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Recommended Road Maintenance Strategy for the Wareng–Mukus Road in Pacitan Regency Based on the Analytical Hierarchy Process (AHP) and the Provincial/*Kabupaten* Road Management System (PKRMS)

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Abstract

Road infrastructure plays a crucial role in supporting regional connectivity, economic activity, and public services. However, limited maintenance budgets require local governments to establish effective road maintenance priorities based on both pavement condition and the strategic importance of road networks. This study aims to determine the recommended maintenance strategy for the Wareng–Mukus Road Section in Pacitan Regency by integrating the Analytical Hierarchy Process (AHP) and the Provincial/Kabupaten Road Management System (PKRMS). AHP was used to determine the relative importance of decision criteria through pairwise comparisons with expert respondents, while PKRMS was used to evaluate pavement condition based on engineering indicators the Surface Distress Index (SDI) and Trafficability Index (TTI) and to identify appropriate maintenance alternatives. The results show that road condition is the most influential criterion (weight 34.27%), followed by traffic volume (23.63%), connectivity (15.65%), economic and agricultural corridor function (12.04%), access to public service facilities (7.70%), and regional development (6.71%). Based on the integrated AHP–PKRMS analysis, periodic preventive maintenance emerged as the most appropriate strategy, with the highest priority value of 57.00%, followed by minor rehabilitation (25.51%) and routine maintenance (17.50%). This recommendation aligns with the existing pavement condition, classified as serviceable fair according to TTI and good according to SDI. The integration of AHP and PKRMS provides a systematic, objective decision-making framework that supports evidence-based maintenance planning, optimizes resource allocation, and enhances the sustainability of road asset management.

INTRODUCTION

Road infrastructure plays a vital role in supporting regional economic growth, social development, and public services. As one of the primary transportation assets, roads facilitate the movement of people and goods, improve accessibility to education, healthcare, tourism, and agricultural markets, and contribute significantly to regional development. Well-maintained road networks reduce travel time, vehicle operating costs, and accident risks while improving logistics efficiency and regional connectivity (Bayoumi et al., 2021; Danza et al., 2025). Conversely, deteriorated road conditions hinder mobility, increase transportation costs, and negatively affect community welfare. The World Bank (2019) emphasizes that quality road infrastructure is a key driver of economic productivity and sustainable development. Similarly, Indonesia’s National Medium-Term Development Plan (RPJMN) 2020–2024 identifies road infrastructure improvement as a strategic priority for strengthening regional connectivity (Ministry of National Development Planning/Bappenas, 2019).

Despite continuous investments in road infrastructure, road deterioration remains a major challenge in Indonesia (Negara, 2016). Statistics Indonesia (BPS, 2020) reported that a substantial proportion of provincial roads remain in fair to poor condition due to excessive axle loads, aging pavement, inadequate drainage systems, extreme weather conditions, and insufficient maintenance funding. These conditions reduce transportation efficiency, increase vehicle operating costs, and compromise traffic safety. Previous studies have also demonstrated that poor road conditions significantly affect logistics performance and regional accessibility, particularly in rural areas (Sawitri, 2023).

Pacitan Regency, located in East Java Province, possesses considerable economic potential supported by agriculture, fisheries, trade, and tourism. The regency is recognized for its agricultural production and renowned tourist destinations, such as Klayar Beach and Watu Karung Beach, which require reliable transportation infrastructure to sustain regional economic activities. Therefore, maintaining road infrastructure is essential to ensure efficient distribution of agricultural products, improve accessibility to tourism destinations, and support the mobility of local communities (Golmohammadı, 2018; Negara, 2016).

Among the strategic provincial road sections in Pacitan Regency, the Wareng–Mukus Road serves as an important transportation corridor connecting residential areas, agricultural production centers, and public service facilities. However, several segments of this road have experienced varying levels of pavement deterioration, including cracking, rutting, potholes, and surface deformation. These deteriorated conditions reduce travel comfort, increase travel time, elevate vehicle operating costs, and pose safety risks for road users (Zakharov et al., 2018; Žuraulis et al., 2021). Consequently, selecting an appropriate maintenance strategy has become a priority for preserving road performance and ensuring long-term serviceability (Hussain, 2019; Kaiser & Barstow, 2022).

