Vol 17, issue 2, April 2026
DOI: 10.26740/jaj.v17n2.p.513-527
https://journal.unesa.ac.id/index.php/aj

Strategic Green Infrastructure Management and Green Budgeting for Sustainable Road Development

Anwar Asihinggalih Antiarini [1], Harsuko Riniwati [1*], Fitri Candra Wardana [1]
[1] Environmental Resource Management and Development, Graduate School, University Brawijaya, Malang
Jalan MT Haryono 169, Malang 65145, Indonesia
e-mail: [a] hinggaliharini@gmail.com*, [b] riniwatisepk@ub.ac.id, and [c] fitri_fia@gub.ac.id
* Corresponding Author

Abstract

Introduction/Main Objectives: This study examines the integration of green infrastructure in road development along the Kepanjen–Pagak corridor in Malang Regency to support community mobility, economic growth, and environmental sustainability. Conventional road development often causes environmental problems such as declining air quality, excessive surface runoff, urban heat island effects, and degradation of roadside vegetation. Therefore, integrating green infrastructure has become increasingly important for sustainable and ecologically responsible road development. The study aims to analyze the existing implementation of green infrastructure, identify internal and external influencing factors, and formulate effective integration strategies using SWOT analysis. The novelty of this research lies in its comprehensive SWOT-based evaluation that integrates environmental, technical, institutional, and socio-economic perspectives within a regional road corridor context. **Methods:** This research employs a descriptive-analytical approach using both primary and secondary data. Primary data were collected through in-depth interviews, stakeholder discussions, and Likert scale (1–4) questionnaires, while secondary data were obtained from policy documents, project reports, and scientific literature. The study area covers approximately 18 km of the Kepanjen–Pagak corridor. Data were analyzed using the SWOT method. **Finding / Results:** The findings indicate that roadside vegetation effectively absorbs pollutants, reduces microclimate temperatures, and improves rainwater infiltration. Sustainable drainage systems and green open spaces also help reduce flood risks and improve the social and visual quality of the corridor. SWOT analysis shows strong institutional and environmental potential despite challenges related to budget limitations, technical capacity, and inter-agency coordination. **Conclusion:** The study concludes that integrating green infrastructure can enhance environmental quality and support sustainable road development, with implications for environmentally sustainable transportation planning in regional corridors.

Keywords: *Green infrastructure; Sustainable Road Development; Roadside Vegetation; SWOT Analysis; Kepanjen–Pagak, Malang*

JEL Classification: M40;M41

Article History: Received: September, 04th 2025 Revised: January, 04th 2026 Accepted: February, 25th 2026 Published: April, 1st 2026
How to cite: Asihinggalih, A et al. (2026). Strategic Green Infrastructure Management and Green Budgeting for Sustainable Road Development. *AKRUAL: Jurnal Akuntansi*, *17*(2). DOI: 10.26740/jaj.v17n2.p.513-527
Conflict of Interest Statement: here is no conflict of interest in the articles resulting from this research

INTRODUCTION

Road infrastructure development plays an important role in supporting economic growth, regional connectivity, and community mobility. Roads function as the primary link between residential areas, trade centers, industrial zones, and production regions, thereby influencing the distribution of goods and services. Adequate transportation infrastructure improves logistics efficiency and strengthens regional competitiveness in supporting economic development (Berland et al., 2017). In addition, integrated road development can expand community accessibility to public facilities and economic activities (Rosalia et al., 2025). The Ministry of Public Works and Housing (2022) also emphasizes that road development is an essential component of equitable national development (Zwierzchowska et al., 2026). Therefore, road infrastructure development is not only intended to facilitate mobility but also to support sustainable regional development.

Despite its importance, road development is still largely dominated by conventional or gray infrastructure approaches that prioritize technical and transportation aspects over environmental sustainability. Conventional road construction generally focuses on road capacity, traffic flow, and vehicle efficiency without adequately considering ecological impacts. Previous studies have shown that conventional road development contributes to the reduction of green open spaces, environmental degradation, increased urban energy consumption, and changes in land use patterns that reduce ecological functions (Hendra et al., 2022; Ismail, 2025; Lamba et al., 2025). Furthermore, the widespread use of impermeable materials such as asphalt and concrete increases surface runoff, thereby elevating the risk of urban flooding and drainage problems (Pallathadka et al., 2022). Conventional drainage systems are often unable to effectively manage stormwater in highly developed areas (Nurhidayati et al., 2024). In addition, extensive hard surfaces contribute to urban heat island effects and declining air quality due to increased transportation emissions (Norton et al., 2015; Jones et al., 2024). These conditions indicate that road infrastructure development has significant environmental implications beyond transportation functions.

In response to growing concerns regarding sustainable development, the concept of green infrastructure has emerged as an alternative approach to infrastructure planning and development. Green infrastructure integrates natural and semi-natural elements into infrastructure systems to provide ecological, social, and environmental benefits (McPhearson et al., 2023). Previous studies have highlighted that green infrastructure can improve environmental quality, increase climate resilience, reduce surface runoff, and enhance urban microclimates (Urrutia, 2025). In road development, green infrastructure can be implemented through roadside vegetation, permeable pavement, green open spaces, and sustainable drainage systems. Such approaches help balance transportation needs with environmental sustainability while improving the quality of urban and regional environments (Sawitri, 2023;Roudo et al., 2024).

