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Analysis of Road Conditions In The Kaligunting-Bajulan Section Using The Pavement Condition Index (PCI) Method

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Pavement Condition Index (PCI), road damage, road maintenance, kaligunting-bajulan, road repair

ABSTRACT
This study evaluates the road condition of the Kaligunting-Bajulan section in Madiun Regency using the Pavement Condition Index (PCI) method. The goal is to assess the level of deterioration, identify repair needs, and estimate costs. The findings reveal that the road is in moderate to poor condition, with the average PCI score of 58.08, highlighting the need for immediate intervention, particularly in segments with the most severe damage. The research employs a combination of field surveys, visual assessments, and drone technology to ensure accurate data collection. The study recommends a cost-efficient repair strategy that includes sealing and repaving damaged sections. This approach helps prioritize road segments based on damage severity and traffic load, ensuring that maintenance efforts are focused on the most critical areas. By utilizing the PCI method, the study offers a transparent and measurable framework for local governments to allocate repair budgets more efficiently, ensuring improved road safety and longer infrastructure lifespan. This research supports the implementation of preventive maintenance strategies and presents a replicable model for managing road infrastructure in other regions with similar challenges.

Introduction

Land transportation has a very vital role in supporting community mobility and economic development of an area. One of the main elements in land transportation is roads that facilitate the movement of goods and people. Adequate road infrastructure contributes to the efficiency of logistics distribution and improved regional accessibility (Sukirman, 2003). However, over time, roads deteriorate due to increased vehicle volumes and loads that exceed pavement capacity (Rahmanto, 2016). Therefore, an accurate and effective evaluation method is needed to objectively assess road conditions. The Pavement Condition Index (PCI) method is one approach that is often used in assessing the level of damage and quality of pavements (Shahin, 1994). PCI was developed by the United States Army Corps of Engineers and has been widely adopted in many countries, including Indonesia (Shahin, 1994). This method provides an assessment in the form of a score between 0 and 100, where lower scores indicate poor road conditions and require immediate repair (Radityasaka, 2021).

Previous research shows that the PCI method has the advantage of providing accurate and measurable results. Radityasaka (2021) in his research found that the Boyolali - Musuk road section has a PCI score of 59%, which indicates a fairly good condition but requires routine maintenance. Meanwhile, research by Yahya (2022) using the PCI method on Jl. Joyo Agung in Malang City shows that most roads are damaged in the moderate to severe category. Road damage such as potholes, cracks, and surface deformation are common problems faced by many regions. Anugrah (2019) revealed that road condition assessment using PCI provides accurate information about the type and level of damage, making it easier to plan repair budgets. Another study by Daksa & Prastyanto (2019) highlighted the importance of selecting the right pavement type based on PCI evaluation results to reduce long-term maintenance costs.

One of the main advantages of the PCI method is its ability to provide a comprehensive overview of road conditions without the need for complex equipment (Salsabilla et al., 2020). The evaluation can be done visually by trained technical personnel, which speeds up the data collection process. Huang et al. (2020) also added that the PCI method provides consistent and reliable results in determining repair priorities. The Directorate General of Highways (2023) emphasizes the importance of regular evaluation of road conditions as part of a preventive maintenance strategy. This evaluation aims to identify early damage and prevent more severe damage, so that repair costs can be minimized. Firmanda et al. (2022) in their research also suggested the application of the PCI method as part of a value engineering program to ensure efficient use of the budget.

The PCI method is not only applied to highways, but also to airports, ports, and parking lots (Shahin, 1994). This flexibility makes PCI an adaptable method for various types of pavements, both flexible and rigid. Marleno et al. (2020) showed that in the Makassar City Middle Ring Road project, a comparison between rigid and flexible pavements was conducted using the PCI method to identify the most effective and economical solution. Anugerah (2019) emphasized the importance of choosing a pavement method that is suitable for environmental and traffic conditions. In a study in Asahan Regency, PCI was used to evaluate rural roads and determine repair priorities based on the level of damage found. The results show that the use of paving blocks has a high effectiveness in reducing road damage compared to other pavements.

PCI also supports a preventive maintenance approach that allows repairs to be made before road conditions deteriorate. Tho'atin et al. (2016) highlighted that the combination of the PCI method with Surface Distress Index (SDI) and International Roughness Index (IRI) can provide a more comprehensive picture of road conditions and help formulate more appropriate maintenance policies (Shirley, 2000). Sana & Oetomo (2019) in their research on infrastructure development risk mitigation showed that the application of the PCI method to a road project in Tuban successfully reduced the risk of damage and increased the service life of the road. This method is considered as one of the effective ways to mitigate structural and functional risks.

