



Rethinking Road Infrastructure Governance: Policy Priorities for Sustainable Improvement and Maintenance

Dwi Putranto Riau*

Universitas Terbuka, Indonesia

DOI: <https://doi.org/10.61987/jsse.v4i2.3079>

Article History:

Received: 15 May 2026

Revised: 11 July 2026

Accepted: 12 August 2026

Keywords:

*road maintenance,
infrastructure policy,
sustainable road management*

*Correspondence Address:

dwiputranto@ecampus.ut.ac.id

Abstract:

Road improvement and maintenance are crucial components of infrastructure development because reliable road networks support mobility, economic growth, and poverty reduction. This study aims to identify and analyze policy priorities for improving and maintaining road infrastructure. The study employed a qualitative research approach to explore the perspectives and experiences of stakeholders involved in the road infrastructure sector. Data were collected through in-depth interviews and supported by relevant documents and previous studies, while thematic analysis was used to identify key policy priorities. The findings identify several interconnected priorities, including strategic road planning and quality targets, stakeholder coordination, maintenance prioritization, budget allocation, project supervision and evaluation, multilevel government coordination, community and private sector participation, technological innovation, periodic maintenance, human resource capacity, land use management, road information systems, road user safety, environmental impact mitigation, and performance monitoring. The findings imply that sustainable road management requires an integrated policy framework rather than fragmented interventions. Policymakers should therefore strengthen coordination, preventive maintenance, resource capacity, technological adoption, public participation, and accountability to improve the effectiveness and sustainability of road infrastructure management.

INTRODUCTION

Road infrastructure is a fundamental component of sustainable development because it enables the movement of people, goods, services, and economic activities across regions. Reliable roads connect communities with markets, workplaces, public services, and other infrastructure systems, making them essential to social and economic integration (Akbar et al., 2025; Solé-Pomies, 2023). However, the benefits of road infrastructure depend not only on construction but also on the capacity to manage projects effectively and maintain completed assets over time. Project manager competency is closely associated with project performance, indicating that managerial and institutional capacity shapes infrastructure outcomes (Issa et al., 2026). Thus, road development should be understood as a continuous governance challenge rather than a construction activity alone (Zakir et al., 2024; Zhong & Ren, 2025). Sustainable outcomes require effective planning, competent management, coordinated implementation, and systematic maintenance throughout the infrastructure life cycle.

The importance of road infrastructure becomes more evident when roads deteriorate or when maintenance systems fail to respond adequately to changing conditions. Poorly maintained roads can reduce mobility, increase travel burdens, constrain economic activity, and weaken access to essential services. The sustainability of road networks therefore depends on institutional capacity to identify maintenance needs, prioritize interventions, and allocate resources consistently (Hendra et al., 2023). Persistent maintenance challenges can become a major obstacle to sustainable development, while implementing routine road maintenance management systems can improve road performance. These conditions highlight the importance of systematic and continuous maintenance (Saleh et al., 2025). Therefore, road policy must move beyond an emphasis on new construction toward a balanced approach that integrates improvement, preservation, routine maintenance, performance monitoring, and long-term sustainability within a coherent policy framework.

Despite the recognized importance of road infrastructure, improving and maintaining roads remains a complex policy problem (Pangesti et al., 2024). Road projects involve multiple stages, including planning, permitting, financing, construction, supervision, maintenance, and evaluation, each of which may involve different institutions and stakeholders. Weak coordination across these stages can create delays, inefficiencies, and inconsistencies between policy objectives and implementation. Communication and coordination innovations can improve the performance of permitting processes related to spatial-use suitability, demonstrating how administrative coordination affects infrastructure-related implementation (Riau et al., 2024). At the project level, managerial competency is also important for project performance (Mairizal et al., 2023). These perspectives indicate that road improvement cannot be addressed through technical interventions alone. Policy effectiveness also depends on institutional coordination, managerial capacity, administrative efficiency, and the ability to connect strategic objectives with operational implementation.