Although green infrastructure provides various benefits, its implementation in developing countries still faces several challenges. Limited financial resources, insufficient technical capacity, weak institutional coordination, and low stakeholder awareness remain major barriers to implementation (Rochana et al., 2015; Ismail, 2025). Existing studies on green infrastructure in transportation systems have also mainly focused on technical and

p-ISSN: 2085-9643 DOI: 10.26740/jaj.v17n2.p.513-527
e-ISSN: 2502-6380 https://journal.unesa.ac.id/index.php/aj

physical design aspects, while research addressing governance, implementation strategies, and institutional integration remains limited (Rhianazala, 2026). In Indonesia, studies specifically examining strategic approaches for integrating green infrastructure into road development projects are still relatively scarce (Lamba et al., 2025). This indicates a research gap related to the strategic and institutional dimensions of green infrastructure implementation in transportation infrastructure development.

The Kepanjen–Pagak road corridor in Malang Regency represents an important case for examining the integration of green infrastructure in road development. This corridor plays a strategic role in supporting regional connectivity and economic activities. However, without proper environmental considerations, road development in this area may increase flood vulnerability, environmental degradation, and the loss of ecological functions. The Directorate General of Highways (2023) emphasizes that sustainable road development should integrate technical, social, and environmental aspects in a balanced manner. Therefore, a comprehensive and environmentally sustainable development approach is necessary for the Kepanjen–Pagak corridor.

Based on these issues, this study aims to analyze the implementation of green infrastructure along the Kepanjen–Pagak road corridor, identify internal and external factors influencing its integration, and formulate strategic recommendations using SWOT analysis. The study contributes to the literature by providing a strategic and institutional perspective on green infrastructure integration in regional road development, particularly in the context of developing countries. The findings are expected to support policymakers and infrastructure planners in promoting environmentally sustainable transportation development.

RESEARCH METHOD

This study used a descriptive-analytical approach supported by SWOT analysis to examine the integration of green infrastructure along the 18 km Kepanjen Pagak road corridor, Malang Regency, which spans dense residential areas, mixed economic zones, agrarian transition areas, and areas with high vegetation cover enabling analysis under varied environmental conditions.

Primary data were collected through in-depth interviews, stakeholder discussions, and 1-4 Likert-scale questionnaire administered to 46 purposively selected respondents (government officials, planning consultants, academics, and infrastructure practitioners) based on their expertise and involvement in infrastructure planning (Creswell, 2023). Secondary data were drawn from policy documents, project reports, government regulations, scientific literature, and satellite imagery. Internal and external strategic factors were weighted and rated, then analyzed using SWOT supported by IFAS (Internal Factor Analysis Summary) and EFAS (External Factor Analysis Summary) matrices to determine their strategic significance.

RESULTS AND DISCUSSION

A total of 46 respondents participated, drawn from government institutions, consultants, contractors, academics, communities, entrepreneurs, and construction services. Their characteristics matter because the quality of SWOT assessments depends on respondents' knowledge, experience, and involvement in infrastructure and environmental management.

Table 1. Respondent Characteristics

Characteristics	Category	Frequency (n)	Percentage (%)
Age	17–25 years	2	4.3
	26–35 years	15	32.6
	36–45 years	11	23.9
	46–55 years	16	34.8
	56–65 years	2	4.3
Gender	Male	37	80.4
	Female	9	19.6
Education Level	Elementary School	2	4.3
	Senior High School/Vocational School	9	19.6
	Diploma (D1–D4)	5	10.9
	Bachelor's Degree (S1)	22	47.8
	Master's Degree (S2)	6	13.0
	Doctoral Degree (S3)	2	4.3
Occupation	Government Officer	32	69.6
	Consultant	7	15.2
	Community Member	3	6.5
	Entrepreneur	2	4.3
	Academic	2	4.3
	Contractor	1	2.2
	Construction Service	1	2.2
Work Experience	< 1 year	7	15.2
	1–5 years	13	28.3
	5–10 years	10	21.7
	> 10 years	16	34.8

Source: Research analysis results, 2026

The respondent profile indicates that most participants were government officials and infrastructure practitioners with considerable professional experience. The majority were aged 46–55 years (34.8%) and had more than 10 years of experience (34.8%), suggesting that the assessment was supported by respondents with substantial expertise in infrastructure planning and environmental management. In terms of educational background, most respondents held a bachelor's degree (47.8%), reflecting an adequate level of understanding regarding sustainable road development and green infrastructure implementation.

p-ISSN: 2085-9643 DOI: 10.26740/jaj.v17n2.p.513-527
e-ISSN: 2502-6380 https://journal.unesa.ac.id/index.php/aj

