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Priority Analysis of Road Maintenance for The Wareng–Mukus Road in Pacitan Regency using The Analytical Hierarchy Process (AHP) and The Provincial and Regency Road Management System (PKRMS)

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ABSTRACT

Road infrastructure plays an essential role in supporting regional connectivity, economic activities, and public accessibility. However, limited maintenance budgets and increasing road deterioration require local governments to establish an objective and systematic priority framework for road maintenance decisions. This study aims to determine the priority of road maintenance strategies for the Wareng–Mukus Road Section in Pacitan Regency by integrating the Analytical Hierarchy Process (AHP) and the Provincial/Kabupaten Road Management System (PKRMS). This research employed a quantitative approach through field surveys, technical road condition assessments, expert questionnaires, and secondary data analysis. The PKRMS method was used to evaluate pavement conditions based on the Treatment Trigger Index (TTI), Surface Distress Index (SDI), serviceability level, and traffic volume, while AHP was applied to determine the weight of maintenance priority criteria through pairwise comparisons. The results indicate that the Wareng–Mukus Road Section remains serviceable, with the SDI assessment categorizing the entire 8.26 km road segment as good condition, while the TTI analysis recommends preventive maintenance to prevent future deterioration. The AHP analysis shows that road condition is the most influential criterion with a weight of 34.27%, followed by traffic volume (23.63%), connectivity (15.65%), economic and agricultural corridor function (12.05%), public service accessibility (7.70%), and regional development (6.71%). This study concludes that the integration of AHP and PKRMS provides an effective decision-support framework for determining road maintenance priorities by considering both technical conditions and strategic road functions. The proposed approach can support more efficient budget allocation and sustainable road asset management.

INTRODUCTION

Road infrastructure plays a strategic role in supporting regional economic growth, social development, and public services. Well-maintained roads facilitate the efficient movement of people and goods, improve accessibility to education, healthcare, tourism, and agricultural markets, and enhance regional competitiveness (Famewo & Shokouhian, 2025). Conversely, deteriorated road conditions increase transportation costs, reduce travel efficiency, accelerate vehicle deterioration, and negatively affect road safety (Septiyani, 2024; Zakharov et al., 2018). According to the World Bank (2019), investments in road infrastructure significantly contribute to economic productivity by reducing logistics costs and improving regional connectivity. Likewise, the Indonesian National Medium-Term Development Plan (RPJMN) 2020–2024 emphasizes the improvement of road infrastructure as one of the national priorities for strengthening interregional connectivity (Ministry of National Development Planning/Bappenas, 2019).

Despite continuous infrastructure development, road deterioration remains one of the major challenges in Indonesia (Alamgir et al., 2019; Ray & Ing, 2016). Data from Statistics Indonesia (BPS, 2020) indicate that a considerable proportion of provincial roads remain in fair to poor condition due to increasing traffic loads, overloaded freight vehicles, adverse weather conditions, inadequate drainage systems, and limited maintenance budgets. Poor road conditions not only increase vehicle operating costs but also reduce transportation efficiency and create safety hazards for road users (Albalate & Fageda, 2019; Jiang et al., 2017). Previous studies have shown that inadequate road maintenance can reduce transportation efficiency by up to 30%, particularly in rural and semi-urban areas (Sawitri, 2023).

Pacitan Regency, located in East Java Province, is an important regional center with significant economic potential in agriculture, fisheries, trade, and tourism. The regency is well known for its agricultural production and internationally recognized tourist destinations, including Klayar Beach, Watu Karung Beach, and several karst cave attractions. The sustainability of these economic sectors depends heavily on the availability of reliable transportation infrastructure. Consequently, maintaining road performance is essential for ensuring the smooth distribution of agricultural products, supporting tourism activities, and improving public mobility.

One of the strategic provincial road sections in Pacitan Regency is the Wareng–Mukus Road, which functions as an important transportation corridor connecting rural communities with economic centers and public service facilities. This road also serves as a major access route for agricultural product distribution and community mobility. However, various segments of the Wareng–Mukus Road have experienced pavement deterioration, including cracking, potholes, and surface deformation, which reduce riding comfort, increase travel time, and elevate vehicle operating costs. The deteriorating condition of this road also affects regional economic activities and limits accessibility for local residents.