The use of the PCI method is also supported by government regulations related to roads and traffic. Government Regulation No. 34/2006 on Roads and Regulation No. 22/2009 on Road Traffic and Transport emphasize the importance of road infrastructure maintenance as part of the government's responsibility in ensuring the safety of road users. Lafatza (2020) showed that repair cost estimation based on the PCI method is more accurate than the conventional method. In a case study on the Situbondo-Bajulmati road section, the use of PCI helped reduce the budget difference between planning and realization. Hardiyatmo (2015) added that in areas with low bearing capacity subgrades, the PCI method can be used to determine the optimal pavement thickness.

With its many benefits, the PCI method has become an essential tool in pavement management. Yusup & Kartika (2019) concluded that the use of PCI in road evaluation not only increases repair efficiency, but also supports sustainable infrastructure development programs. The Kaligunting - Bajulan road section in Madiun Regency is a strategic link that supports local commodity distribution and regional economic activities. However, the condition of this road has suffered serious damage due to traffic loads that exceed the design capacity. This damage includes potholes, cracks and surface deformation, potentially increasing the risk of accidents and vehicle operating costs.

Periodic road condition assessment using the PCI method is a crucial step to ensure timely repair interventions. This method not only provides an objective picture of road conditions, but also supports preventive maintenance planning to extend road service life and reduce long-term maintenance costs. Through this research, it is hoped that it can provide appropriate recommendations regarding the repair of the Kaligunting - Bajulan road section, as well as assist local governments in allocating budgets efficiently for the repair and maintenance of road infrastructure.

Literature Review

Basic Concept of Pavement Condition Index (PCI)

The Pavement Condition Index (PCI) method is one of the quantitative approaches used to objectively assess pavement condition. PCI was first developed by the United States Army Corps of Engineers and has been widely adopted in various road infrastructure projects (Shahin, 2005a). The method assigns a score between 0 and 100, where a score of 100 indicates perfect road condition, while a score close to 0 indicates severe deterioration that requires immediate repair. A PCI evaluation involves identifying and quantifying the type and extent of damage to the road surface. This process includes a visual survey to determine the types of cracks, potholes, and deformations present (Radityasaka, 2021). By using PCI, stakeholders can prioritize repairs and allocate budgets more efficiently, thereby supporting sustainable road maintenance.

The Importance of PCI in Pavement Management

The use of PCI in pavement management is crucial to ensure that roads remain in optimal condition. One of the main benefits of this method is its ability to detect deterioration early, thus preventing further costly damage (Huang et al., 2020). Regular evaluation using PCI allows for more structured and measurable maintenance planning. Firmanda et al. (2022) stated that the PCI method provides accurate information on road conditions, enabling timely repair planning. This is particularly important in large-scale projects, such as highways and airports, where the resilience of infrastructure greatly affects the smooth running of economic activity and transportation.

Comparison of PCI Method with Other Methods

PCI has advantages over other methods such as Surface Distress Index (SDI) and International Roughness Index (IRI). PCI focuses more on simple yet effective visual assessment, while the SDI method tends to be more complex and requires in-depth analysis (Tho'atin et al., 2016). PCI also provides results in the form of scores that are easily understood and interpreted by policy makers. Anugrah (2021) revealed that PCI has greater flexibility in adapting to various types of road damage, both on urban and rural roads. In contrast, other methods such as IRI are more used to measure driving comfort and are less specific in evaluating certain types of defects.

Factors Affecting PCI Outcomes

Many factors influence the evaluation results using the PCI method, one of which is the quality of pavement materials. Low-quality materials tend to develop cracks and deformations more quickly, significantly lowering the PCI score (Hardiyatmo, 2016). In addition, weather factors and traffic loads also play an important role in accelerating the road deterioration process. Salsabilla (2020) added that accuracy in field data collection greatly affects the accuracy of PCI results. Therefore, regular and structured surveys are necessary to ensure the results are representative of the actual condition of the road.

PCI Implementation in Road Projects in Indonesia

In Indonesia, the PCI method is starting to be widely applied in various road infrastructure projects. The Directorate General of Highways (2023) has adopted this method as part of the national road maintenance program, with the aim of improving efficiency and accuracy in repair budget allocation. PCI helps in prioritizing road sections that require immediate intervention. Several studies in Indonesia, such as the one conducted by Daksa & Prastyanto (2019), show that the use of PCI is effective in identifying damage types and determining repair strategies. As a result, road projects using this method tend to have a longer service life and lower maintenance costs in the long run.