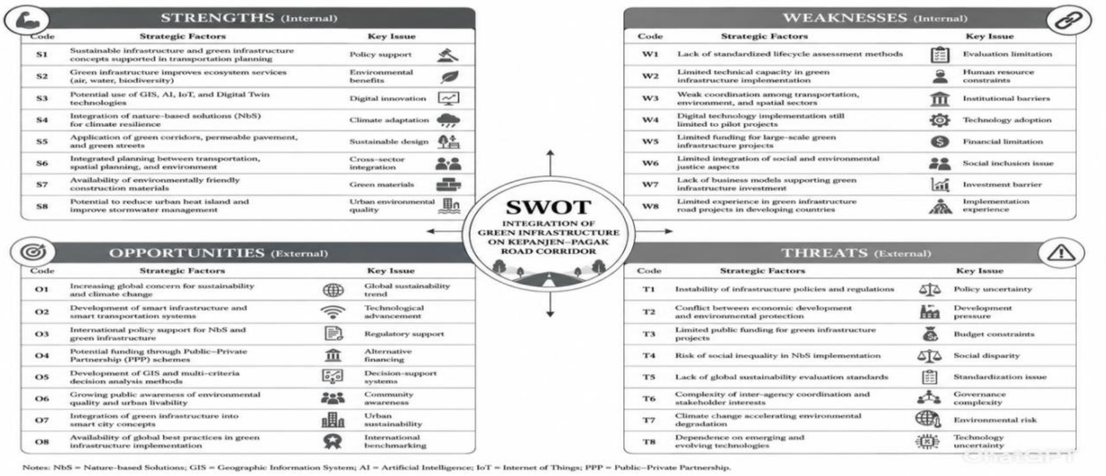

Figure 1. SWOT Integration of Green Infrastructure on Kepanjen Pagak Corridor
Source: Results of researcher identification and analysis (2026)

Integration of green infrastructure in the Kepanjen Pagak road corridor has considerable potential to support sustainable transportation development, as the road development system already possesses conceptual, technological, and environmental strengths including sustainable transportation planning concepts, the application of nature-based solutions, and the potential use of digital technologies such as GIS and IoT (García Sánchez & Govindarajulu, 2023) that provide a strong foundation for environmentally oriented road development and enable green infrastructure to contribute not only to transportation functions but also to ecosystem services such as urban cooling, stormwater management, and environmental quality improvement, although significant challenges remain in the form of limited technical capacity, weak institutional coordination, insufficient funding mechanisms, and the absence of standardized evaluation frameworks, indicating that implementation is not yet fully integrated into infrastructure governance and that its success depends not only on physical design but also on institutional readiness, policy integration, and long-term financing support.

From the external perspective, the study reveals substantial opportunities driven by increasing global attention to sustainability, technological advancement, smart city development, and international support for nature-based solutions (Timur et al., 2025). The study concludes that this integration effectively enhances environmental quality and supports sustainable road development, with strategic priorities including preserving existing vegetation, implementing adaptive road design, strengthening sustainable management of green elements, and improving inter-agency coordination demonstrating that green infrastructure integration can serve as a practical framework for environmentally sustainable transportation development in regional corridors (Nurhidayati et al., 2024).

The IFAS analysis shows a relatively strong internal condition, with a total score of 3.165 (strengths subtotal 1.644; weaknesses subtotal 1.521). The leading strength is support for sustainable infrastructure and green infrastructure concepts within the transportation system, while the main weakness is limited funding for green infrastructure development.

Table 2. Matriks IFAS (selected top factors; full 16-item matrix available in the original dataset)

No	Top Strengths (S) / Weaknesses (W)	Weight	Rating	Score
S1	Support for the concept of sustainable infrastructure development	0.078	3.696	0.288
S2	Capability of green infrastructure to improve ecosystem services	0.075	3.565	0.267
S4	Integration of nature-based solutions	0.068	3.306	0.225
	Subtotal Strengths (8 indicators)	0.515		1.644
W5	Limited funding sources for green infrastructure development	0.069	3.321	0.229
W6	Lack of integration of social and environmental justice aspects	0.068	3.286	0.223
W3	Limited cross-sector coordination among sectors	0.064	3.116	0.199
	Subtotal Weaknesses (8 indicators)	0.485		1.521
	Total IFAS	1.000		3.165

Source: Process data (2026)

The EFAS analysis produced a total score of 3.093, with opportunities totaling 1.612 and threats totaling 1.481. External conditions are sufficiently supportive of implementation: the greatest opportunity is rising public awareness of environmental quality, while the primary threat is conflict between economic development and environmental protection.

Table 3. Matriks EFAS (selected top factors; full 16-item matrix available in the original dataset)

Code	Top Opportunities (O) / Threats (T)	Weight	Rating	Score
O6	Increasing public awareness of environmental quality	0.071	3.408	0.242
O2	Development of smart infrastructure	0.071	3.392	0.241
O7	Integration of GI within the smart city concept	0.070	3.382	0.237
	Subtotal Opportunities (8 indicators)	0.511		1.612
T2	Conflicts of interest between economic development and environmental protection	0.072	3.437	0.247
T3	Limited public funding for green infrastructure projects	0.069	3.330	0.230
T1	Instability of infrastructure development policies and regulations	0.067	3.254	0.218
	Subtotal Threats (8 indicators)	0.489		1.481
	Total EFAS	1.000		3.093

Source: Process data (2026)

The SWOT coordinates were calculated as X = Strengths – Weaknesses = 0.123 and Y = Opportunities – Threats = 0.131. Both positive values place the strategy in

Vol 17, issue 2, April 2026
DOI: 10.26740/jaj.v17n2.p.513-527
https://journal.unesa.ac.id/index.php/aj

Quadrant I (Strength–Opportunity), indicating dominant internal strengths and favorable external opportunities that support an aggressive strategy—using strengths to maximize opportunities.

