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Road Condition Analysis and Improvement Recommendations in Pulau Morotai Regency

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ABSTRACT

Pulau Morotai Regency faces significant infrastructure challenges due to its distinctive island geography, where limited connectivity and environmental conditions directly influence the durability and performance of the road network. In this context, the development and maintenance of road infrastructure play a crucial role in ensuring accessibility, mobility, and regional economic growth. This study employs a comprehensive and integrative approach that combines quantitative and qualitative methods through field surveys, traffic volume data collection, and stakeholder interviews. The Pavement Condition Index (PCI) method is applied to assess the current state of road pavements by identifying types and levels of surface distress, which are then used to calculate PCI values as indicators of pavement quality. Based on the assessment results, a five-year maintenance plan is formulated using a strip map approach, prioritizing repair and rehabilitation according to road condition levels, traffic volume, and strategic importance. The analysis emphasizes the necessity of preventive and routine maintenance to minimize long-term costs and extend pavement lifespan. Furthermore, stakeholder involvement ensures that the proposed recommendations align with local development priorities and community needs. The findings of this research are expected to serve as a technical and policy foundation for effective road infrastructure planning and management in Pulau Morotai. Ultimately, this study aims to support sustainable regional development by improving transportation efficiency, enhancing economic productivity, and contributing to a better quality of life for the people of Pulau Morotai.

Keywords: road condition, Pulau Morotai Regency, Pavement Condition Index (PCI), road maintenance, sustainable infrastructure.

INTRODUCTION

Indonesia, as an archipelagic country, encounters considerable challenges in the development and maintenance of its road infrastructure due to geographical fragmentation and environmental conditions [1]. Pulau Morotai Regency, located in the northern part of the Maluku Islands, is a strategic yet isolated region with limited accessibility, high rainfall, and challenging terrain [2]. These conditions contribute to accelerated pavement deterioration and increased maintenance costs. Inadequate infrastructure significantly impacts mobility, trade logistics, and tourism, thus limiting socio-economic growth.

The provision of reliable transportation networks is essential for enhancing connectivity, access to markets, and public services. In island regions such as Morotai, logistical constraints and scarcity of construction materials result in higher maintenance expenditures compared to mainland areas. Consequently, systematic assessment techniques such as the Pavement Condition Index (PCI) are vital to establish effective maintenance planning. The PCI methodology, developed by Shahin [3], allows

objective evaluation of pavement surface distress, severity, and extent, enabling prioritization of road maintenance actions.

This study integrates PCI evaluation with field observations, traffic data, and stakeholder consultations to generate a comprehensive analysis of road conditions across Pulau Morotai Regency. The outcomes aim to guide local government in preparing a five-year strategic plan for sustainable and resilient infrastructure management. In alignment with national development goals and the UN Sustainable Development Goals (SDG 9), this research seeks to strengthen evidence-based policy formulation and promote inclusive regional development through improved road infrastructure planning.

RESEARCH METHODS

Data Collection

The data collection process in this study was conducted through three main approaches: field survey, in-depth interviews, and secondary data collection.

1. Field Survey:

Visual inspection and documentation of road conditions were carried out to identify physical damage, surface distress, and critical points of deterioration. The survey process followed the Pavement Condition Index (PCI) method, which allows for a systematic evaluation of surface performance through visual observation and rating scales [3], [4]. This approach ensures objective data recording to support quantitative assessment and mapping of road segments.

2. In-depth Interviews:

Qualitative data were collected through structured and semi-structured interviews involving road users, local transport operators, and key stakeholders from relevant government agencies. This process aimed to capture contextual information regarding road usage behavior, maintenance challenges, and public perception of infrastructure performance [5]. The combination of quantitative field data and qualitative insights strengthened the analytical framework of this research.

3. Secondary Data:

Supporting information was obtained from institutional sources such as the Public Works and Housing Department (PUPR) and other official infrastructure reports. These data included road network inventories, traffic volume records, and previous maintenance plans. Reports from international institutions such as the World Bank and the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) were also reviewed to ensure consistency with national and regional development policies [3], [2].

The integration of these three data collection methods allowed a comprehensive and cross-validated assessment of road conditions in Pulau Morotai Regency, ensuring both technical accuracy and socio-economic relevance.