Road maintenance should not merely focus on repairing damaged pavement but should also consider the most appropriate treatment strategy based on the severity of pavement distress, road functionality, traffic demand, and available financial resources (Hafez et al., 2019; Manurung et al., 2022; Nautiyal & Sharma, 2022). In practice, limited maintenance budgets prevent local governments from applying comprehensive rehabilitation to all damaged road sections simultaneously (Donev & Hoffmann, 2020). Therefore, selecting an optimal maintenance strategy requires systematic decision-making that integrates engineering assessments with socioeconomic considerations to maximize the effectiveness of maintenance investments.

The Analytical Hierarchy Process (AHP) is a widely recognized multi-criteria decision-making method that enables decision-makers to determine the relative importance of various technical and non-technical criteria through pairwise comparisons. Meanwhile, the Provincial/Kabupaten Road Management System (PKRMS) provides a systematic framework for evaluating pavement conditions and recommending appropriate maintenance treatments based on engineering indicators. By integrating these two approaches, maintenance decisions can consider both stakeholder preferences and objective road condition assessments, resulting in more rational, transparent, and accountable maintenance recommendations (Masagung et al., 2023).

The integration of AHP and PKRMS offers a comprehensive framework for developing effective road maintenance strategies (Nurizi Sulaiman et al., 2025). AHP is employed to determine the relative weights of decision criteria, while PKRMS evaluates pavement conditions and identifies suitable maintenance alternatives, such as routine maintenance, periodic maintenance, preventive maintenance, or rehabilitation (Sawitri, 2023; Supriadi et al., 2018). The combined approach enables decision-makers to formulate maintenance strategies that not only address existing pavement deterioration but also optimize the allocation of limited maintenance resources and extend pavement service life.

The novelty of this study lies in the integrated application of AHP and PKRMS to formulate a maintenance strategy for a single road corridor the Wareng Mukus Road rather than ranking multiple road sections for budget allocation. Unlike previous studies that use these tools primarily for prioritization, this research focuses on selecting the most appropriate maintenance treatment based on existing pavement condition and strategic importance. Additionally, this study introduces six comprehensive criteria within the AHP framework road condition, traffic volume, connectivity, regional development, economic and agricultural corridor function, and access to public services to provide a holistic assessment of maintenance needs. This integration of PKRMS engineering data with AHP-based multi-criteria analysis offers a novel methodological contribution for producing scientifically justified, context-specific maintenance recommendations that support sustainable road asset management at the local government level.

Therefore, this research aims to formulate a recommended road maintenance strategy for the Wareng–Mukus Road in Pacitan Regency based on the integration of the Analytical Hierarchy Process (AHP) and the Provincial/Kabupaten Road Management System (PKRMS). The research is expected to produce scientifically justified maintenance recommendations that support evidence-based decision-making, improve the effectiveness of road asset management, optimize maintenance budgeting, and contribute to sustainable transportation infrastructure development in Pacitan Regency.

METHOD

The research was conducted on the Wareng–Mukus Road, a provincial road section located in Pacitan Regency, East Java Province. The study aimed to develop a recommended road maintenance strategy by integrating the Provincial/Kabupaten Road Management System (PKRMS) and the Analytical Hierarchy Process (AHP) (Arifin et al., 2025; Witjaksana et al., 2025). The research was carried out over a period of approximately two weeks, including field observations, data collection, data processing, and analysis. The instruments used in this study consisted of a Global Positioning System (GPS), a distance measuring device, a survey vehicle, a tablet or laptop computer, and Microsoft Access software to operate the PKRMS application.

The study utilized both primary and secondary data. Primary data were collected through road inventory surveys, pavement condition surveys, GPS coordinate measurements, and questionnaires distributed to expert respondents to determine the relative importance of the decision criteria used in the AHP analysis. Secondary data included traffic volume data, unit costs for road maintenance activities, administrative data for the Wareng–Mukus Road, and other supporting technical documents obtained from the relevant government agencies. These data served as the basis for evaluating the road condition and formulating the recommended maintenance strategy.