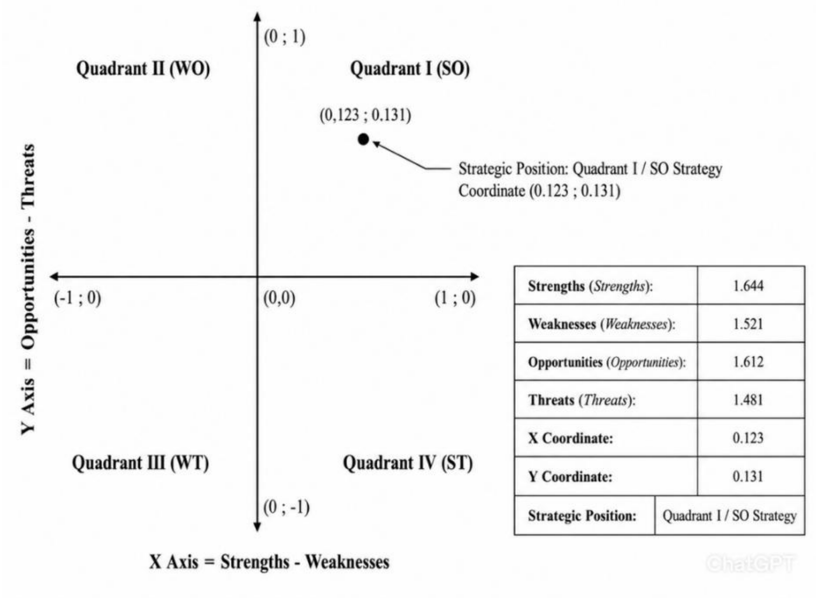

Figure 2. SWOT Quadrant Diagram for Green Infrastructure Integration.
Source: Process data (2026)

The findings indicate that road infrastructure development is gradually shifting toward a sustainability-oriented and climate-resilient approach, integrating environmental considerations, climate adaptation, GIS-based digital technologies, and regulatory preparedness into planning processes (Pallathadka et al., 2022), as green infrastructure concepts green roads, roadside vegetation, eco-friendly drainage, and nature-based solutions are increasingly incorporated to mitigate rainfall runoff, emissions, and other environmental impacts, even though development still contributes to green space loss, runoff increases, habitat fragmentation, land-use conversion, air pollution, and noise (Rannu et al., 2025), while adoption of more sustainable drainage measures (infiltration wells, integrated drainage, roadside greening, biopores) and GIS-supported spatial and climate-risk analysis (Ashley et al., 2005) remains limited and inconsistent due to weak institutional readiness, uneven regulatory implementation, constrained financing, technical and topographic limitations, and insufficient cross-sector coordination and environmental monitoring underscoring that stronger governance, consistent regulation, wider adoption of nature-based solutions, better drainage management, adequate financing, improved technological capacity, and more effective collaboration are still needed to achieve integrated, effective green road infrastructure.

