Harga$$

RESULTS AND DISCUSSION

Road Condition Analysis Using the Pavement Condition Index (PCI) Method

Based on visual observations in the field, the survey data is used to assess road conditions using PCI.

Table 1. Damage in Pavement Condition Index (PCI) Method

Damage Type		
1. Crocodile Skin Crack	8. Splice Crack (m)	15. Groove (m2)
2. Overweight (m2)	9. Roadside Crack Vertical Drop (m)	16. Sungkur (m2)

Damage Type		
3. Checkered Crack)	10. Longitudinal or Transverse Cracks	17. Broken Slip (m2)
4. Basin	11. Patches	18. Floating Seam (m2)
5. Curly (m2)	12. Aggregate Wear (m)	19. Grain Release (m2)
6. Demolition (m2)	13. Holes (Counts)	20. Hairline Cracks (m2)
7. Edge Crack (m)	14. Rail Intersection (m2)	

The assessment was carried out on road sections every 100 m on each segment on the Durenan - Prigi Road Section (Link 006).

Pavement Condition Assessment

Road condition assessment is carried out by considering the type of damage according to the type of damage in the PCI method. The area of each damage encountered is calculated to determine the *Densisty* value of the damage to the area of the road segment. The *Densisty* calculation is as follows:

1. ***Densisty* calculation at STA 001+000 sd 001+100**

   a. *Alligator Crack*
   Length : 30 Meters
   Width : 2 Meters
   Extensive : 60 m^2
   Density : $\frac{AD}{AS}\ x\ 100\%$
   Density : $\frac{60}{500}\ x\ 100\%$
   Density : 12%

   b. Aggregate Wear (Polished Aggregate)
   Length : 21 Meters
   Width : 2 Meters
   Extensive : 42 m^2
   Density : $\frac{AD}{AS}\ x\ 100\%$
   Density : $\frac{42}{500}\ x\ 100\%$
   Density : 8.4%

   c. *Potholes*
   Length : 0.3
   Width : 0.4

Extensive : 0.12 m^2

Length : 0.3
Width : 0.3
Extensive : 0.09 m^2
Total Area : 0.21 m^2
Density : $\frac{AD}{AS}\ x\ 100\%$
Density : $\frac{(0.09+0.21)}{500}\ x\ 100\%$
Density : 0.042%

2. Calculation of Deduct Value (DV) at STA 001+000 sd 001+100

The Deduct Value (DV) value is obtained using a graph according to the damage encountered, the determination of the *deduct value* is as follows:

a. *Alligator Crack*

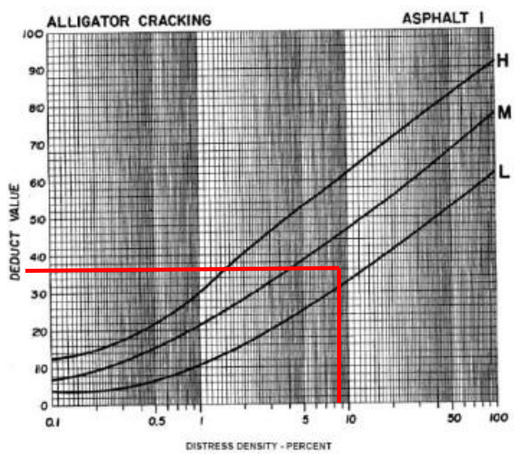

Figure 1 . Deduct Value Graph of *Alligator Cracking* Damage

Damage to crocodile skin cracks at STA 001+000 to 001+100 has a *Density* value of 12% with a damage level of *Low (*L), so that based on the results of the graph it is found that with a density value of 12% with a Low damage level, the *Deduct Value value* is 34.