Road deterioration on the Wareng–Mukus Road generates multidimensional impacts. Economically, damaged pavement increases transportation and logistics costs while reducing the efficiency of agricultural distribution. Socially, deteriorated roads contribute to longer travel times, decreased accessibility to education and healthcare services, increased accident risks, and reduced overall community productivity. Previous studies reported that poor road conditions can significantly increase logistics costs and reduce accessibility, ultimately affecting regional economic development and public welfare (Bayoumi et al., 2021; Danza et al., 2025).

One of the main challenges faced by the local government is the limitation of maintenance funding compared with the increasing number of road sections requiring intervention (Hayat & Amaratunga, 2017). Consequently, not all damaged road segments can be repaired simultaneously, making an objective prioritization system essential. Maintenance priorities should consider not only the physical condition of the pavement but also traffic characteristics, road functionality, accessibility, economic contribution, and public service importance. Therefore, decision-making requires a systematic and data-driven approach capable of integrating multiple evaluation criteria.

The Analytical Hierarchy Process (AHP) is a well-established multi-criteria decision-making method that enables experts to determine the relative importance of evaluation criteria through pairwise comparisons. AHP has been widely applied in infrastructure management because it provides a consistent framework for assigning weights to technical and socioeconomic factors. However, AHP alone cannot comprehensively evaluate road conditions based on engineering assessment. Therefore, it is integrated with the Provincial/Kabupaten Road Management System (PKRMS), a road asset management system developed to assess pavement conditions and recommend appropriate maintenance treatments based on technical road performance indicators.

The integration of AHP and PKRMS provides a comprehensive framework for determining road maintenance priorities. AHP establishes the relative importance of decision criteria, while PKRMS evaluates road conditions and identifies the most appropriate maintenance alternatives. The combination of these methods enables objective, transparent, and scientifically justifiable decision-making, ensuring that limited maintenance resources are allocated to road sections with the greatest strategic importance and highest maintenance urgency.

Based on these considerations, this study aims to analyze the priority of road maintenance for the Wareng–Mukus Road in Pacitan Regency using the integration of the Analytical Hierarchy Process (AHP) and the Provincial/Kabupaten Road Management System (PKRMS). The study is expected to produce a priority ranking of maintenance alternatives that can support evidence-based decision-making by local governments, improve the effectiveness of maintenance planning, optimize budget allocation, and ultimately enhance regional connectivity, transportation safety, and sustainable infrastructure management.

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 analyze the priority of road maintenance by integrating the Provincial/Kabupaten Road Management System (PKRMS) and the Analytical Hierarchy Process (AHP). 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 (Konkimalla, 2023; Sharif et al., 2024).

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 existing road condition and establishing maintenance priorities.

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 requirements, determine maintenance priorities, and estimate maintenance costs. Subsequently, the AHP method was employed to determine the relative weights of the decision criteria influencing maintenance prioritization, 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, enabling the prioritization process to consider both engineering assessments and socioeconomic factors. The integrated analysis produced a priority ranking of road maintenance alternatives for the Wareng–Mukus Road, providing an objective and systematic basis for determining maintenance priorities and supporting more effective road asset management and budget allocation in Pacitan Regency.

RESULTS AND DISCUSSION

General Description of the Research Object

This section presents the results of the road maintenance prioritization analysis for the Wareng–Mukus Road Section, Pacitan Regency. The analysis was conducted in accordance with the scope of the study, which focuses exclusively on a single road section, namely the Wareng–Mukus Road Section, without comparing it with other road sections. Therefore, the analysis is directed toward determining the most appropriate maintenance strategy for this road section.

The primary data used in this study were obtained from the Road Management System (PKRMS) Semester I of 2026 and the Analytic Hierarchy Process (AHP) questionnaire. PKRMS was employed to evaluate the technical condition of the road, whereas AHP was used to determine the relative importance of the evaluation criteria and prioritize the alternative maintenance treatments. The integration of these two approaches provides a more objective and technically appropriate recommendation for road maintenance.

Table 1. Information of the Wareng–Mukus Road Section, Pacitan Regency

Description	Information
Road Section Number	003
Road Section Name	Wareng–Mukus (Central Java Provincial Boundary)
Road Length	8.26 km
Pavement Width	7.08 m
Pavement Type	Asphalt

Based on Table 1, the Wareng–Mukus Road Section has a total length of 8.26 km with an asphalt pavement width of 7.08 m. The road section was analyzed as a single analysis unit, and the appropriate maintenance strategy was subsequently determined based on the PKRMS technical assessment and the priority weights obtained from the AHP analysis.Results and discussion contain findings of research and their discussion. All findings must be supported by sufficient data. This part must answer the hypothesis of the research stated in the Introduction.