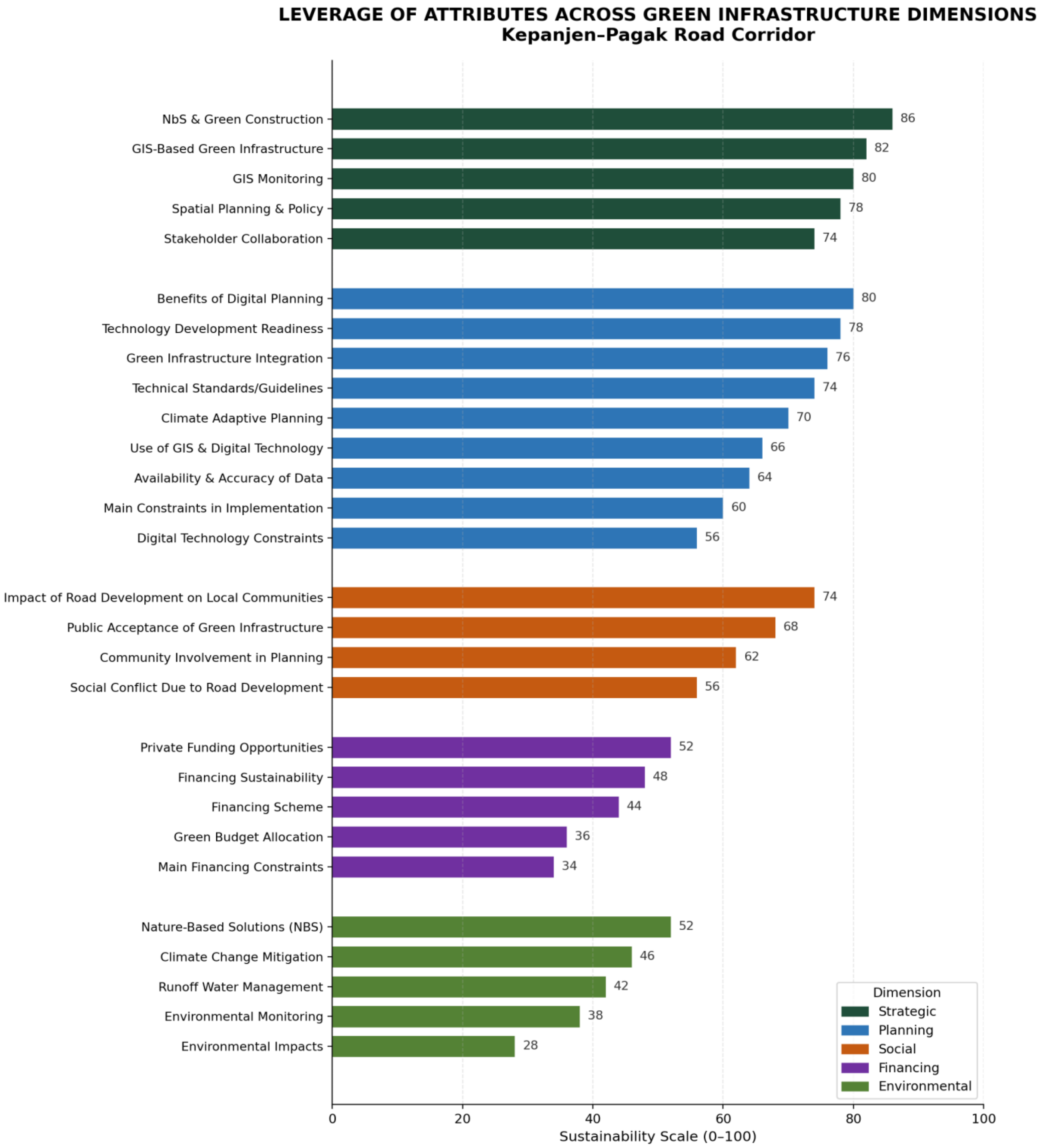

Figure 3. (a) Leverage Attibute of Planning Dimension, (b) Leverage Attibute of Environmental Dimension, (c) Leverage Attibute of Social Dimension, (d) Leverage Attibute of Economic Dimension,(e) Leverage Attibute of Strategic Dimension
Source: Process data (2026)

The interview findings indicate that the green infrastructure strategy for the Kepanjen–Pagak road development requires an integrated approach combining environmental, technological, governance, and institutional aspects. Respondents

p-ISSN: 2085-9643 DOI: 10.26740/jaj.v17n2.p.513-527
e-ISSN: 2502-6380 https://journal.unesa.ac.id/index.php/aj

emphasized the importance of developing green corridors, sustainable drainage systems, and GIS-based planning to support adaptive and data-driven infrastructure management. In addition, successful implementation depends on multi-stakeholder collaboration and institutional readiness in supporting sustainable infrastructure development.

Table 4. Interview Findings and Proposed Strategy

Respondent Group	Interview Statement	Key Findings	Proposed Strategy
Local Government Officials	*"Road development should not only focus on connectivity, but also consider environmental aspects such as green drainage systems and green open spaces."*	Road infrastructure needs to be integrated with environmental management	Development of green corridors and green drainage systems
Planning Consultants	*"Road planning requires accurate spatial data so that flood-prone areas and environmental impacts can be anticipated from the beginning."*	Technology-based and data-driven planning still needs improvement	Utilization of GIS and digital modeling
Academics	*"Green infrastructure should become part of sustainable regional planning to prevent environmental degradation caused by road development."*	Sustainability governance must be integrated into infrastructure planning	Strengthening sustainable policies and environmental evaluation
Infrastructure Practitioners	*"The main challenge is not only physical construction, but also stakeholder coordination and the maintenance of green infrastructure."*	Collaboration and technical capacity are critical for project sustainability	Collaborative governance and institutional capacity building

Source: data processed

The strategic mapping shows that green infrastructure-based road development requires a multidimensional approach integrating environmental, technological, collaborative, and institutional aspects where green corridors and water infiltration systems strengthen environmental resilience, GIS and digital monitoring support evidence-based planning, and collaborative governance with institutional capacity building ensures long-term sustainability transforming conventional road development into adaptive, sustainable infrastructure management expected to improve environmental resilience, reduce flood risk and urban heat island effects, enhance environmental quality, and support a sustainable transportation system, ultimately demonstrating that sustainable road development requires an integrated approach balancing infrastructure performance, environmental protection, and long-term regional sustainability.

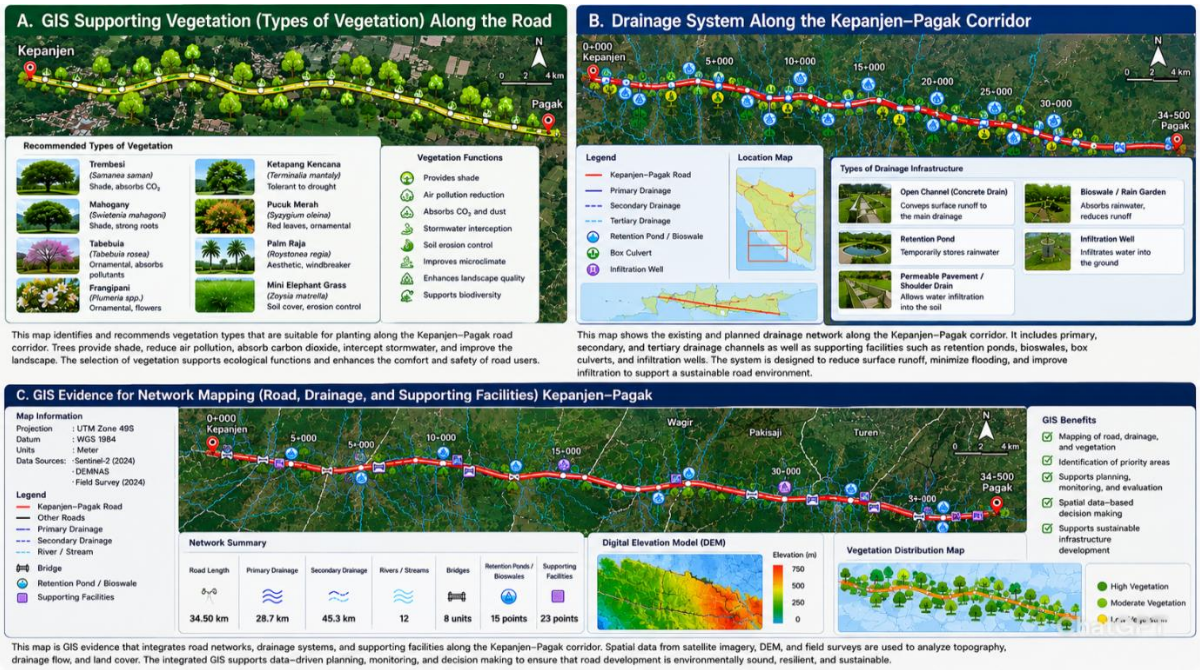

Figure 5. Integrated GIS Approach for Vegetation and Drainage Planning in Green Road Infrastructure Development
Source: Process data (2026)

