Analysis of Priority Provincial Road Sections in East Java Province Using Analytical Hierarchy Process Based on the Provincial/District Roads Management System

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ABSTRACT
The management of transportation infrastructure plays a vital role in supporting regional connectivity and sustainable development. However, limited government budgets often constrain the ability to maintain the entire road network, requiring a decision-making model that can objectively determine maintenance priorities. This research aims to determine the priority order of provincial road segments requiring maintenance within the UPT PJJ Malang area by integrating the Analytical Hierarchy Process (AHP) method with the Provincial/Kabupaten Roads Management System (PKRMS). The study adopts a quantitative descriptive method that combines technical data from PKRMS with expert-based weighting analysis through AHP. The expected outcome is a decision-support model that can rank road segments according to their strategic, technical, and socio-economic importance. This approach not only supports transparent and efficient infrastructure management but also provides an applied learning framework for vocational engineering education, fostering smart and sustainable human resources in the field of transportation infrastructure management.

Keywords: *Analytical Hierarchy Process (AHP), Provincial/District Roads Management System (PKRMS), Multi Criteria Analysis (MCA), infrastructure management, transportation integration*

1. INTRODUCTION

Transportation networks are the backbone of regional and national development, serving as the foundation for economic activities, logistics, tourism, and social mobility. In developing regions such as East Java Province, Indonesia, road infrastructure plays a critical role in linking industrial centers, agricultural zones, and urban settlements. Efficient road management directly contributes to reducing logistics costs, supporting equitable economic growth, and enhancing public access to essential services. However, over the past decade, the condition of many provincial roads has declined due to a combination of aging infrastructure, increasing vehicle loads, and the delayed implementation of maintenance programs. Limited government budgets often result in uneven distribution of maintenance funding, where resources are concentrated on a few major corridors while secondary roads deteriorate rapidly. This imbalance leads to reduced accessibility, slower economic distribution, and increased transportation costs. Therefore, identifying which road segments should be prioritized for maintenance has become an urgent issue for regional infrastructure agencies.

The Provincial/District Roads Management System (PKRMS) has been adopted by the East Java Provincial Public Works Department as a key decision-support platform for road asset management. PKRMS collects and manages comprehensive data on road inventory, condition, traffic volume, and maintenance history. The system uses indicators such as the Pavement Condition Index (PCI) to categorize road quality from excellent to poor. Although PKRMS provides reliable technical data, its limitation lies in its inability to capture non-quantitative aspects such as socio-economic function, policy priorities, and regional connectivity that significantly influence the urgency of maintenance interventions.

To overcome these limitations, the Analytical Hierarchy Process (AHP) is integrated into the analysis framework. AHP, developed by Thomas L. Saaty in the 1970s, is a multi-criteria decision-making method that helps decision-makers structure complex problems into hierarchical levels of criteria and sub-criteria. By allowing experts to perform pairwise comparisons, AHP quantifies subjective judgments into objective priority scales. This capability is essential for infrastructure planning, where decisions often involve trade-offs between technical, financial, and socio-economic factors.

Integrating AHP with PKRMS offers several potential advantages. First, it allows the inclusion of qualitative judgment from experts, such as the importance of a road's connectivity to airports, ports, or economic centers, alongside quantitative PCI data. Second, it introduces a transparent and consistent weighting mechanism that improves decision accountability. Third, it creates a replicable framework that can be adapted by other regions or institutions to improve maintenance decision-making processes. From a broader perspective, this integration supports the vision of developing an intelligent transportation management system that promotes sustainability and resilience. As Indonesia transitions toward a more data-driven governance model, the combination of PKRMS and AHP aligns with the concept of smart infrastructure management, where digital tools and analytical methods are used to enhance service delivery and resource allocation.

Furthermore, this study also carries an educational dimension, particularly within the field of vocational engineering and applied sciences. The implementation of data-based decision-making models such as AHP-PKRMS can serve as an applied learning example in civil engineering education, fostering students' analytical thinking and technical problem-solving skills. By linking academic research with real-world infrastructure management practices, vocational institutions can better prepare graduates to address modern challenges in sustainable transportation systems.

In summary, this study seeks to develop a transparent, data-driven, and policy-sensitive model for determining road maintenance priorities in the UPT PJJ Malang region. The integration of PKRMS and AHP is expected to produce a practical framework that not only enhances infrastructure management efficiency but also contributes to Indonesia's broader agenda of integrating transportation networks particularly between road and aviation systems to promote human development and national competitiveness.