PKRMS Analysis Results of the Wareng–Mukus Road Section

The PKRMS analysis was conducted to evaluate the technical condition of the Wareng–Mukus Road Section. The assessment included the Treatment Trigger Index (TTI), Surface Distress Index (SDI), road serviceability level, and traffic volume. These parameters served as the preliminary basis for determining the priority of maintenance alternatives before conducting the AHP weighting process

Road Condition Based on the Treatment Trigger Index (TTI)

The Treatment Trigger Index (TTI) analysis was performed to determine the maintenance requirements of the Wareng–Mukus Road Section. Based on the PKRMS analysis, the road condition classified according to the TTI parameter is presented in Table 2.

Table 2. Road Condition Based on the Treatment Trigger Index (TTI)

Road Condition	Length	Percentage
Good	0.00 km	0.00%
Fair	8.26 km	100.00%
Minor Damage	0.00 km	0.00%
Severe Damage	0.00 km	0.00%
Total	8.26 km	100.00%

The PKRMS results indicate that the entire Wareng–Mukus Road Section is classified as being in fair condition according to the TTI assessment. Although no severe pavement deterioration has been identified, appropriate maintenance is required to prevent further deterioration into minor or severe damage. Therefore, preventive maintenance is considered the most suitable treatment alternative for maintaining the pavement condition.

Road Serviceability Level

The road serviceability assessment indicates that the entire Wareng–Mukus Road Section remains serviceable. However, this condition does not imply that maintenance activities can be postponed. Since the road is classified as being in fair condition according to the TTI analysis, early maintenance intervention is necessary to preserve its serviceability and prevent future deterioration.

Table 3. Road Serviceability Level

Category	Length	Percentage
Serviceable Road	8.26 km	100.00%
Unserviceable Road	0.00 km	0.00%
Total	8.26 km	100.00%

Road Condition Based on the Surface Distress Index (SDI)

In addition to the TTI assessment, the road condition was also evaluated using the Surface Distress Index (SDI). The SDI assessment was conducted to identify the pavement surface condition and determine whether the road remains serviceable. This information is essential in pavement management because it provides an indication of the urgency of maintenance actions. The summary of the SDI assessment for the Wareng–Mukus Road Section is presented in Table 4.

Table 4. Road Condition Based on the Surface Distress Index (SDI)

SDI Condition	Length	Percentage
Good	8.26 km	100.00%
Fair	0.00 km	0.00%
Minor Damage	0.00 km	0.00%
Severe Damage	0.00 km	0.00%
Total	8.26 km	100.00%

Based on the SDI assessment, the entire road section is classified as being in good condition. The difference between the TTI and SDI results indicates that although the pavement surface remains in good condition, the maintenance trigger index suggests that preventive intervention should be considered. Therefore, the preliminary recommendation derived from the PKRMS analysis emphasizes preventive maintenance and routine maintenance, rather than rehabilitation.

Traffic Volume

Traffic volume was analyzed to determine the magnitude of traffic loading on the Wareng–Mukus Road Section. Within the PKRMS framework, traffic volume is an important indicator because repeated vehicle loading significantly influences pavement deterioration. Higher traffic intensity generally results in greater cumulative loading on the pavement structure, thereby accelerating pavement degradation. Consequently, the Average Annual Daily Traffic (AADT) value was used as one of the evaluation criteria for determining the appropriate maintenance strategy. The AADT values for the Wareng–Mukus Road Section are presented in Table 5.

Table 5. Average Annual Daily Traffic (AADT)

Indicator	Value
Total AADT (excluding motorcycles)	1,150
Motorcycle AADT	2,525

Although the road section is currently in relatively good condition, traffic volume remains an important consideration because repeated vehicle loading may accelerate pavement deterioration. Therefore, the AADT value was incorporated as one of the evaluation criteria in the AHP analysis.

Development of the AHP Hierarchy

The Analytic Hierarchy Process (AHP) was applied to determine the priority of maintenance alternatives for the Wareng–Mukus Road Section. The hierarchy consists of three levels: the goal at the first level, the evaluation criteria at the second level, and the maintenance alternatives at the third level.