The condition of road infrastructure plays a critical role in supporting economic activities and regional connectivity. The Kaligunting-Bajulan road section in Madiun Regency has suffered significant damage due to increased traffic volumes and vehicle loads that exceed its designed capacity. If left unaddressed, the deteriorating road conditions could lead to higher vehicle operating costs, increased accident risks, and further infrastructure degradation. Thus, this study is urgent as it aims to identify the specific repair needs and provide a clear, systematic prioritization for immediate maintenance, which is crucial for improving road safety and reducing long-term maintenance costs.

While various studies have applied the Pavement Condition Index (PCI) method in road management, there is a lack of research focused on its practical application in rural and regional roads in Indonesia, particularly in areas experiencing high traffic loads. Existing literature predominantly emphasizes urban road conditions or large-scale projects, leaving a gap in understanding how PCI can be effectively applied to local roads that serve critical regional functions. This study bridges that gap by focusing on a road section in Madiun Regency, providing insights into how PCI can be used for effective maintenance planning in the context of local road networks.

The novelty of this study lies in the application of the PCI method to a regional road network that faces heavy traffic loads and frequent damage. Unlike previous studies that often focus on urban or national road systems, this research focuses on a critical rural road section, offering new perspectives on the application of PCI for local government decision-making. Furthermore, the study incorporates modern technology, such as drones, to enhance data collection accuracy and efficiency, presenting an innovative approach to traditional road maintenance assessments.

The primary goal of this study is to evaluate the condition of the Kaligunting-Bajulan road section using the PCI method and provide recommendations for prioritized repairs. By identifying the most severely damaged segments and estimating repair costs, the study aims to help local governments make data-driven decisions regarding road maintenance. The benefits of this research include improved road safety, more efficient allocation of maintenance resources, and reduced long-term repair costs. Additionally, the findings provide a model that can be applied to other regions with similar road management challenges, contributing to better infrastructure planning and sustainability.

Research Methods

Research Design

This study used a quantitative approach with a field survey method to collect data on pavement conditions. This approach allows the collection of objective and measurable data, so that the results of the analysis can be used as a basis for planning road improvements. The Pavement Condition Index (PCI) method was used as the main tool in assessing pavement condition. The research design also involved a comparative study by comparing the PCI evaluation results with other methods, such as Surface Distress Index (SDI) and International Roughness Index (IRI). Thus, this research not only evaluates road conditions but also provides recommendations on the most effective methods to use in Indonesia.

Location and Time of Research

This research was conducted on the Kaligunting - Bajulan road section, Madiun Regency, which has a length of 4.96 km. This location was chosen because it is a strategic route that experiences high levels of damage due to heavy traffic volumes. The research was carried out for three months, including the stages of data collection, analysis, and preparation of recommendations. The research was conducted during the dry season to avoid obstacles due to weather conditions that could affect the survey results. With stable weather conditions, the PCI evaluation results are expected to be more accurate and representative.

Data Collection

Data was collected through a visual survey in the field by identifying the type and level of damage to the road surface. The survey team took measurements using a standard PCI form that has been adapted to the guidelines of the Directorate General of Highways (2023). Each road segment was divided into 100-meter intervals to facilitate damage identification. In addition to the visual survey, the study also used drones to get an overview of the general road condition. This approach allows for a more comprehensive analysis and detects damage that is difficult to see from the road surface.

Data Analysis

The data obtained was analyzed using the PCI method by calculating the total deduct value (TDV) of each road segment. The PCI score is then categorized into five levels, namely very good, good, medium, bad, and very bad. These results were used to prioritize improvements to the road segments studied. The analysis also included a comparison of the PCI scores with results from the SDI and IRI methods to ensure data consistency. By comparing these three methods, the research was able to provide a more comprehensive picture of road conditions.

Estimated Repair Cost

Based on the results of the PCI analysis, the estimated repair costs are calculated using the analysis of unit price of work (AHSP) method issued by the Ministry of PUPR. This calculation includes the cost of materials, labor, and heavy equipment needed for each type of road damage. This cost estimate became the basis for preparing the budget plan. In addition, this study also considered various alternative repair solutions, such as overlay, patching, and full reconstruction. Each solution was compared in terms of cost and durability to find the most efficient and sustainable repair recommendation.