2. LITERATURE REVIEW

2.1. Analytical Hierarchy Process (AHP) in Infrastructure Decision-Making

The Analytical Hierarchy Process (AHP), developed by Saaty (2000), is a structured technique designed to assist complex decision-making processes involving multiple and often conflicting criteria. It decomposes a decision problem into a hierarchy, allowing comparisons between elements based on their relative importance. AHP uses a scale of 1 to 9 to measure preferences, where 1 indicates equal importance and 9 indicates extreme importance of one element over another.

In infrastructure planning, AHP is particularly useful for prioritizing maintenance projects, evaluating investment options, and assessing risk. Several studies have successfully implemented AHP in transportation management. For example, Irawan and Suprapto (2020) applied AHP to optimize the allocation of limited road maintenance budgets by incorporating both technical and socio-economic considerations. Their study demonstrated that roads connecting public service facilities and economic centers tend to receive the highest priority scores. Similarly, Halich et al. (2023) confirmed that AHP's hierarchical structure enhances transparency and reproducibility in infrastructure-related decision-making, providing a more objective foundation compared to subjective administrative judgment.

AHP's strength lies in its ability to convert qualitative assessments into quantitative values through a systematic consistency check using the Consistency Ratio (CR). A CR value less than or equal to 0.1 indicates that expert judgments are consistent enough to be considered valid. This makes AHP highly suitable for problems involving multidisciplinary evaluation criteria, such as transportation infrastructure, where decisions depend on engineering conditions, socio-economic impacts, and government policies.

The AHP framework for this research consists of three hierarchical levels:

a. Level 1: Goal
   Determining the priority of provincial road maintenance in the UPT PJJ Malang region.
b. Level 2: Criteria
   Road Condition, Connectivity, Accessibility, Economic Importance, Public Service, and Policy Relevance.
c. Level 3: Alternative
   Specific road segments identified within the PKRMS database (e.g., Malang–Blitar Road, Kepanjen–Turen Road, Lawang–Singosari Road, etc.).

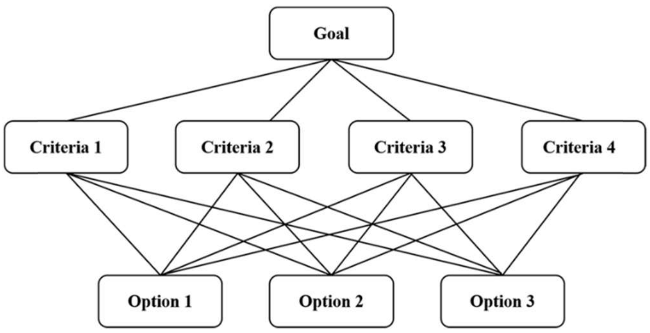

Figure 1 AHP Framework

2.2. Provincial/District Roads Management System (PKRMS)

The Provincial/District Roads Management System (PKRMS) is an integrated platform designed to manage road asset data for both provincial and district levels in Indonesia. It was developed to standardize data collection and analysis related to road networks, conditions, and maintenance activities under the Directorate General of Highways (Direktorat Jenderal Bina Marga). PKRMS includes several key components: road inventory data, pavement condition assessment (typically using PCI values), traffic volume data, and maintenance history. According to Bappenas (2023), the system plays a central role in supporting evidence-based decision-making in infrastructure planning. By providing a digital platform for monitoring and evaluating road conditions, PKRMS helps local governments identify road segments requiring urgent repair, rehabilitation, or preservation.

Despite its benefits, PKRMS's limitation lies in its analytical scope. The system primarily relies on numerical condition data and does not include qualitative parameters, such as strategic economic connectivity or regional policy priorities. Consequently, while PKRMS can provide a technical diagnosis, it lacks the capacity to deliver a holistic prioritization framework that considers broader development objectives.

2.3. Integration of AHP and PKRMS

Integrating AHP with PKRMS offers a comprehensive solution for improving road maintenance decision-making. The synergy between these two systems allows technical condition data (from PKRMS) to be evaluated alongside qualitative and policy-driven factors (through AHP). The resulting hybrid model provides decision-makers with a multi-dimensional perspective on infrastructure priorities. According to research by Halich et al. (2023), the integration of data-based management systems and multi-criteria decision-making methods improves accuracy and fairness in resource allocation. Roads that serve multiple strategic functions such as connecting airports, ports, or industrial zones an be identified and prioritized using a combination of PCI scores and expert judgment weights. This integration reduces the risk of bias and ensures that infrastructure investment decisions align with both technical needs and socio-economic goals.