Table 6. AHP Hierarchical Structure

Level	Element	Description

Level 1	Goal	Determine the priority maintenance strategy for the Wareng–Mukus Road Section
Level 2	Criteria	K1–K6 as defined in Chapter III
Level 3	Alternatives	Routine maintenance, preventive periodic maintenance, and minor rehabilitation

Table 7. AHP Hierarchical Structure (Continued)

Code		Criterion
K1		Road Condition
K2		Traffic Volume
K3		Connectivity
K4		Regional Development
K5		Connectivity to Economic and Agricultural Areas
K6		Connectivity to Public Service Facilities
Code	Maintenance Alternative	Description
A1	Routine Maintenance	Minor repairs, drainage cleaning, shoulder maintenance, and localized repairs
A2	Preventive Periodic Maintenance	Surface treatment to preserve pavement condition and prevent further deterioration
A3	Minor Rehabilitation	Structural strengthening or localized rehabilitation for sections requiring more extensive repair

AHP Questionnaire Data

The AHP questionnaire was distributed to six respondents. Each respondent assessed the relative importance of the evaluation criteria using Saaty's pairwise comparison scale. The individual judgments were then aggregated using the geometric mean (geomean) to obtain a single representative value for each pairwise comparison.

Table 8. Results of the AHP Questionnaire

Respondent	K1:K2	K1:K3	K1:K4	K1:K5	K1:K6
R1	2.00	3.00	5.00	3.00	4.00
R2	1.00	3.00	4.00	3.00	4.00
R3	2.00	2.00	5.00	3.00	3.00
R4	2.00	3.00	5.00	4.00	4.00
R5	1.00	2.00	4.00	3.00	3.00
R6	2.00	3.00	4.00	3.00	4.00
Geomean	1.587	2.621	4.472	3.147	3.634
Respondent	K2:K3	K2:K4	K2:K5	K2:K6	K3:K4
R1	2.00	4.00	2.00	3.00	3.00
R2	2.00	3.00	2.00	3.00	2.00
R3	2.00	4.00	2.00	3.00	3.00
R4	2.00	4.00	3.00	3.00	2.00
R5	1.00	3.00	2.00	2.00	2.00
R6	2.00	3.00	2.00	3.00	2.00
Geomean	1.782	3.464	2.140	2.804	2.289

Respondent	K3:K5	K3:K6	K4:K5	K4:K6	K5:K6

R1	2.00	2.00	0.50	1.00	2.00
R2	2.00	2.00	0.50	1.00	2.00
R3	2.00	2.00	0.33	0.50	2.00
R4	2.00	3.00	0.50	1.00	2.00
R5	1.00	2.00	0.50	1.00	2.00
R6	2.00	2.00	0.50	1.00	2.00
Geomean	1.782	2.140	0.467	0.891	2.000

The geometric mean values represent the aggregated judgments of all respondents. A value greater than 1 indicates that the first criterion is considered more important than the second criterion, whereas a value less than 1 indicates that the second criterion is considered more important than the first criterion.

Pairwise Comparison Matrix of the Evaluation Criteria

The pairwise comparison matrix was constructed using the geometric mean values obtained from the respondents' judgments. The matrix serves as the basis for calculating the priority weights of each evaluation criterion.

Table 9. Pairwise Comparison Matrix of the Evaluation Criteria

Criteria	K1	K2	K3	K4	K5	K6
K1	1.000	1.587	2.621	4.472	3.147	3.634
K2	0.630	1.000	1.782	3.464	2.140	2.804
K3	0.382	0.561	1.000	2.289	1.782	2.140
K4	0.224	0.289	0.437	1.000	0.467	0.891
K5	0.318	0.467	0.561	2.143	1.000	2.000
K6	0.275	0.357	0.467	1.122	0.500	1.000
Total	2.828	4.261	6.868	14.492	9.036	12.469

The pairwise comparison matrix was developed from the geometric mean values. The principal diagonal contains a value of 1.000, indicating that each criterion is equally important when compared with itself. The values below the principal diagonal are the reciprocals of the corresponding values above the diagonal.

Matrix Normalization and Criteria Priority Weights

The normalized matrix was used to determine the priority weight of each evaluation criterion, representing its relative importance in selecting the most appropriate maintenance strategy for the Wareng–Mukus Road Section. These priority weights were subsequently applied in evaluating the maintenance alternatives. The results of the matrix normalization and the priority weights are presented in Table 10.