b. *Polished* Aggregate Wear

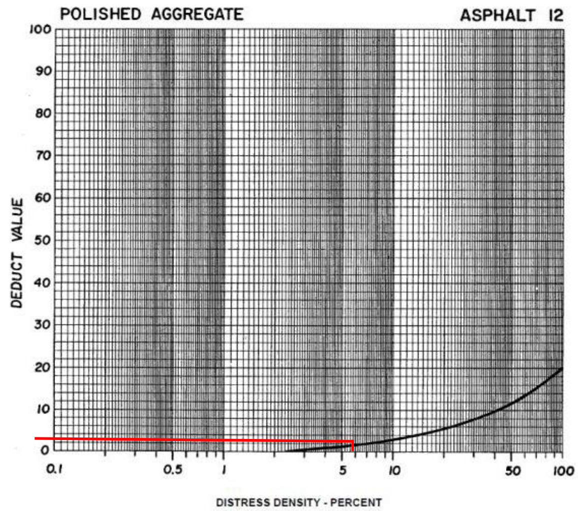

Figure 2. *Polished Aggregate* Damage Deduct Value Chart

Damage to *Polished* Aggregate at STA 001+000 sd 001+100 has a *Density* value of 8% where for damage in the form of aggregate wear does not have a level of damage, so based on the results of the graph it is found that with a density value of 8%, the *Deduct Value value* is 2.2.

c. *Potholes*

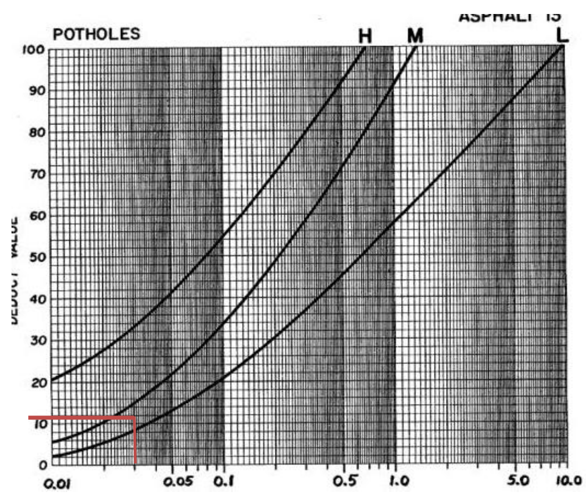

Figure 4. *Potholes* Damage Deduct Value Graph

Damage *Potholes* at STA 001+000 sd 001+100 has a *Density* value of 0.042% with a damage level of *Low* (L), so based on the results of the graph it is found that with a density value of 0.042%, the *Deduct Value value* is 11.

3. Calculating the Maximum Permitted Value

The calculation of the maximum allowable value is used deduct value data with the highest value, while the calculation of the maximum allowable value is as follows:

M = 1 + (9/98)(100-HDV)
M = 1 + (9/98) (100-34)
M = 7.06 > 3 (Sum of Deduct values)

4. Determining the *Corected Deduct Value* CDV)

The Corrected Deduct Value (CDV) value is calculated based on the *Total Deduct Value* (TDV) value according to the CDV graph.

1. Total Deduct Value = 34 + 11 + 2.2
   Total Deduct Value = 47.2
   Total Q = 3
   CDV value = 31
2. Total Deduct Value = 34 + 11 + 2
   Total Deduct Value = 47
   Total Q = 2
   CDV value = 32
3. Total Deduct Value = 34 + 2 + 2
   Total Deduct Value = 38
   Quantity Q = 1
   CDV value = 38

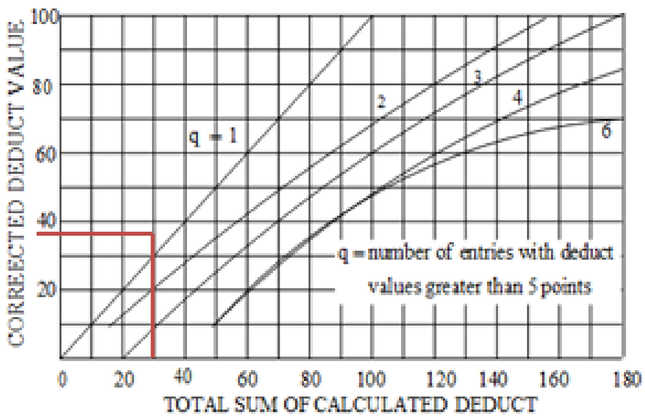

Image 3. Corrected Deduct Value (CDV) Chart

Based on this graph, the *Corrected Deduct Value* (CDV) is 31, 32 and 38 so that the maximum CDV of 38 is used.

Determining the Pavement Condition Index Value

After getting the Corrected Deduct Value (CDV) value, the next step is to calculate the PCI value, while the PCI value is obtained by the following formula:

PCI = 100 - CDV max

PCI = 100 - 38

PCI = 62

Based on the PCI value, the STA 001+000 to 001+100 road segment has an assessment in the "GOOD" category. Furthermore, it is found that the lowest condition assessment is Poor and the best is Execelent.