In practice, road infrastructure management faces competing priorities involving development, maintenance, sustainability, and available resources. The pressure to expand infrastructure may encourage greater attention toward new projects, while existing roads simultaneously require routine and preventive maintenance to preserve their performance (Anastasiadou & Kehagia, 2025). Structured routine maintenance management improves road performance, reinforcing the need for maintenance systems that operate continuously rather than reactively (Triyono et al., 2024). At the same time, project performance depends on the competencies of those responsible for managing infrastructure development (Mairizal et al., 2023). These findings reveal an important field-level challenge: road infrastructure outcomes are influenced by the interaction of technical conditions, management capacity, institutional processes, and maintenance practices. Consequently, policies that treat road development and maintenance as separate activities may overlook important connections affecting infrastructure performance and sustainability.

The existing literature offers several important perspectives on road infrastructure policy. Project manager competency is relevant to project performance, emphasizing the human and managerial dimension of infrastructure delivery. Routine maintenance management improves road performance, underscoring the importance of

systematic maintenance. Road maintenance challenges can also become a major obstacle to sustainable development, highlighting the broader developmental consequences of inadequate maintenance (Tosulpa et al., 2025). Together, these perspectives indicate that sustainable road infrastructure requires more than physical construction; it requires capable management and effective maintenance systems. However, these perspectives primarily address particular dimensions of infrastructure performance. They provide important foundations for examining road policy. However, they do not fully explain how planning, coordination, financing, maintenance, stakeholder involvement, and innovation can be integrated into a comprehensive policy framework for road improvement and maintenance.

Other studies further emphasize the institutional and collaborative dimensions of infrastructure development. Communication and coordination can improve administrative performance in spatial-use permitting, illustrating the importance of institutional connectivity in infrastructure processes. Public-private partnerships also represent an important approach to transportation infrastructure development, particularly in toll road development. These perspectives suggest that road infrastructure policy increasingly requires collaboration beyond a single government institution. Nevertheless, coordination, partnership, management competency, and maintenance are often examined as separate concerns. This fragmentation leaves an analytical gap concerning how these dimensions can be brought together within a unified policy perspective. A more integrated understanding is therefore needed to explain how road improvement and maintenance policies can simultaneously address implementation capacity, institutional coordination, financing arrangements, maintenance performance, and stakeholder participation while supporting sustainable infrastructure outcomes.

This study addresses this gap by proposing an integrated perspective on road improvement and maintenance policy. Rather than examining construction, maintenance, management, coordination, and financing as isolated policy areas, the study argues that their effectiveness depends on how they interact within a broader governance framework. The novelty lies in connecting project management competency, systematic maintenance, institutional coordination, communication, and public-private collaboration as complementary elements of sustainable road infrastructure policy. The central argument is that improving road conditions requires policy priorities that link strategic planning with implementation capacity and long-term asset preservation. Accordingly, this study aims to identify and analyze the key policy priorities for improving and maintaining road infrastructure and to explain how these priorities can be integrated into a more coherent approach to sustainable road management. The study therefore contributes a policy-oriented framework for understanding road infrastructure beyond construction alone.

RESEARCH METHODS

This study employed a qualitative research approach using a case study design to examine policy priorities for road infrastructure improvement and maintenance (De Medeiros Pereira et al., 2024; Nugraha et al., 2025). A qualitative approach was selected because the study sought to understand how stakeholders involved in infrastructure development and management perceive, implement, and experience road infrastructure policies. The case study design enabled the research to examine the relationships among

planning, project management, maintenance, coordination, financing, and stakeholder involvement within the context of road infrastructure policy. The study was descriptive and interpretive, focusing on identifying recurring issues, policy priorities, and institutional challenges rather than measuring the statistical relationships between variables (Gbaguidi, 2026; Lei et al., 2025). This approach was considered appropriate for developing a comprehensive understanding of road infrastructure management because sustainable road performance involves interactions among technical, managerial, institutional, and policy dimensions. The analysis therefore emphasized stakeholders' experiences and perspectives on improving and maintaining road infrastructure over the long term.

The research focused on the road infrastructure sector and involved stakeholders with knowledge and experience related to road development, management, maintenance, and policy implementation. Participants were selected purposively based on their relevance to the research objectives and their involvement in road infrastructure processes. Data were collected primarily through in-depth interviews designed to obtain detailed information regarding policy implementation, maintenance priorities, coordination mechanisms, resource allocation, management capacity, stakeholder participation, and technological innovation. Interviews were conducted sequentially so emerging issues from earlier interviews could inform subsequent discussions. In addition to interview data, the study examined relevant policy documents, institutional documents, reports, and other supporting materials concerning road infrastructure improvement and maintenance (Agabu et al., 2023; Mohamed et al., 2025). Combining interview and documentary data enabled the researchers to compare stakeholder perspectives with documented policy and management practices, providing a broader basis for identifying the principal policy priorities and challenges.