Results and Discussions

Results

Existing Road Condition

Based on the field survey conducted, the existing condition of the Kaligunting - Bajulan road section shows damage in various segments. This damage includes longitudinal cracks, potholes, and rutting. The survey results show that most road segments have PCI values below 70, indicating that the road condition is in the moderate to poor category. The most dominant damage was found on segments 2 to 4, with alligator cracking as the most common type of damage. In addition to physical damage, heavy traffic factors also worsen road conditions. Heavy vehicle volumes that exceed the pavement capacity accelerate the surface degradation process. This result is consistent with previous research that shows the relationship between excessive traffic loads and accelerated road deterioration (Radityasaka, 2021). During the rainy season, road conditions worsen due to standing water that enlarges potholes and accelerates surface peeling. The survey also shows that segments 5 to 7 have better PCI scores than other segments. This is due to partial repairs made in the previous year. However, the survey indicated that the repairs were temporary and required further intervention.

PCI Evaluation Results

Evaluation using the PCI method provides a quantitative picture of the level of damage on each road segment. The evaluation results show that the Kaligunting - Bajulan road segment has an average PCI score of 58.08. This value indicates that the road is in moderate condition and requires preventive repair to avoid further deterioration.

Table 1. PCI Value of Segment STA 000-000 - 004+960

Segment	STA			PCI Value	Category
1	000+000	-	000+100	12	Very Poor
2	000+100	-	000+200	16	Very Poor
3	000+200	-	000+300	49	Medium (fair)
4	000+300	-	000+400	47	Medium (fair)
5	000+400	-	000+500	58	Good
6	000+500	-	000+600	54	Medium (fair)
7	000+600	-	000+700	40	Poor
8	000+700	-	000+800	50	Medium (fair)
9	000+800	-	000+900	39	Poor
10	000+900	-	001+000	59	Good
11	001+000	-	001+100	51	Medium (fair)
12	001+100	-	001+200	35	Poor
13	001+200	-	001+300	45	Medium (fair)
14	001+300	-	001+400	45	Medium (fair)
15	001+400	-	001+500	51	Medium (fair)
16	001+500	-	001+600	52	Medium (fair)
17	001+600	-	001+700	54	Medium (fair)
18	001+700	-	001+800	52	Medium (fair)
19	001+800	-	001+900	61	Good
20	001+900	-	002+000	57	Good
21	002+000	-	002+100	57	Good
22	002+100	-	002+200	61	Good

Table 1. PCI Value of Segment STA 000-000 - 004+960

Segment	STA			PCI Value	Category
23	002+200	-	002+300	61	Good
24	002+300	-	002+400	56	Good
25	002+400	-	002+500	55	Medium (fair)
26	002+500	-	002+600	58	Good
27	002+600	-	002+700	45	Medium (fair)
28	002+700	-	002+800	70	Good
29	002+800	-	002+900	100	Execelent
30	002+900	-	003+000	100	Execelent
31	003+000	-	003+100	100	Execelent
32	003+100	-	003+200	100	Execelent
33	003+200	-	003+300	100	Execelent
34	003+300	-	003+400	100	Execelent
35	003+400	-	003+500	100	Execelent
36	003+500	-	003+600	100	Execelent
37	003+600	-	003+700	100	Execelent
38	003+700	-	003+800	100	Execelent
39	003+800	-	003+900	100	Execelent
40	003+900	-	004+000	58	Good
41	004+000	-	004+100	57	Good
42	004+100	-	004+200	49	Medium (fair)
43	004+200	-	004+300	50	Medium (fair)
44	004+300	-	004+400	44	Medium (fair)
45	004+400	-	004+500	43	Medium (fair)
46	004+500	-	004+600	18	Very Poor
47	004+600	-	004+700	15	Very Poor
48	004+700	-	004+800	30	Poor
49	004+800	-	004+900	21	Very Poor
50	004+900	-	004+960	29	Poor
Σ PCI				2904	
Average PCI STA 000+000 - 004+960					58,08

Based on table 1. calculation of PCI value for STA 000+000 - STA 004+960, the average PCI value is 58.08, which is calculated from the total PCI value of each segment divided by the number of existing segments. This result shows that the condition of the pavement is included in the *good* category. Thus, it can be concluded that the pavement condition on the Kaligunting-Bajulan Road section, which has a length of 4.96 km, is in good condition and requires routine maintenance.

Calculation of Cost Budget Plan (RAB)

The total estimated cost of Rp 2,761,123,884 covers various types of works, including repaving using AC-WC layer with excavation method using cold milling machine. This treatment is applied for damages such as alligator cracking, longitudinal/transverse cracking, curling, patching, and potholes, where the overlapping damage locations require comprehensive repair. In addition, for damage in the form of grain release, the sealing method is used as a preventive measure to prevent further damage. This cost breakdown is prepared based on the applicable analysis of unit price of work (AHSP), including the cost of materials, labor, and heavy equipment required for each type of work, so that the estimation results are more accurate and in accordance with field conditions.