Moreover, the combined PKRMS-AHP framework contributes to sustainable transportation planning. As noted by Bappenas (2023), sustainability in infrastructure not only refers to physical longevity but also includes economic efficiency, social inclusivity, and environmental responsibility. Through AHP-PKRMS integration, decision-makers can incorporate sustainability indicators, such as accessibility to rural areas, reduction in vehicle emissions, and enhancement of mobility equity.

3. RESEARCH METHODOLOGY

3.1. Research Flowchart

The overall research methodology can be visualized in the flowchart below:

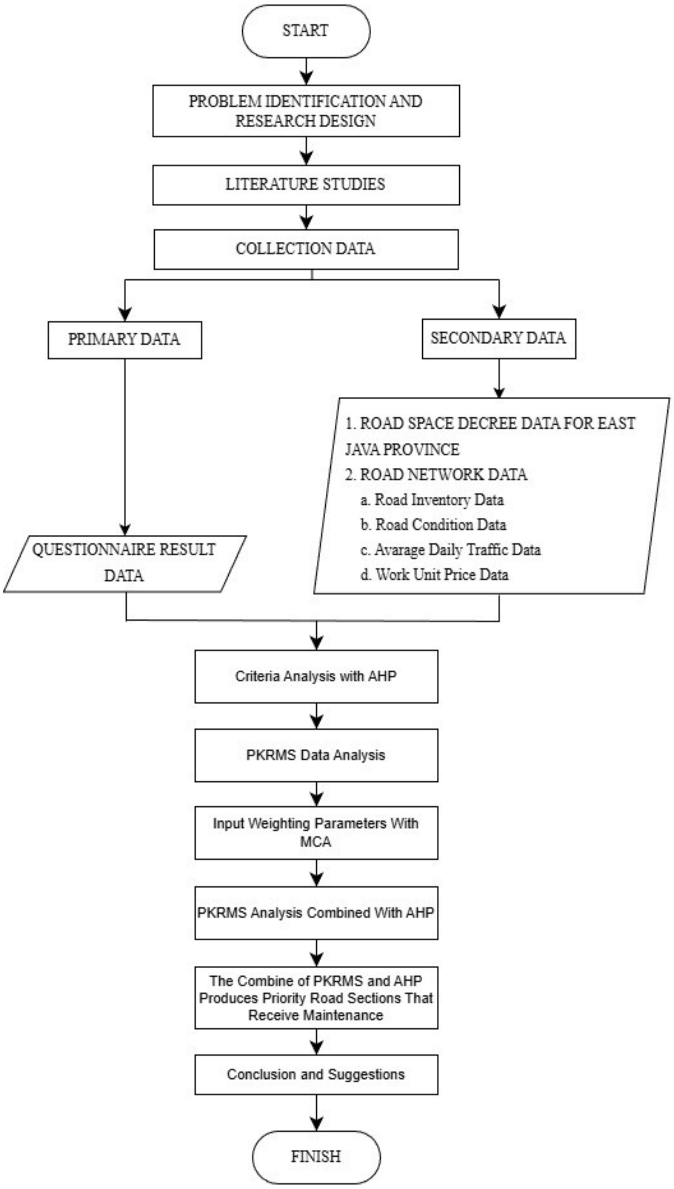

Figure 2 Research Flow Diagram

3.2. Research Population and Sample

The research population includes all provincial road segments within the working area of UPT PJJ Malang that are registered in the Provincial/District Roads Management System (PKRMS) and have complete data regarding pavement conditions, road length, classification, and recommended maintenance actions.

The population was determined using the expert choice approach, which involves selecting respondents with relevant expertise and experience in road management. This approach was chosen because the Analytical Hierarchy Process (AHP) relies on expert judgment to produce valid weighting results that reflect real conditions (Saaty, 1990). The expert population consists of 147 employees of the East Java Provincial Public Works and Highways Department.
The research sample was selected from this population for further analysis. The number of samples was determined using the Slovin formula with a 15% margin of error, resulting in 36 respondents representing the overall population. Sample selection considered data completeness and the representativeness of road conditions across the UPT PJJ Malang area. The respondents included employees with technical, administrative, and policy-related understanding of road management. Therefore, the results of this study are expected to accurately and systematically reflect the priority of provincial road maintenance using the AHP method.