Data were analyzed thematically through a systematic process of data condensation, data display, and conclusion drawing and verification. Interview transcripts and documentary materials were first reviewed repeatedly to identify information relevant to the research objectives. The data were then condensed by selecting, organizing, and categorizing statements and information related to road planning, project management competency, institutional coordination, maintenance management, financing, stakeholder participation, public-private collaboration, technological innovation, and sustainability (Triyono et al., 2024). The categorized data were subsequently displayed in thematic groupings to identify patterns, relationships, similarities, and differences across the collected information. The final stage involved interpreting the identified patterns and verifying the consistency of emerging findings across different data sources. This analytical process enabled the study to move from individual stakeholder experiences toward broader policy priorities for road infrastructure improvement and maintenance. The resulting themes were then used to formulate an integrated interpretation of sustainable road management and its implementation requirements.

RESULTS AND DISCUSSION

Results

This study identifies several major policy priorities to improve and maintain Indonesia's road infrastructure. The findings demonstrate that effective road management requires attention to interconnected technical, institutional, financial, social, and technological dimensions. The identified priorities are not independent

interventions but mutually reinforcing elements that collectively support sustainable road improvement and maintenance. The findings indicate that road policy should prioritize determining road quality standards and strategic planning; coordinating and integrating stakeholders; setting road maintenance priorities; and allocating adequate budgets. Furthermore, supervision and evaluation of road project implementation, coordination between central and regional governments, and increased community participation and private sector involvement emerged as important priorities. The findings also emphasize the use of technology, periodic maintenance of national and strategic roads, strengthening human resource capacity, regulation and law enforcement, road management information systems, road user safety and comfort, environmental impact mitigation, and performance monitoring as essential components of effective road governance.

Determination of Road Quality and Strategic Planning

The findings show that determining road quality and improving strategic planning constitute fundamental policy priorities. Road policies need to consider road user preferences, physical road conditions, accessibility, supporting facilities, road capacity, and regional development needs. Comprehensive, data-based planning is required to ensure road development and maintenance programs align with actual priorities. The findings also indicate the importance of integrating national, regional, and local road network planning. Mapping existing road conditions and identifying infrastructure needs are necessary to support appropriate decision-making. Road quality is therefore viewed not only in terms of physical pavement conditions but also in relation to accessibility, safety, user needs, and regional economic functions.

Coordination and Integration among Stakeholders

The study found that coordination and integration among stakeholders are essential for improving road conditions and implementing maintenance programs effectively. The findings emphasize the need for collaboration among government institutions responsible for infrastructure, transportation, regulation, and traffic management. Poor communication and fragmented institutional responsibilities may create inconsistencies between planning and implementation. Coordination between stakeholders is therefore necessary to align policies, programs, responsibilities, and available resources. The findings further demonstrate that integrated collaboration can support more effective implementation of road improvement and maintenance programs and reduce institutional overlap.

Road Maintenance Priorities and Budget Allocation

Road maintenance emerged as one of the most important priorities identified in the study. The findings indicate that inadequate maintenance can accelerate road deterioration, reduce road quality, disrupt mobility, and increase congestion. Regular, periodic maintenance is therefore necessary to preserve the condition and functionality of road infrastructure. Respondents also identified inadequate funding as a major obstacle, with some indicating that available maintenance budgets remain substantially below actual needs. The findings show that government funding should prioritize routine and preventive maintenance in addition to the construction of new road sections. Alternative financing mechanisms, including private participation, infrastructure

investment schemes, and other funding arrangements, were also identified as potential strategies for supporting sustainable road maintenance.

Supervision, Evaluation, and Coordination between Levels of Government

The findings indicate that adequate funding alone is insufficient without effective supervision and evaluation. Road construction and maintenance projects require systematic monitoring to ensure that implementation meets established quality standards and project objectives. Strong supervision is also necessary to increase transparency and accountability in the use of public resources. In addition, the study found that coordination between central and regional governments remains important because road management responsibilities are distributed across different levels of government. Differences in authority, resources, and local priorities require an integrated approach to planning, programming, implementation, and maintenance. Improved communication and coordination can therefore reduce inconsistencies between national policies and local infrastructure needs.