Damage Management Plan

Based on the damage encountered, it will be planned to handle the damage encountered, as for the recapitulation of damage is as follows:

Table 2. Volume of Damage

No.	Type of Damage	Volume		Unit
		Extensive	Volume	
1	Crocodile Skin Crack	475	475	m2
2	Overweight	6	6	m2
3	Plaid Crack	1730	1730	m2
4	Curly	85.5	85.5	m2
5	Vertical Descending Curb Crack	35	35	m2
6	Longitudinal or Transverse Cracks	290	290	m2
7	Patches	3057	3057	m2
8	Aggregate Wear	33659	33659	m2
9	Hole	28.08	1.1232	m3
10	Granule Release	60	60	m2

Based on the data recapitulation, the volume of each damage can be known so that the handling plan for each damage is known. In accordance with the damage that arises, it can still be handled with Routine Road Maintenance.

Discussion

The findings of this study indicate that the Durenan-Prigi road section has an average Pavement Condition Index (PCI) value of 88.05, which classifies it as "Perfect." While the overall road condition is commendable, localized damages, including crocodile skin cracks, potholes, aggregate wear, and longitudinal or transverse cracks, highlight the need for targeted maintenance interventions. These results align with previous studies by Sandyna et al. (2022), which emphasized the PCI method's capacity to provide detailed evaluations of road conditions through visual assessment of various damage types.

Relevance of the PCI Method in Road Maintenance

The PCI method has proven to be a reliable tool for assessing road surface conditions, offering a systematic approach to evaluating damage types and severity. Compared to traditional methods, PCI allows for a more comprehensive categorization of defects, which facilitates precise planning and budgeting for maintenance. By identifying damage-specific solutions, such as patching, sealing, and slurry sealing, this study demonstrates the practicality of PCI in formulating cost-effective maintenance strategies. The integration of these solutions can help maintain the road's structural integrity and extend its service life, consistent with the findings of Gusnilawati et al. (2021).

Challenges in Maintaining Optimal Road Conditions

Despite its high PCI score, the Durenan-Prigi road faces challenges related to drainage infrastructure. Inadequate drainage exacerbates water retention during heavy rains, accelerating damage to the road surface. This is consistent with observations by Nugroho and Marleno (2020), who noted that poor drainage is a primary contributor to premature road deterioration. Addressing drainage issues is therefore critical to sustaining the road's current condition and preventing future damage.

Implications for Cost-Effective Maintenance

The damage management plan developed in this study prioritizes routine maintenance activities tailored to the observed defects. Slurry sealing for aggregate wear, crack sealing for checkered cracks, and patching for crocodile skin cracks and potholes are cost-efficient measures that address the specific needs of the road. This targeted approach minimizes the likelihood of extensive repairs, reducing long-term maintenance costs and ensuring uninterrupted access to tourist destinations in Trenggalek Regency.

Recommendations for Future Research

While the PCI method provides valuable insights, further studies could compare its effectiveness with alternative assessment methods, such as the International Roughness Index (IRI) or Surface Distress Index (SDI), to validate its robustness across different road conditions. Additionally, incorporating environmental factors, such as rainfall intensity and vehicle load patterns, into maintenance planning models could enhance the predictive accuracy of road deterioration trends.

CONCLUSIONS

Based on the analysis that has been calculated, the conclusions that can be drawn are, The types of damage that occur on the Durenan - Prigi Road Section are Crocodile Skin Cracks (alligator cracks), Overweight, Block Cracks, Curling, Curb Cracks, Longitudinal or vertical cracks, Patches, Aggregate Scouring, and Potholes, based on the calculation of the road condition value using the method using the PCI method has an average PCI value of 88.05 so that it has a "Perfect" category. The handling plan is in accordance with the damage that appears, the handling plan is Patching and patching holes (Repair of Hot Mix Cold Hampar Asbuton) with a volume of 36.54 m3, Slurry Seal Type 3 with a thickness of 6-9 mm with a volume of 32,719 m2 and Sealing Type 1 work (Cracks 0.20 - 0.50 cm) with a volume of 1730 m2.

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