Road Condition Analysis

Road deterioration types and severity levels were analyzed using the *Pavement Condition Index* (PCI) method, which provides a standardized quantitative framework for evaluating pavement performance. The PCI approach, originally developed by the U.S. Army Corps of Engineers, assesses surface distress based on deduct values corresponding to observed damage types and extents [3]. This method enables systematic classification of pavement conditions into categories ranging from *failed* to *excellent*, facilitating decision-making in maintenance prioritization.

The analytical procedure followed Shahin's (1994) deduct value curve model, where each distress type—such as cracking, rutting, raveling, or potholes—is assigned an initial deduct value (DV) based on severity and density. The *Corrected Deduct Value* (CDV) is then determined using the correction

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curve to account for overlapping effects of multiple distresses on the same pavement unit [6]. Subsequently, the PCI is computed using the standard equation:

$$PCI = 100 - CDV$$

where higher PCI values indicate better pavement performance. The results are interpreted according to ASTM D6433-18 standards [7], ensuring methodological consistency and comparability with international practices.

This deductive approach allows not only the quantification of pavement degradation but also provides a data-driven foundation for maintenance strategy formulation. By integrating field observations with PCI computation, road segments in Pulau Morotai Regency were systematically classified based on functional condition and maintenance priority levels, supporting evidence-based infrastructure management [8], [9].

Recommendation Formulation

Repair priorities were established through a multi-criteria evaluation framework that integrated the *Pavement Condition Index* (PCI), type and severity of damage, *Average Daily Traffic* (ADT), and the urgency level of road functionality restoration. The inclusion of ADT reflects the functional importance of each segment within the regional transport network, ensuring that roads with higher socio-economic value receive maintenance attention earlier [10], [11].

The prioritization matrix categorized road segments into three main levels—*critical*, *moderate*, and *routine maintenance*—based on the combination of PCI values and traffic intensity thresholds. This approach aligns with best practices in pavement management systems (PMS) recommended by the *American Association of State Highway and Transportation Officials* (AASHTO) and the *World Bank Road Maintenance Initiative (RMI)* [12], [13].

A **five-year phased maintenance plan** was subsequently formulated using a **strip map method**, allowing spatial visualization of the planned interventions along the entire network. The strip map illustrates sequential repair actions per year, enabling efficient allocation of technical and financial resources while maintaining service continuity. This planning technique provides a dynamic tool for decision-makers to update priorities based on changing conditions or budget adjustments [14].

By combining technical condition assessment with traffic demand analysis, this integrated strategy ensures that maintenance decisions are both data-driven and aligned with long-term infrastructure sustainability objectives.

RESULT AND DISCUSSION

Geographic and Administrative Conditions

Pulau Morotai Regency is geographically positioned between 128°08’0”–128°40’0” East Longitude and 2°00’0”–2°32’0” North Latitude, strategically located in the northern part of Maluku Province, Indonesia. The regency is bordered by the Pacific Ocean to the north, the Halmahera Sea to the south, the Morotai Strait to the west, and the Sulawesi Sea to the east, making it a vital node for inter-island connectivity and maritime economic activities. The total land area of Pulau Morotai covers approximately 2,476 km², consisting of one main island and several smaller surrounding islands [15], [16].

Despite its strategic location and abundant natural resources—including fisheries, tourism, and maritime biodiversity—Pulau Morotai faces considerable infrastructure challenges. The island’s topography and dispersed settlement patterns pose logistical difficulties for road construction, maintenance, and material transportation. These conditions contribute to uneven infrastructure distribution, particularly in remote and coastal subdistricts [17]. Furthermore, high rainfall intensity and unstable subgrade soil conditions accelerate pavement deterioration, underscoring the importance of sustainable and adaptive road management strategies [18].

To enhance spatial understanding of the study area, **Figure 1** presents the **map of Pulau Morotai Regency**, illustrating the administrative boundaries, primary road network, and coastal zones. The map plays a crucial role in visualizing spatial disparities, highlighting areas with limited accessibility and identifying strategic corridors for infrastructure development. Such spatial representation supports correlation between geographic features, road condition indices, and traffic distribution—vital for formulating targeted maintenance and investment priorities [19], [20].