Community Participation and Private Sector Involvement

The findings demonstrate that community participation is an important component of effective road governance. Communities as road users possess direct knowledge and experience regarding road conditions, accessibility, safety, and maintenance needs. However, the study found that communities are often insufficiently involved in infrastructure decision-making. Greater participation is therefore needed in monitoring road conditions, reporting damage, and providing input for policy development and maintenance programs. The findings also identify an increased role for the private sector in road development and management. Private participation can contribute additional resources, technical expertise, innovation, and investment. However, such involvement requires appropriate government supervision and regulation to ensure that public interests, road quality, safety, and accountability remain protected.

Technology, Human Resources, and Information Systems

The adoption of technology emerged as another important policy priority. The findings indicate that monitoring technologies, sensors, cameras, remote systems, road quality testing equipment, and integrated information systems can improve the efficiency and effectiveness of road management. Technology can support faster identification of road damage, more accurate data collection, and improved maintenance decisions. However, respondents also identified investment limitations and insufficient human resource capacity as obstacles to technological adoption. Therefore, technological development should be accompanied by capacity building for personnel responsible for planning, construction, supervision, and maintenance. The findings also highlight the importance of an integrated road management information system containing data on road conditions, maintenance history, public reports, and infrastructure performance.

Regulation, Land Use Rights, Safety, and Environmental Sustainability

The findings show that effective road management also requires stronger regulation and law enforcement. Regulatory enforcement is necessary to improve discipline, accountability, and compliance among relevant stakeholders. Land acquisition and land use rights were identified as additional challenges that may delay road

construction and generate disputes with affected communities. Transparent procedures, fair compensation, and effective dispute-resolution mechanisms are therefore necessary. The study further identifies road user safety and comfort as essential priorities. Improvements in road facilities, signs, markings, and traffic management are required to support safer and more accessible transportation. Finally, road construction and maintenance policies should incorporate environmental impact mitigation and sustainability. Road development should therefore consider environmental consequences while strengthening performance monitoring and analysis to support long-term infrastructure sustainability.

Discussion

The findings indicate that effective road infrastructure improvement requires a shift from project-oriented intervention to integrated, continuous management. The identified priorities strategic planning, maintenance prioritization, project supervision, stakeholder coordination, financing, technological innovation, and performance monitoring demonstrate that interconnected managerial and institutional factors influence road infrastructure performance. This finding is consistent with Mairizal et al. (2023), who emphasize the importance of project manager competency in determining project performance. Competent management is particularly important because road infrastructure projects involve complex technical, administrative, and organizational processes. At the same time, the findings extend this perspective by demonstrating that managerial capacity should not be considered only at the individual project level. It must be linked to broader institutional coordination and long-term maintenance arrangements (Ibrahim et al., 2026; Sasai et al., 2024). Thus, improving road infrastructure performance requires a governance approach that integrates project management capacity with systematic maintenance and policy implementation.

The findings also demonstrate that maintenance should be treated as a central component of road infrastructure policy rather than as a secondary activity after construction. The emphasis on routine and periodic maintenance, maintenance prioritization, and performance monitoring reflects the need to preserve infrastructure quality throughout its operational life. This finding aligns with Triyono et al. (2024), who show that implementing a routine road maintenance management system can improve road performance. The present study extends this argument by situating maintenance within a broader policy framework that includes planning, financing, coordination, and supervision. Paul (2023) similarly identifies road maintenance challenges as a major obstacle to sustainable development, suggesting that inadequate maintenance can undermine the broader developmental benefits of infrastructure investment. Therefore, road policy should prioritize preventive, systematic maintenance alongside infrastructure improvement to reduce deterioration and support long-term sustainability (Dokyi et al., 2025).