Figure 5 shows the GIS-based green infrastructure approach along the Kepanjen Pagak corridor, integrating vegetation planning, drainage systems, and supporting infrastructure networks within a spatial planning framework for sustainable, climate-resilient road development. GIS is used to recommend suitable species (Samanea saman, mahogany, tabebuya, palm) for carbon absorption, pollution reduction, shading, erosion control, and landscape quality (McPhearson et al., 2023), while drainage mapping shows an integrated system open concrete drains, bioswales, retention ponds, permeable pavement, box culverts, and infiltration wells to reduce runoff and flood risk; network mapping of roads, drainage, rivers, bridges, and facilities further uses spatial data (DEM, field surveys) to analyze topography, drainage flow, and land cover for more accurate planning and monitoring (Bato & Lestari, 2000.), highlighting that combining GIS, green vegetation planning, and sustainable drainage is key to environmentally friendly, data-driven, climate-adaptive road infrastructure.

Implementing green infrastructure integration on the Kepanjen Pagak road section requires a comprehensive, multidimensional approach that strengthens not only environmental sustainability but also institutional coordination, technological application, and financial planning through green budgeting mechanisms (Palliwoda et al., 2022; Angghita & Tahalele, 2026), translating strategic priorities green corridors, sustainable drainage systems, and GIS-based spatial planning into actionable programs supported by cross-sector collaboration among government agencies, planners, and local stakeholders.

p-ISSN: 2085-9643 DOI: 10.26740/jaj.v17n2.p.513-527
e-ISSN: 2502-6380 https://journal.unesa.ac.id/index.php/aj

Green budgeting serves as a key financial instrument ensuring infrastructure investments align with environmental objectives, directing budget allocations toward nature-based solutions, climate-resilient infrastructure, and low-impact development, including financing for roadside greening, infiltration systems, environmental monitoring, and digital GIS-based planning tools (Demir et al., 2025), thereby embedding environmental considerations within fiscal decision-making rather than treating them as merely technical requirements. Overall, this integrated approach strengthens green infrastructure implementation by aligning policy, planning, and budgeting systems to support sustainable, climate-resilient road development (Rhianazala, 2026).

The proposed framework for green infrastructure development along the Kepanjen Pagak corridor emphasizes the integration of management systems, financing mechanisms, and spatial technologies to support sustainable transportation infrastructure, demonstrating that successful green corridor implementation depends not only on physical infrastructure provision but also on institutional coordination, environmental governance, and evidence-based spatial planning supported by GIS and Nature-Based Solutions (NbS) (Norton et al., 2015) . From the management perspective, the framework highlights the importance of inter-agency collaboration among public works departments, environmental agencies, transportation authorities, and regional spatial planning institutions, as components such as roadside green belts, sustainable drainage systems (SuDS), and pedestrian green networks require integrated governance structures to ensure effective maintenance, environmental monitoring, and policy synchronization. Kavisri et al., (2023) reflecting principles of adaptive management, institutional integration, and long-term environmental stewardship that are increasingly important given the corridor's strategic role in regional mobility, economic activity, and urban expansion.

The management aspect plays a crucial role in ensuring that green infrastructure strategies are effectively implemented through clear institutional coordination, defined responsibilities, and cross-sector collaboration (Syahid Ardillah et al., 2024), while proper cost allocation ensures financial resources are distributed efficiently across components such as vegetation development, drainage systems, GIS technology, and climate resilience measures, optimizing investment and avoiding budget inefficiencies (Berland et al., 2017 ; García Sánchez & Govindarajulu, 2023). Integrating transparent financial planning with GIS and NbS further enhances accountability by making planning decisions more evidence-based and traceable (Urrutia, 2025), and in the long term, this integrated approach is expected to improve governance transparency, strengthen public trust, and support more sustainable and resilient infrastructure outcomes by ensuring that environmental objectives and financial resources are managed in a coordinated and transparent manner (Hendra et al., 2022).

The cost dimension reveals (appendix A: working paper green budget allocation) that green infrastructure development involves relatively high initial investment particularly for ecological restoration, permeable pavements, environmental sensors, GIS platforms, and drainage rehabilitation though long-term benefits potentially outweigh these costs through reduced flood mitigation expenses, improved environmental quality, lower maintenance costs, and enhanced urban resilience (Demir et al., 2025), consistent with sustainable infrastructure financing literature arguing that environmentally integrated infrastructure generates long-term economic efficiency and social value, with collaborative financing mechanisms government budgets, public-private partnerships (PPP), corporate social responsibility (CSR), and environmental grants further improving financial sustainability within regional corridors ((Liu et al., 2020; (Herath & Bai, 2024; Ashley et al., 2005), while supporting the transition toward low-carbon, environmentally resilient transportation corridors and improving accountability and policy effectiveness through GIS-based monitoring and periodic environmental performance assessments.