Data analysis was conducted using descriptive and quantitative approaches through the integration of PKRMS and AHP. The PKRMS analysis began by inputting road inventory, pavement condition, road structure, traffic volume, and unit cost data into the application to evaluate pavement performance, identify maintenance needs, recommend appropriate maintenance treatments, and estimate maintenance costs. Subsequently, the AHP method was employed to determine the relative weights of the decision criteria influencing the maintenance strategy, namely road condition, traffic volume, connectivity, regional development, economic and agricultural connectivity, and accessibility to public service facilities. Expert judgments were obtained through pairwise comparison matrices, and the consistency of the responses was evaluated using the Consistency Index (CI) and Consistency Ratio (CR), with a CR value of 0.10 or less considered acceptable. The criterion weights obtained from AHP were then incorporated into the Multi-Criteria Analysis (MCA) component of PKRMS, allowing the recommended maintenance strategy to consider both engineering assessments and socioeconomic priorities. The final output of the study was a scientifically justified road maintenance strategy for the Wareng–Mukus Road in Pacitan Regency based on the integrated application of PKRMS and AHP.

RESULTS AND DISCUSSION

Priority Analysis of Maintenance Alternatives

After determining the priority weights of the evaluation criteria, the next step was to assess the maintenance alternatives for each criterion. The evaluated alternatives consisted of routine maintenance, preventive periodic maintenance, and minor rehabilitation.

Table 1. Priority Analysis of Maintenance Alternatives

Criteria	A1 Routine Maintenance	A2 Preventive Periodic Maintenance	A3 Minor Rehabilitation	Dominant Alternative
K1 Road Condition	0.150	0.650	0.200	A2 Preventive Periodic Maintenance
K2 Traffic Volume	0.200	0.550	0.250	A2 Preventive Periodic Maintenance
K3 Connectivity	0.180	0.520	0.300	A2 Preventive Periodic Maintenance
K4 Regional Development	0.160	0.500	0.340	A2 Preventive Periodic Maintenance
K5 Connectivity to Economic and Agricultural Areas	0.170	0.530	0.300	A2 Preventive Periodic Maintenance
K6 Connectivity to Public Service Facilities	0.220	0.500	0.280	A2 Preventive Periodic Maintenance

Source: AHP analysis results

The evaluation results indicate that preventive periodic maintenance (A2) is the dominant alternative across all evaluation criteria. This finding is consistent with the PKRMS assessment, which classified the Wareng–Mukus Road Section as being in fair condition according to the TTI and good condition according to the SDI. Under these pavement characteristics, the most appropriate strategy is to prevent further deterioration rather than implementing major rehabilitation measures.

Final Priority of Maintenance Alternatives

The final priority of the maintenance alternatives was determined by combining the priority weights of the evaluation criteria with the corresponding alternative weights under each criterion. This process was conducted to identify the most appropriate maintenance strategy for the Wareng–Mukus Road Section. The alternatives evaluated included routine maintenance, preventive periodic maintenance, and minor rehabilitation. The alternative with the highest overall score represents the preferred maintenance strategy based on the AHP analysis. The final priority ranking is presented in Table 2.

Table 2. Final Priority Ranking of Maintenance Alternatives

Rank	Alternative	Final Score	Percentage	Interpretation
1	A2 Preventive Periodic Maintenance	0.570	57.00%	Primary Priority
2	A3 Minor Rehabilitation	0.255	25.51%	Supporting Priority
3	A1 Routine Maintenance	0.175	17.50%	Basic Maintenance

Source: AHP synthesis results

The calculation results indicate that preventive periodic maintenance (A2) achieved the highest final score of 0.570 (57.00%). Minor rehabilitation (A3) ranked second with a score of 0.255 (25.51%), while routine maintenance (A1) ranked third with a score of 0.175 (17.50%).

These findings demonstrate that preventive periodic maintenance is the most appropriate maintenance strategy for the Wareng–Mukus Road Section. This recommendation is justified because the road remains serviceable, while the entire section is classified as being in fair condition according to the TTI assessment. Implementing preventive periodic maintenance is expected to preserve the pavement's serviceability and minimize the risk of further deterioration.

PKRMS Analysis Integrated with AHP

The integration of the PKRMS and AHP methods was performed by using the PKRMS assessment as the basis for evaluating the technical condition of the road, while the AHP priority weights were incorporated as the Multi-Criteria Analysis (MCA) weighting factors. In this study, the integration was not intended to compare different road sections but rather to strengthen the decision-making process in selecting the most appropriate maintenance strategy for the Wareng–Mukus Road Section.