3.3. Data Collection Procedures

Procedures data collection in this research was carried out by:

1. Primary Data, is data from a questionnaire regarding road sections in UPT PJJ Malang.
2. Secondary data includes East Java Province Road Space Decree Data, road network data which includes: road inventory data, road condition data, average daily traffic data (LHR), work unit price data.

3.4 Criteria Analysis using the AHP Method

This stage aims to determine the relative importance weight between the criteria used in priority assessment. The criteria used include:

1. Road conditions: assess the level of damage that has occurred on the road surface. Condition assessment is carried out based on pavement quality categories, namely good, moderate, slightly damaged and heavily damaged, which shows the extent to which the road is still suitable for use and requires maintenance or repair action.
2. Priority Areas: Priority areas refer to the strategic development zones of East Java Province, which serve as the main focus of regional growth. These include the Gerbangkertosusila area (Gresik, Bangkalan, Mojokerto, Surabaya, Sidoarjo, and Lamongan), the Bromo Tengger Semeru region, as well as the Selingkar Wilis area and the Southern Cross Route. Road segments located within these areas play a crucial role in supporting economic development, tourism activities, and enhancing regional connectivity.
3. Connectivity: Connectivity represents the function of a road segment in linking different areas, such as cities, districts, or centers of economic activity. This criterion reflects the importance of a road in facilitating the movement of people, goods, and services, thereby strengthening the overall transportation network and regional integration.
4. Level Of Service (LoS)
   The level of service assesses the ability of a road segment to accommodate traffic flow, determined by the comparison between Average Daily Traffic (ADT) and the road's capacity. Roads with a low level of service are typically characterized by traffic congestion, high vehicle density, and reduced travel speeds, indicating the need for capacity improvements or geometric enhancements to restore optimal performance.
5. Accessibility
   Accessibility measures the ease with which people can reach specific areas or public facilities through the existing road network. This aspect highlights the role of roads in connecting strategic locations, such as government centers, educational institutions, healthcare facilities, markets, and other socio-economic activity areas, thereby supporting community mobility and regional development.
6. Policy
   Policy reflects the direction of road infrastructure development established by the regional or provincial government. The assessment is carried out by examining the alignment of each road segment with official planning documents, such as the Regional Medium-Term Development Plan (RPJMD) and the Regional Spatial Plan (RTRW), which serve as the foundation for determining road infrastructure handling priorities.

Each expert respondent provided a pairwise comparison assessment among the criteria using the Saaty scale (1–9), where a value of 1 indicates equal importance between criteria and 9 signifies that one criterion is extremely more important than the other. The questionnaire data were then processed to obtain the pairwise comparison matrix, the maximum eigenvalue, the priority weight for each criterion, and the consistency ratio (CR) to evaluate the reliability of the judgments. The results are considered consistent if $CR \leq 0.1$, if the CR value exceeds 0.1, the assessments must be revised until consistency is achieved. The final weights derived from this process are subsequently used as weighting factors in the next stage of analysis.

3.5 PKRMS Data Analysis

The secondary data used in this study were obtained from the Provincial/District Roads Management System (PKRMS) managed by the East Java Provincial Public Works and Highways Department, specifically within the working area of UPT Road and Bridge Management (PJJ) Malang. The data include:

1. The length and classification of provincial road segments,
2. Road condition ratings (good, fair, minor damage, severe damage),
3. Road condition strip maps,
4. Average Daily Traffic (ADT) volumes, and
5. Road maintenance cost estimates.

The analysis of PKRMS data produces a road condition value that reflects the level of pavement performance and the estimated maintenance requirements whether routine, periodic, or reconstruction works. These data are processed to generate initial condition indicators that describe the existing state of the road network. Each parameter is quantified into a condition score or index, enabling integration with the Analytical Hierarchy Process (AHP) model for determining road maintenance priorities.

3.6 Integration Analysis of PKRMS and AHP

In order to establish a comprehensive and objective prioritization of provincial road maintenance, this study integrates technical performance data obtained from the Provincial/Kabupaten Roads Management System (PKRMS) with non-technical evaluation criteria derived from the Analytical Hierarchy Process (AHP) within the analytical framework of Multi-Criteria Analysis (MCA). The MCA approach serves as a structured decision-support framework that consolidates multiple technical and strategic indicators into a unified, quantifiable assessment system, ensuring that the prioritization process is rational, transparent, and accountable.