Another important finding concerns communication and coordination among institutions and stakeholders. The study identifies coordination as a critical priority because road infrastructure development involves multiple actors with different responsibilities, resources, and institutional interests. Fragmented responsibilities can weaken implementation and reduce the effectiveness of otherwise well-designed policies. Riau et al. (2024) support this finding by demonstrating the importance of communication and coordination in improving the performance of spatial-use permitting

processes. Their findings reinforce the argument that infrastructure performance depends not only on technical capacity but also on the effectiveness of administrative relationships among institutions. The present study contributes to this perspective by linking coordination directly to road improvement and maintenance, including planning, implementation, supervision, and evaluation. Effective coordination should therefore be institutionalized through clearer responsibilities, information sharing, integrated decision-making, and continuous communication among relevant stakeholders rather than relying solely on informal cooperation.

The findings also highlight the importance of alternative financing and private-sector collaboration in supporting sustainable road infrastructure management. Public resources may not always be sufficient to meet the diverse requirements of infrastructure development and long-term maintenance. Steelyana and Kinanti (2023) emphasize the potential role of public-private partnerships in transportation infrastructure development, particularly in toll road development. The present study supports this perspective while extending it beyond infrastructure construction by emphasizing the relevance of collaboration to broader road management needs. Private-sector participation can provide additional financial resources, managerial expertise, technological capacity, and innovation when supported by appropriate governance arrangements. However, collaboration should not simply be viewed as a mechanism for transferring financial responsibility. Effective partnerships require clear institutional roles, accountability mechanisms, performance standards, and alignment between private interests and public infrastructure objectives. Consequently, alternative financing should be part of an integrated policy strategy rather than an isolated funding solution.

The study also identifies technological innovation, human resource capacity, land-use management, safety, environmental mitigation, and performance evaluation as interconnected elements of effective road infrastructure policy. These findings suggest that sustainable road management requires institutional capabilities that extend beyond conventional engineering functions. Mairizal et al. (2023) demonstrate the importance of competency in infrastructure project performance, while Triyono et al. (2024) emphasize systematic management to maintain road performance. Together, these perspectives support the need to strengthen both human and organizational capabilities (Akbar et al., 2025; Hendra et al., 2023). The findings further suggest that technological adoption should be accompanied by improvements in staff competencies and institutional systems; technology alone cannot guarantee better infrastructure outcomes. Similarly, performance monitoring should be connected to decision-making so that information on road conditions can inform maintenance priorities, resource allocation, and policy adjustments. This integrated capability is essential to transform infrastructure management from reactive problem-solving into proactive, evidence-based decision-making.

Overall, the findings contribute to the literature by developing an integrated policy perspective that connects road improvement with long-term maintenance, management competency, institutional coordination, financing, technological innovation, and stakeholder collaboration. Existing studies have addressed these dimensions from relatively distinct perspectives: Mairizal et al. (2023) focus on managerial competency and project performance, Paul (2023) emphasizes maintenance challenges and sustainable development, Triyono et al. (2024) examine routine maintenance management, Riau et al. (2024) highlight communication and coordination,

and Steelyana and Kinanti (2023) discuss public-private partnerships in transportation infrastructure. This study contributes by bringing these perspectives together into a coherent policy framework. The findings indicate that sustainable road infrastructure cannot be achieved through construction or maintenance interventions alone. Instead, it requires integrated governance in which planning, competent management, coordinated institutions, adequate financing, systematic maintenance, innovation, and stakeholder participation reinforce one another. This perspective provides a basis for moving from fragmented road policies to more sustainable, performance-oriented infrastructure management (Dinca et al., 2026).

CONCLUSION

This study shows that improving and maintaining road infrastructure in Indonesia requires a holistic, integrated policy approach rather than fragmented technical interventions. The most important lesson derived from this research is that sustainable road management depends on the interconnection of strategic planning, road quality targets, stakeholder coordination, maintenance prioritization, adequate financing, effective supervision, multilevel government coordination, community and private sector participation, technological innovation, human resource capacity, regulatory enforcement, information systems, road user safety, and environmental sustainability. The study's primary scholarly contribution lies in integrating these diverse policy priorities into a comprehensive framework for understanding road governance and sustainable infrastructure management. However, this study is limited by its qualitative design and the perspectives of the selected stakeholders, which may not fully represent the diversity of road management conditions across Indonesia. Future research should therefore examine these priorities across regions, use comparative or mixed-methods approaches, and assess the effectiveness of integrated policy strategies in improving road quality and long-term maintenance outcomes.