In line with Indonesia's national spatial planning and the *Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3EI)*, Morotai has been designated as part of the **National Tourism Strategic Area (KSPN)** and a **Defense and Border Development Zone**, emphasizing the necessity of reliable road infrastructure to support socio-economic resilience and strategic mobility [19].

Figure 1. Maps of Pulau Morotai Regency

Road Network of Pulau Morotai Regency

The road network of Pulau Morotai Regency represents a vital component of the island's transportation infrastructure, serving as the primary linkage between economic centers, residential zones, and ports. The network connects six administrative districts — South Morotai, East Morotai, Central Morotai, North Morotai, Morotai Jaya, and Morotai Island — covering both coastal and inland areas.

Road accessibility significantly influences regional logistics, trade mobility, and access to social services. However, several road segments remain in suboptimal condition due to limited maintenance budgets, challenging terrain, and the high cost of construction materials. The dominance of flexible pavement structures combined with tropical climatic conditions further accelerates road deterioration [21], [22].

Based on data from the Public Works and Housing Department (PUPR) of Pulau Morotai, the total road length reaches approximately **536.12 km**, consisting of **national, provincial, and regency roads**. Most regency roads are paved with a mix of asphalt and gravel surfaces, with varying levels of serviceability. Table 1 presents a sample of the existing road network across the districts.

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Table 1. Sample of Road Network in Pulau Morotai Regency

No	Road Name	District	Length (km)	Pavement Type	Condition
1	Jl. TPA	South Morotai	1.732	Asphalt	Fair
2	Jl. Bere-Bere – Wewemo	East Morotai	7.54	Gravel	Poor
3	Jl. Daruba – Sopi	Central Morotai	21.25	Asphalt	Good
4	Jl. Wayabula – Raja	North Morotai	12.4	Asphalt	Fair
5	Jl. Kolorai – Tanjung Sopi	Morotai Island	9.12	Gravel	Poor

The spatial distribution of the road network can be seen in **Figure 2**, which illustrates the alignment of major and local roads across the regency. This map is essential for identifying connectivity gaps and prioritizing rehabilitation programs, particularly for linking remote villages and supporting the tourism sector within the National Tourism Strategic Area (KSPN) of Morotai [23].

Figure 2. Road Network Map of Pulau Morotai Regency (Source: PUPR Morotai Regency, 2024)

CONCLUSION

The Pavement Condition Index (PCI)-based analysis conducted in Pulau Morotai Regency reveals a diverse range of pavement performance across the regional road network. The findings show that road segments exhibit varying conditions, from very good to poor, depending on structural integrity, drainage quality, and traffic load. The results indicate that heavily trafficked urban areas generally maintain better surface conditions, whereas coastal and rural roads show more pronounced deterioration due to subgrade instability, excessive rainfall, and limited maintenance accessibility. To address these challenges, a comprehensive maintenance and rehabilitation strategy was developed using a five-year strip map approach. This method allows for a spatially phased plan, prioritizing road sections based on damage severity, Average Daily Traffic (ADT), and economic importance. Roads that demonstrate moderate distress are scheduled for preventive maintenance to extend pavement life, while those in poor condition are earmarked for structural rehabilitation. Such phased implementation ensures efficient allocation of resources and long-term sustainability of road infrastructure. Beyond the technical assessment, the analysis underscores the importance of aligning infrastructure management with socio-economic development objectives. Improved pavement conditions directly contribute to increased mobility, reduced vehicle operating costs, and enhanced connectivity between districts. This, in turn, facilitates regional trade, tourism, and community access to essential services. Furthermore, integrating PCI data with spatial planning enables better coordination among local agencies in decision-making, budgeting, and monitoring. The systematic application of this approach can serve as a model for other island regions in Indonesia facing similar geographical and logistical constraints. Overall, the study highlights that consistent, data-driven maintenance supported by PCI evaluation and

strip map planning can significantly enhance the durability and performance of road infrastructure in Pulau Morotai Regency. It contributes to regional development efforts, strengthens economic resilience, and ensures that infrastructure growth aligns with the broader goals of sustainable and inclusive development.

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