Multi-Criteria Analysis (MCA) is a systematic decision-making methodology designed to evaluate and rank alternatives based on multiple, often conflicting, criteria with varying degrees of importance. Within the scope of this research, MCA functions as an integrative platform that combines:

1. Quantitative data from PKRMS, representing the physical and functional performance of road segments such as International Roughness Index (IRI), Pavement Condition Index (PCI), Road Condition Index (RCI), and Average Daily Traffic (ADT/LHR); and
2. Weighted criteria from AHP, reflecting non-technical and strategic considerations, including network connectivity, development priority zones, service level, accessibility, and alignment with regional transport policy.

Through the MCA framework, both datasets are synthesized to produce a composite priority score that quantifies the relative urgency of maintenance interventions for each provincial road segment. The integration procedure involves combining the technical score from PKRMS (T_i) and the non-technical score from AHP (N_i) within the MCA model. The process includes data normalization, weight allocation, and the aggregation of weighted criterion scores for each alternative road segment.

The MCA computation model is formulated as follows:

$$S_i = \sum_{j=1}^{n} \quad (W_j \times X_{ij})$$

where:
S_i = total priority score of road segment i
W_j = weight of criterion j (obtained from AHP)
X_{ij} = performance or condition value of road segment i under criterion j (derived from PKRMS)
n= total number of evaluation criteria.

The resulting value of S_i represents a final integrated priority index, capturing both technical and strategic dimensions of road performance. This index serves as the basis for ranking and categorizing road segments according to their respective maintenance priorities

The final outcome of this analysis not only identifies the road segments that require immediate maintenance interventions but also provides a strategic foundation for budgeting and maintenance program planning by the Public Works and Highways Department (Dinas Pekerjaan Umum dan Bina Marga) of East Java Province. The combined application of the Provincial/Kabupaten Roads Management System (PKRMS) and the Analytical Hierarchy Process (AHP) ensures that the decision-making process is conducted in an objective, quantitative, and transparent manner, thereby producing reliable and evidence-based **results** that can serve as a reference for determining future provincial road maintenance priorities.

4. ANALYSIS RESULT

At this stage, the research has developed a comprehensive model that integrates the Analytical Hierarchy Process (AHP) with the Provincial/Regency Road Management System (PKRMS) to determine the priority of provincial road sections requiring treatment within the UPT PJJ Malang area. Since the implementation and validation processes have not yet been completed, this section presents the expected analytical results that are likely to be obtained after the full analysis is conducted.

In line with the objectives previously described, this study aims to:

1. Develop a transparent and data-based model to determine the priority of provincial road sections requiring maintenance or improvement.
2. Produce consistent and measurable weights for the six selected evaluation criteria.
3. Integrate these criteria with PKRMS road condition data to generate a priority ranking of provincial road sectors that require maintenance or intervention.

4. Provide a replicable framework that can be adopted by other regions or used as a decision-support tool by the Public Works and Highways Department.

The following subsections describe the expected analytical results for each criterion, based on a review of relevant literature, preliminary PKRMS data, and expert opinions collected during the research process.

5. CONCLUSION

This study is expected to produce a comprehensive and objective model for determining the priority of provincial road maintenance through the integration of the Analytical Hierarchy Process (AHP) and the Provincial/Kabupaten Roads Management System (PKRMS) within the framework of Multi-Criteria Analysis (MCA). This integrated approach is anticipated to combine the strength of technical data from PKRMS with non-technical criteria derived from AHP, including connectivity, priority areas, road service levels, accessibility, and regional policy.

The expected outcome of this study is the development of a composite priority ranking for provincial road segments within the UPT PJJ Malang region, representing a balanced consideration between technical conditions and strategic importance. Accordingly, road segments that play a critical role in regional connectivity, economic activity, and public service are expected to be prioritized according to their respective levels of urgency.

Furthermore, this integrated model is expected to serve as a data-driven decision-support tool for road management authorities. By applying AHP and PKRMS approach, the prioritization process can become more transparent, objective, and consistent, thereby supporting the enhancement of provincial road network performance in a sustainable and accountable manner.

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