ACKNOWLEDGEMENT

The authors sincerely thank all individuals and institutions that contributed to this study. Special appreciation is extended to the stakeholders who provided valuable insights, information, and perspectives on road infrastructure improvement and maintenance policies. The authors also acknowledge the support and assistance received during data collection and analysis. Finally, the authors are grateful to their academic colleagues and research partners for their constructive feedback and encouragement throughout the development of this manuscript.

REFERENCES

- Agabu, K. L., Kaliba, C., & Mwanaumo, E. M. (2023). Sustainable Prioritization of Public Asphalt Paved Road Maintenance. *International Journal of Engineering and Management Research*, 13(6), 17–31. <https://doi.org/10.31033/ijemr.13.6.3>
- Akbar, S. F., Patriadi, A., & Sajiyo. (2025). Analysis of the Determination of the Priority Level of Road Handling Based on the Multi-Criteria Analysis Method (MCA) on Provincial Roads in Sidoarjo. *Asian Journal of Engineering, Social and Health*, 4(8). <https://doi.org/10.46799/ajesh.v4i8.669>

- Anastasiadou, K., & Kehagia, F. (2025). Road Safety Improvement and Sustainable Urban Mobility: Identification and Prioritization of Factors and Policies Through a Multi-Criteria Approach. *Urban Science*, 9(4), 93. <https://doi.org/10.3390/urbansci9040093>
- De Medeiros Pereira, H., Elievam Bessa, J., & De Albuquerque Nóbrega, R. A. (2024). Geospatial-Based Decision Support System for Prioritizing Road Segments for Maintenance and Rehabilitation. *Case Studies on Transport Policy*, 16, 101170. <https://doi.org/10.1016/j.cstp.2024.101170>
- Dinca, L., Murariu, G., Chira, D., & Opra, B. (2026). Green Street Management Practices and Performance: A Global Review Integrating Bibliometric and Qualitative Analyses. *Sustainability*, 18(4), 1732. <https://doi.org/10.3390/su18041732>
- Dokyi, G., Osei, K., Tookey, J., & Rotimi, F. (2025). A SWOT Analysis of Stakeholder Perspectives on the Strategic Application of Economic Sustainability Indicators in Ghana's Road Infrastructure Development. *International Journal of Sustainable Transportation*, 19(5), 375–392. <https://doi.org/10.1080/15568318.2025.2496894>
- Gbaguidi, A. H. F. (2026). An Integrated Methodological Framework for Sustainable Urban Road Infrastructure Management, The Global Durability Index (IGD) and Prioritization Matrix Applied to Porto-Novo (Benin). *Engineering and Technology Journal*, 11(3), 9216–9219. <https://doi.org/10.47191/etj/v11i03.12>
- Hendra, S., Ngemba, H. R., Laila, R., Sadik, J., Indrajaya, M. A., Alamsyah, H. A., Hidayah, A., & Rahmawati, S. (2023). Decision Support System Determining Priority for Road Improvements to Support Sustainable Road Construction. *IOP Conference Series: Earth and Environmental Science*, 1157(1), 012040. <https://doi.org/10.1088/1755-1315/1157/1/012040>
- Ibrahim, F., Abdullah, M. E., Mohamad, S. B. H. S., Razman, R., & Yaacob, H. (2026). Potential of Performance-Based Contracting for Sustainable Highway Maintenance in Malaysia. *IOP Conference Series: Earth and Environmental Science*, 1619(1), 012050. <https://doi.org/10.1088/1755-1315/1619/1/012050>
- Issa, A., Alhadidi, T. I., & Alazmi, A. (2026). Green Road Index Development: Policy Implications and Strategic Prioritization for Sustainable Transportation Infrastructure. *Journal of Infrastructure Preservation and Resilience*, 7, 16. <https://doi.org/10.1186/s43065-026-00175-1>
- Lei, X., Dong, Y., & Frangopol, D. M. (2025). Integration of Inspection and Monitoring Data for RL-Enhanced Sustainable Life-Cycle Management of Infrastructure Networks. *Structure and Infrastructure Engineering*, 21(7–8), 1288–1302. <https://doi.org/10.1080/15732479.2025.2453484>
- Mairizal, M., Alifiardi, R., Pratama, G. A., Abd Majid, M. Z., & Ngian, S. P. (2023). Project Managers Competency on Project Performance of Green Toll Road Development Project in Indonesia. *SINERGI*, 27(3), 333–342. <https://doi.org/10.22441/sinergi.2023.3.005>
- Mohamed, A. G., Alqahtani, F. K., Ismail, E. R., & Nabawy, M. (2025). Synergizing GIS and Genetic Algorithms to Enhance Road Management and Fund Allocation With a Comprehensive Case Study Approach. *Scientific Reports*, 15, 4634. <https://doi.org/10.1038/s41598-025-88760-4>