Table 3. PKRMS Analysis Integrated with AHP (Criteria Weights)

Code	Criterion	AHP Weight	MCA Weight (%)	Rank
K1	Road Condition	0.343	34.27%	1
K2	Traffic Volume	0.236	23.63%	2
K3	Connectivity	0.157	15.65%	3

Code	Criterion	AHP Weight	MCA Weight (%)	Rank
K5	Connectivity to Economic and Agricultural Areas	0.120	12.05%	4
K6	Connectivity to Public Service Facilities	0.077	7.70%	5
K4	Regional Development	0.067	6.71%	6

Source: Integrated AHP-PKRMS analysis.

The highest MCA weight is associated with Road Condition (K1), indicating that the technical condition of the pavement remains the primary consideration in the integrated decision-making process. Traffic Volume (K2) and Connectivity (K3) are the next most influential criteria, reflecting their significant contribution to determining maintenance requirements.

Table 4. PKRMS Analysis Integrated with AHP (Decision Matrix)

PKRMS Condition	Length	PKRMS Recommendation	AHP Integration Result	Decision
Fair (TTI)	8.26 km	Periodic or preventive maintenance	A2 achieved the highest score	Preventive periodic maintenance is the primary priority

Source: PKRMS analysis and AHP integration results.

Table 4. PKRMS Analysis Integrated with AHP (Decision Matrix) (Continued)

PKRMS Condition	Length	PKRMS Recommendation	AHP Integration Result	Decision
Good (SDI)	8.26 km	Routine maintenance to preserve pavement condition	A1 remains necessary as basic maintenance	Routine maintenance serves as a supporting activity
Severe Damage	0.00 km	Major rehabilitation is not required	A3 is not the primary priority	Minor rehabilitation is only required if localized damage occurs

Source: PKRMS analysis and AHP integration results

The integrated analysis demonstrates that the recommended maintenance strategy considers not only the physical condition of the pavement but also the strategic importance of the road section in supporting transportation services. Consequently, this integrated approach provides a more comprehensive basis for decision-making than using either the PKRMS or AHP method independently.

Preliminary Estimation of Maintenance Quantity

The preliminary maintenance quantity was estimated based on the road length and pavement width. Since the entire road section was classified as being in fair condition according to the TTI assessment, the initial maintenance area targeted for preventive periodic maintenance was calculated by multiplying the road length by the pavement width.

Table 5. Preliminary Estimation of Maintenance Quantity

Description	Value
Road Length	8.26 km
Pavement Width	7.08 m

Description	Value
Estimated Maintenance Area	58,480.80 m²
Priority Maintenance Method	Preventive Periodic Maintenance

Source: PKRMS inventory data analysis

The final maintenance cost cannot be determined at this stage because the applicable unit prices for maintenance activities have not yet been incorporated into the analysis. Therefore, this study presents only the preliminary maintenance quantity.

CONCLUSION

Based on the integrated PKRMS and AHP analysis, the most appropriate treatment strategy for the Wareng–Mukus Road Section is periodic preventive maintenance, with a priority value of 57.00%, followed by minor rehabilitation (25.51%) and routine maintenance (17.50%). This recommendation is consistent with the current road condition, which is classified as serviceable, with a fair condition based on the Trafficability Index (TTI) and a good condition based on the Surface Distress Index (SDI). Therefore, periodic preventive maintenance is considered the most effective strategy to preserve pavement performance and prevent further deterioration, thereby extending the service life of the road. Based on the findings of this study, it is recommended that the local government of Pacitan Regency implement periodic preventive maintenance as the primary treatment strategy for the Wareng–Mukus Road Section to prevent further deterioration and extend pavement service life, with budget allocations prioritized according to road condition and traffic volume as the most influential criteria. Regular PKRMS surveys should be conducted to monitor pavement performance and update maintenance recommendations periodically. For future research, similar studies should be extended to other road sections in Pacitan Regency to develop a comprehensive road maintenance master plan, incorporating additional criteria such as road safety, environmental impact, and climate resilience, as well as utilizing GIS technology for spatial visualization of road condition data and maintenance priority mapping.

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