Table 2: Budget Details

No.	Jobs	Volume	Unit	Unit Price	Total
1	Sealing	2,286.00	m2	IDR 31,642.00	IDR 72,333,612.00
2	Asphalt				
	CMM Excavation	567.04	M3	IDR 454,100.00	IDR 257,492,864.00
	Tack Coat	7,088.00	1	IDR 21,200.00	IDR 150,265,600.00
	AC-WC	1,304.19	Tons	IDR 1,749,000.00	IDR 2,281,031,808.00
	TOTAL				IDR 2,761,123,884.00
	UPDATE				IDR 2,761,123,884.00
Amount: Two Billion Seven Hundred Sixty One Million One Hundred Twenty Three Thousand Eight Hundred Eighty Four Rupiahs					

Handling Priority

The prioritization of road damage is determined based on the PCI and RAB evaluation results. Segments with PCI scores below 50 receive the highest priority for repair. This aims to prevent further damage that could increase future repair costs. With segments 2 and 3 as the top priority. These segments are the most severely damaged and require immediate intervention. The second priority is segments 4 and 5 which have PCI scores between 50 to 60. These segments will receive repairs in the form of light overlays and sealing of cracks. Segments with PCI scores above 70 only require routine maintenance and cleaning of drainage channels to prevent waterlogging. Thus, budget allocation can be more focused on segments that require major repairs.

Discussion

The PCI method provides accurate and measurable results in evaluating the condition of the Kaligunting - Bajulan road. By using this approach, stakeholders can prioritize improvements that are more efficient and within the available budget. The results of the evaluation show that the PCI method is able to identify various types of defects commonly found on roads with high traffic volumes. The evaluation also showed that previous periodic repairs had a positive impact on certain segments. However, without preventive maintenance, defects tend to return within a short period of time. Therefore, a PCI-based maintenance strategy is recommended to be implemented on an ongoing basis. This is in line with the recommendations of the Directorate General of Highways (2023) which emphasizes the importance of preventive maintenance in road infrastructure management. The cost budget plan prepared based on the PCI results provides transparency in the process of allocating funds. With a detailed RAB, road improvement projects can run more effectively and accountably. PCI evaluation not only helps in planning repairs, but also as a tool to monitor the progress of road conditions on a regular basis.

In addition, the implementation of PCI in Indonesia is expected to become a standard in evaluating road conditions in various regions. This research shows that the PCI method can be applied in various geographical conditions and pavement types, making its flexibility an advantage in road management. The utilization of technology such as drones in the survey also strengthens data accuracy and speeds up the evaluation process. In general, the results of this study support the use of the PCI method as a key tool in road condition evaluation. With proper application, this method can help improve the quality of road infrastructure in Indonesia and support regional economic growth through better connectivity

The Kaligunting - Bajulan road section was repaired using a detailed and technical method. The repair process involved several important stages, starting with a visual survey to identify the type and extent of damage on each road segment. For severe damage such as alligator cracking and curling, the action taken was to excavate the old asphalt material using a cold milling machine to a certain depth, followed by spraying tack coat to ensure optimal adhesion before a new layer of AC-WC was applied. Potholes and patches are treated with patching to seal the damaged area, while grain release is handled with sealing. This approach ensures that each type of damage is treated accordingly, extending the service life of the road and improving the safety and comfort of road users.

Conclusion

Based on the results of research and analysis using the Pavement Condition Index (PCI) method, it can be concluded that the condition of the Kaligunting - Bajulan road section is in the moderate to poor category. The average PCI score of 55.75 indicates that most road segments require regular repair and maintenance to prevent further damage. Segments with PCI values below 50 require immediate attention in the form of comprehensive repairs. The evaluation also identified the most dominant types of damage, namely longitudinal cracks, potholes and ruts. The main factor influencing deterioration is the volume of heavy vehicles traveling on a daily basis, which exceeds the design capacity of the road. These results indicate the need for regular monitoring and implementation of preventive maintenance strategies to ensure a longer service life of the road. The application of the PCI method has proven effective in providing an objective and measurable picture of road conditions. By using PCI, repair priorities can be determined more efficiently, allowing the available budget to be allocated according to the level of deterioration. This conclusion supports the recommendation to make the PCI method the standard for road condition evaluation in Indonesia.

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