The study reveals that, the Management, Cost, and Spatial Integration Framework for Green Infrastructure Development in the Kepanjen Pagak corridor demonstrates that sustainable corridor planning requires a multidimensional approach integrating governance capacity, financial sustainability, spatial intelligence, and ecological resilience (Ismail, 2025), contributing theoretically to sustainable infrastructure and green governance literature by emphasizing the strategic role of GIS and NbS in adaptive, data-driven infrastructure management, while practically providing policy guidance for local governments and regional planners in designing environmentally sustainable transportation corridors aligned with long-term regional development objectives (Yang et al., 2020). The proposed green budgeting model recommends allocating approximately 20% 30% of the total road infrastructure budget to green infrastructure components supporting investments in green corridors, sustainable drainage systems, permeable surfaces, GIS-based ecological planning, climate resilience infrastructure, and environmental monitoring systems (Jones et al., 2024) while the remaining 70% 80% continues to support conventional infrastructure needs such as road construction, transportation facilities, and structural improvements, enabling local governments to simultaneously enhance transportation connectivity and environmental sustainability, and supporting ESG-oriented regional development through improved environmental quality, stronger climate adaptation capacity, smart infrastructure management, and long-term sustainable infrastructure governance.

CONCLUSION

This study shows that the integration of green infrastructure in the development of the Kepanjen Pagak road corridor has not yet been implemented optimally, as development remains predominantly focused on transportation functions, traffic capacity, and roadway performance, leaving ecological components roadside vegetation, infiltration areas, green corridors, and sustainable drainage not systematically integrated into road planning. So, the corridor's ecological functions, including stormwater management, microclimate regulation, pollution reduction, and environmental quality improvement, remain underutilized. Integration is shaped by internal strengths (support for sustainable infrastructure concepts, ecological benefits, planning technologies, and green-corridor potential) and weaknesses (limited technical capacity, weak inter-sectoral coordination, financial constraints, and the absence of technical standards), alongside external opportunities (environmental awareness, nature-based-solutions support, sustainable urban development) and threats (policy uncertainty, limited public funding, economic environmental conflicts, institutional complexity).

Based on the SWOT analysis, the strategic position of green infrastructure integration lies in Quadrant I (Strength Opportunity), indicating that existing strengths can be leveraged to maximize external opportunities. The recommended strategy therefore

p-ISSN: 2085-9643 DOI: 10.26740/jaj.v17n2.p.513-527
e-ISSN: 2502-6380 https://journal.unesa.ac.id/index.php/aj

emphasizes sustainable road corridor development through green corridors, sustainable drainage systems, bioswales, permeable pavements, vegetation enhancement, GIS-based planning, and institutional strengthening supporting transportation connectivity and regional accessibility alongside ecological resilience, environmental sustainability, and improved urban environmental quality within the Kepanjen Pagak corridor.

ACKNOWLEDGMENT

The author would like to express sincere appreciation to the supervisors for their invaluable guidance, constructive feedback, and continuous support throughout the research process, as well as to all lecturers and academic staff for their knowledge and assistance during the study period.Gratitude is also extended to the respondents and stakeholders along the Kepanjen–Pagak road corridor for their cooperation and valuable contributions.

AUTHORSHIP CONTRIBUTION STATEMENT

Conceptualisation, A.A.; methodology, A.A.; formal analysis, A.A.; investigation, A.A.; writing—original draft preparation, A.A..; writing—review and editing, H.R. and F.C.; supervision, H.R. and F.C.; project administration, L.Z. All authors have read and agreed to the published version of the manuscript

REFRENCES

Angghita, L. J., & Tahalele, M. (2026). *Peran nature-based solution dalam penanggulangan banjir dan ketahanan iklim perkotaan : kajian literatur ilmiah*. *10*(1), 1–17.

Ashley, R. M., Balmfort, D. J., Saul, A. J., & Blanskby, J. D. (2005). Flooding in the future - Predicting climate change, risks and responses in urban areas. *Water Science and Technology*, *52*(5), 265–273. https://doi.org/10.2166/wst.2005.0142

Bato, B. E., & Lestari, L. A. (n.d.). *Respon Kebijakan Indonesia Terhadap Perubahan Iklim :*

Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., & Hopton, M. E. (2017). The role of trees in urban stormwater management. *Landscape and Urban Planning*, *162*, 167–177. https://doi.org/10.1016/j.landurbplan.2017.02.017

Demir, S., Dilman Gokkaya, M., & Ersoz, N. D. (2025). Prioritization Blue-Green Infrastructure Strategies: Developing a Hybrid Quantitative Approach Model for Sustainable Urban Water Management. *Water Resources Management*, *39*(8), 3901–3919. https://doi.org/10.1007/s11269-025-04136-3

García Sánchez, F., & Govindarajulu, D. (2023). Integrating blue-green infrastructure in urban planning for climate adaptation: Lessons from Chennai and Kochi, India. *Land Use Policy*, *124*(August 2022), 0–3. https://doi.org/10.1016/j.landusepol.2022.106455

Hendra, L., Mais, R. G., & Cahyani, P. R. (2022). *Journal of Economics and Business Aseanomics Analysis of Green Sukuk Potential Against Green Infrastructure in*. *7*(2), 16–31.

Herath, P., & Bai, X. (2024). Benefits and co-benefits of urban green infrastructure for sustainable cities: six current and emerging themes. *Sustainability Science*, *19*(3), 1039–1063. https://doi.org/10.1007/s11625-024-01475-9

Ismail, N. (2025). *Manajemen pembangunan infrastruktur kota yang berkelanjutan dan berwawasan lingkungan studi kasus kota depok*. *11*(1), 166–181.