Table 10. Normalized Matrix and Criteria Priority Weights

Criteria	K1	K2	K3	K4	K5	K6	Total	Weight	Percentage	Rank

K1	0.354	0.373	0.382	0.309	0.348	0.291	2.056	0.343	34.27%	1
K2	0.223	0.235	0.259	0.239	0.237	0.225	1.418	0.236	23.63%	2
K3	0.135	0.132	0.146	0.158	0.197	0.172	0.939	0.157	15.65%	3
K4	0.079	0.068	0.064	0.069	0.052	0.071	0.403	0.067	6.71%	6
K5	0.112	0.110	0.082	0.148	0.111	0.160	0.723	0.120	12.05%	4
K6	0.097	0.084	0.068	0.077	0.055	0.080	0.462	0.077	7.70%	5
Total	1.000	1.000	1.000	1.000	1.000	1.000	6.000	1.000	100.00%	

The normalized matrix indicates that Road Condition (K1) is the most influential criterion, accounting for 34.27% of the overall priority weight. Traffic Volume (K2) ranks second with a weight of 23.63%, followed by Connectivity (K3) with 15.65%. Connectivity to Economic and Agricultural Areas (K5) contributes 12.05%, Connectivity to Public Service Facilities (K6) accounts for 7.70%, while Regional Development (K4) has the lowest priority weight of 6.71%.

Consistency Test of the AHP Matrix

The consistency test was conducted to verify that the pairwise comparison judgments provided by the respondents were logically consistent and not randomly assigned. In the AHP method, the calculated priority weights are considered valid only if the Consistency Ratio (CR) is less than 0.10. The consistency analysis involved calculating the maximum eigenvalue (λmax), Consistency Index (CI), Random Index (RI), and Consistency Ratio (CR). The results are presented in Table 11.

Table 11. Consistency Test Results of the AHP Matrix

Component	Value
Maximum Eigenvalue (λmax)	6.058
Consistency Index (CI)	0.0116
Random Index (RI)	1.24
Consistency Ratio (CR)	0.0094

The calculated Consistency Ratio (CR) is 0.0094, which is substantially lower than the acceptable threshold of 0.10. Therefore, the pairwise comparison matrix is considered consistent, indicating that the respondents' judgments are reliable. Consequently, the derived priority weights are valid and can be used in determining the priority maintenance strategy for the Wareng–Mukus Road Section.

CONCLUSION

Based on the research findings, the integration of the Analytical Hierarchy Process (AHP) and the Provincial/Kabupaten Road Management System (PKRMS) successfully provide an objective framework for determining road maintenance priorities on the Wareng–Mukus Road Section in Pacitan Regency. The results indicate that road condition is the most dominant criterion influencing maintenance decisions, with a priority weight of 34.27%, followed by traffic volume (23.63%), connectivity (15.65%), economic and agricultural corridor function (12.05%), access to public service facilities (7.70%), and regional development (6.71%). The PKRMS assessment shows that the road section remains serviceable, with the Surface Distress Index (SDI) categorizing the entire 8.26 km section as good condition, while the Treatment Trigger Index (TTI) indicates the need for preventive maintenance to avoid future deterioration. These findings confirm that road maintenance prioritization should consider not only the technical condition of pavement but also the strategic function of roads in supporting mobility, economic activities, public accessibility, and sustainable regional development. The combination of AHP and PKRMS provides a systematic, transparent, and data-driven approach that can assist local governments in optimizing limited maintenance budgets and improving road asset management decisions. Future research is recommended to expand the scope of analysis by involving multiple road sections with different characteristics to enable comparative evaluation and broader validation of the proposed prioritization framework. Further studies may also incorporate additional variables, such as road safety indicators, environmental factors, climate-related risks, vehicle load variations, and long-term maintenance cost analysis to improve the comprehensiveness of decision-making models. The involvement of a larger number and wider range of expert respondents is also suggested to strengthen the reliability of AHP weighting results. In addition, future researchers may integrate advanced decision-support methods, such as Geographic Information Systems (GIS), machine learning, or dynamic asset management models, to develop more adaptive and predictive road maintenance strategies. Such improvements are expected to support more efficient infrastructure planning and contribute to sustainable transportation development at regional and national levels.

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