- Nugraha, M. A., Muhidong, J., & Soma, A. (2025). Multi-Criteria Decision-Making in Road Maintenance: An AHP-GIS Approach. *International Journal of the Analytic Hierarchy Process*, 17(3). <https://doi.org/10.13033/ijahp.v17i3.1307>
- Pangesti, R. D., Sulistiawati, B. H., Wahyono, H. L., Junaidi, & Goro, G. L. (2024). Prioritas Pemeliharaan Jalan Berbasis Treatment Priority Index (TPI) di Jalan Perkerasan Aspal. *Bangun Rekaprima*, 10(1), 48–56. <https://doi.org/10.32497/bangunrekaprima.v10i1.5473>
- Paul, G. C. (2023). Road Maintenance Challenges: The Greatest Obstacle to Sustainable Development in South Sudan. *Journal of Sustainable Social Change*, 15(1), 31–41. <https://doi.org/10.5590/JSSC.2023.15.1.03>
- Riau, D. P., Akbar, Y. M., Akadira, T., Muhtarom, & Diana, B. A. (2024). Communication and Coordination Innovations in Improving the Performance of Permits for Suitability for Spatial Use Activities. *International Journal of Sustainable Development and Planning*, 19(7), 2719–2727. <https://doi.org/10.18280/ijstdp.190728>
- Saleh, B. R., Tjaronge, M. W., & Tumpu, M. (2025). Road Management Policy Formulation Strategy for Sustainable Development. *International Journal of Current Science Research and Review*, 8(9), 4618–4624. <https://doi.org/10.47191/ijcsrr/V8-i9-24>
- Sasai, K., Chouinard, L., Power, G., Conciatori, D., & Zufferey, N. (2024). Accounting for Traffic Disturbance in Road Infrastructure Management: Optimal Maintenance and Rehabilitation Planning for the Society. *Transportation Research Part A: Policy and Practice*, 183, 104040. <https://doi.org/10.1016/j.tra.2024.104040>
- Solé-Pomies, R. (2023). Infrastructural Expertise for Sustainable Mobility: Evolutions of Road Management in French Local Governments. *Transportation Research Procedia*, 72, 3505–3512. <https://doi.org/10.1016/j.trpro.2023.11.762>
- Steelyana, E., & Kinanti, D. (2023). Public Private Partnership in Transportation Infrastructure: A Review on Toll Road Development. *E3S Web of Conferences*, 388, 01017. <https://doi.org/10.1051/e3sconf/202338801017>
- Tosulpa, M. E., Putranto, L. S., & Sulistyorini, R. (2026). Road Damage Management Model Due to Overloading: AHP Priorities and Policy Implications (Case Study of Lampung Province). *Advance Sustainable Science, Engineering and Technology*, 8(1), 02601015-01–02601015-13. <https://doi.org/10.26877/asset.v8i1.2629>
- Triyono, A. H., Hermani, W. T., Amrulloh, N. S., & Setyawan, A. (2024). Improved Road Performance Through the Implementation of Routine Road Maintenance Management System. *Journal of Applied Engineering Science*, 22(3), 646–653. <https://doi.org/10.5937/jaes0-50995>
- Zakir, D., Greenwood, I., & Ayoobi, A. (2024). *Sustainable Transport Infrastructure: Road Asset Management in the CAREC Region*. Asian Development Bank. <https://doi.org/10.56506/XZVX6537>
- Zhong, Z., & Ren, Z. (2026). Deep Learning and TOPSIS-Based Multi-Criteria Decision-Making Framework for Urban Road Defect Detection and Sustainable Maintenance Planning. *Scientific Reports*, 16, 2045. <https://doi.org/10.1038/s41598-025-31682-y>