Jones, L., Fletcher, D., Fitch, A., Kuyer, J., & Dickie, I. (2024). Economic value of the hot-day cooling provided by urban green and blue space. *Urban Forestry and Urban Greening*, *93*, 128212. https://doi.org/10.1016/j.ufug.2024.128212

Kavisri, M., Abraham, M., Namasivayam, S. K. R., Aravindkumar, J., Balaji, D., Sathishkumar, R., Sigamani, S., Srinivasan, R., & Moovendhan, M. (2023). Adsorption isotherm, kinetics and response surface methodology optimization of cadmium (Cd) removal from aqueous solution by chitosan biopolymers from cephalopod waste. *Journal of Environmental Management*, *335*(February), 117484. https://doi.org/10.1016/j.jenvman.2023.117484

Lamba, N., Aksa, K., & Amri, E. (2025). Strategi Penguatan Fungsi Dan Distribusi Ruang Terbuka Hijau Berbasis Spasial Dalam Perencanaan Tata Ruang Perkotaan Nabire. *Urban and Regional Studies Journal*, *8*(1), 123–135. https://doi.org/10.35965/ursj.v8i1.7632

Liu, J., Li, H., Wang, Y., & Zhang, H. (2020). Integrated life cycle assessment of permeable pavement: Model development and case study. *Transportation Research Part D: Transport and Environment*, *85*(June), 102381. https://doi.org/10.1016/j.trd.2020.102381

McPhearson, T., Kabisch, N., & Frantzeskaki, N. (2023). Nature-based solutions for sustainable, resilient, and equitable cities. *Nature-Based Solutions for Cities*, 1–11. https://doi.org/10.4337/9781800376762.00008

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning*, *134*, 127–138. https://doi.org/10.1016/j.landurbplan.2014.10.018

Nurhidayati et al., 2021. (2024). *Dalam Mengurangi Genangan Air Pada Jalur Pedestrian Di Kota Pontianak the Effectiveness of Green Infrastructure To Reduce Puddles on*. *12*(April), 37–52.

Pallathadka, A., Sauer, J., Chang, H., & Grimm, N. B. (2022). Full title: Urban flood risk and green infrastructure: Who is exposed to risk and who benefits from investment? A case study of three U.S. Cities. *Landscape and Urban Planning*, *223*(April), 104417. https://doi.org/10.1016/j.landurbplan.2022.104417

Palliwoda, J., Haase, A., Suppee, C., Rink, D., & Priess, J. A. (2022). Visions for development and management of urban green and blue infrastructure: a citizen's perspective. *Ecology and Society*, *27*(2). https://doi.org/10.5751/ES-13129-270208

Rannu, M., Pratiwi, A. A. R., Juliar, E., Oktariana, M. Q., Dzulfiyanto, R., Wildan, A., Nugraha, P., Sumpeno, Y., & Siregar, A. (2025). *Integrasi Rain Garden pada Badan Jalan Kota Baru Parahyangan Bandung Barat*. *18*, 173–185. https://doi.org/10.32897/techno.2025.18.2.4130

Rhianazala, A. (2026). *Analyzing the Challenges of Flood Management Policies in Bekasi City through Target Mapping Techniques*. *11*(1), 108–133.

Rochana, S. H., Kombaitan, B., & Purwanda, E. (2015). Road Infrastructure and Spatial

p-ISSN: 2085-9643 DOI: 10.26740/jaj.v17n2.p.513-527
e-ISSN: 2502-6380 https://journal.unesa.ac.id/index.php/aj

Economic Dependence in. *Journal of Indonesian Economy and Business*, *30*(3), 239–246.

Rosalia, D., Hadi, S. P., Studi, P., & Komunikasi, I. (2025). *BERKELANJUTAN*. *11*(1).

Roudo, M., Indriyani, W., Mahardika, Y. C., Indratmoko, S., & Anggono, P. (2024). The Link between Road Infrastructure Quality and Fiscal Decentralization: Evidence from Subnational Indonesia. *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi Dan Pembangunan*, *25*(2), 294–314. https://doi.org/10.23917/jep.v25i2.23682

Sawitri, D. (2023). The Contribution of Road Construction on Regional Economic Development in Indonesia. *Jurnal Perencanaan Pembangunan: The Indonesian Journal of Development Planning*, *7*(3), 313–333. https://doi.org/10.36574/jpp.v7i3.409

Syahid Ardillah, J., Rahman, R., Jufriadi, & Alwan. (2024). Green Open Space Development Efforts in Realising Sustainable Development in Masamba City. *Journal of Urban and Regional Spatial*, *4*(3), 234–241. https://ejournalfakultasteknikunibos.id/index.php/jups

Timur, P., Sasmita, A. C., Jaya, R. P., & Widiasaputra, I. (2025). *Nature-Based Solutions (NbS) as a Sociotechnical Intervention in Urban River Restoration*. *1*(2), 86–103.

Urrutia, C. (2025). *Nature-based solutions for climate and biodiversity protection in selected national climate contributions*. 107. https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/05_2025_cc.pdf

Yang, L., van Dam, K. H., & Zhang, L. (2020). Developing goals and indicators for the design of sustainable and integrated transport infrastructure and urban spaces. *Sustainability (Switzerland)*, *12*(22), 1–34. https://doi.org/10.3390/su12229677

Zwierzchowska, I., Stępniewska, M., & Wolszczak, G. (2026). Systemic approach to green infrastructure and nature-based solutions uptake: Insights from the Polish cities. *Ambio*, *Ec 2013*. https://doi.org/10.1007/s13280-025-02336-0