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Evaluating and Strengthening Green Policy Implementation on Indonesian Toll Roads

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Abstract
Toll road development plays a significant role in driving economic growth and interregional connectivity. However, it also poses serious environmental challenges such as carbon emissions, land degradation, and high energy consumption. The green toll road concept has emerged through the implementation of green policy that emphasizes sustainability across all stages of development and management. In Indonesia, the Green Toll Road Indonesia (GTRI) standard has been developed by the Green Product Council Indonesia (GPCI), yet its implementation is still uneven across toll roads. This study aims to evaluate the level of green policy implementation, identify gaps between certified and non-certified toll roads, and provide more comprehensive policy strengthening recommendations. The study compares six toll roads using GTRI indicators covering planning, construction, and operational aspects. Gempol–Pandaan and Kunciran–Serpong toll roads are selected as certified examples. Medan–Binjai, Pekanbaru–Dumai, TBPPKA, and JORR-S are analyzed as non-certified roads. Data were collected through interviews and document analysis. The results show a clear difference between certified and non-certified toll roads. Certified roads demonstrate better consistency in applying sustainability principles. Non-certified roads still face challenges such as weak regulations, limited human resources, absence of sustainable SOPs, and lack of stakeholder collaboration. The main recommendation of this study highlights the need to design green policy practices in a more integrated manner, starting from planning, construction, to operation and maintenance. This requires systemic support through regulatory alignment, education, stakeholder collaboration, and green financing to promote more sustainable toll road management in Indonesia.
Keywords: *green policy, toll roads, sustainability, GTRI, policy evaluation*

1. INTRODUCTION

Toll road infrastructure development has become one of the key drivers of economic growth and interregional connectivity. However, along with the increasing pace of construction, various negative environmental impacts have emerged, including land degradation, rising carbon emissions, and high energy and material consumption (Shang et al., 2024). To address these challenges, the concept of the green toll road has been introduced as an approach that integrates environmentally friendly principles, resource efficiency, and social responsibility throughout the entire toll road life cycle, from planning to operation (Rahmat et al., 2023).

Globally, several countries have successfully implemented green infrastructure policies through various initiatives, such as China's Green BRI program (Cuiyun & Chazhong, 2020), green incentives for infrastructure operators in Malaysia (Liberalesso et al., 2020), and the adoption of environmentally friendly technologies and standards in Europe and the United States (An et al., 2021). The implementation of green policies in infrastructure not only drives operational efficiency but also strengthens commitments to climate change mitigation and long-term sustainability.

In Indonesia, awareness of the importance of sustainable toll roads is reflected in the implementation of the Green Toll Road Indonesia (GTRI) certification developed by the Green Product Council Indonesia (GPCI). GTRI assessment covers multiple sustainability aspects, including planning, construction, construction materials, access, feasibility, service, energy efficiency, water efficiency, environmental management, and regional collaboration (Indonesia, 2023). Toll roads such as Pandaan–Malang, Gempol–Pandaan, Bali–Mandara, and Kunciran–Serpong have obtained this certification, marking progress in applying environmentally friendly principles.

Nevertheless, the implementation of green policies on most toll roads in Indonesia still faces numerous challenges. Interviews with toll road management personnel revealed obstacles such as limited technological capabilities, high implementation costs, lack of incentives, weak regulatory enforcement and evaluation, and a predominant focus on technical and economic efficiency over sustainability goals. At present, there is no regulation that strictly mandates toll roads to adopt green policies or comply with

GTRI standards. Without such policies, several negative consequences are likely to occur, including pollution, deforestation, habitat destruction, depletion of natural resources, and exacerbation of climate change impacts. Additionally, failure to adopt green policies also leads to lost opportunities for cost savings, improved efficiency, and enhanced reputation (Taghavi et al., 2021).

Non-compliance with green toll road certification can significantly contribute to CO_2 emissions, resulting in air pollution and environmental degradation (Rahmat et al., 2023). Furthermore, it can reduce operational efficiency, as green assessment systems help improve toll road performance and services through continuous evaluation (Adzar et al., 2019). From an economic perspective, non-compliance also poses a risk of deterring investors who are increasingly concerned about environmental and reputational risks (Asy'Ary & Utomo, 2020). Moreover, public trust and stakeholder support may be undermined, while criticism from environmental organizations and communities may intensify (Hemantha Jayakody & Vaz, 2023).

Toll road infrastructure development in Indonesia continues to accelerate in line with government efforts to enhance interregional connectivity. However, in practice, these efforts still face serious challenges in integrating sustainability principles. This is evident in certain toll road projects that fail to fully adopt sustainable practices. For instance, the Terbanggi Besar–Pematang Panggang–Kayu Agung and Pekanbaru–Dumai toll roads experienced significant pavement deterioration before reaching their design lifespan, resulting in high maintenance costs—an outcome that contradicts the principles of efficiency and sustainability in long-term infrastructure management.

Some toll roads in Indonesia have started adopting GTRI standards as part of the shift toward sustainable development. The Gempol–Pandaan and Kunciran–Serpong toll roads, which have achieved GTRI certification, demonstrate better performance in both planning and operations. These examples illustrate the potential benefits of applying green policies in toll road management.

The disparity in implementation levels between certified and uncertified toll roads highlights the gap in green policy adoption in the toll road sector. This study examines six toll roads as case studies—two certified under GTRI (Gempol–Pandaan and Kunciran–Serpong) and four uncertified (Pekanbaru–Dumai, Terbanggi Besar–Pematang Panggang–Kayu Agung, Medan–Binjai, and Jakarta Outer Ring Road South Section). The selection was based on a purposive sampling approach to represent diverse geographic locations, operational characteristics, and varying implementation conditions. Availability of data and access to key informants were also considered in the selection process.

The two certified toll roads serve as benchmarks for ideal green policy application, while the four uncertified roads represent large-scale toll operations with distinct challenges and characteristics. The primary objective of this research is to evaluate green policy implementation on these six toll roads based on GTRI indicators, identify differences in implementation between certified and uncertified roads, and propose actionable recommendations for the three main phases of toll road development—planning, construction, and operation. The findings are expected to contribute to the development of more environmentally friendly, efficient, and sustainable toll road management systems, and to support the formulation of national green policy regulations.

2. LITERATURE REVIEW

2.1Green Policy

A green policy refers to a set of guidelines or strategies adopted by an organization or company to minimize environmental impacts and promote sustainable practices. Such policies typically include measures such as eco-labeling, energy efficiency, recycling, and the use of clean technologies to mitigate negative environmental effects. The core principles of a green policy involve sustainable resource management, environmental impact reduction, and innovations that simultaneously enhance environmental and economic performance. Its implementation also emphasizes the importance of stakeholder collaboration, the use of environmentally friendly technologies, and the cultivation of an organizational culture that supports sustainability values. The implementation of a green policy generally follows several key stages (Wang & Juo, 2021):

1. Identification of relevant environmental aspects.
2. Development of environmentally friendly strategies.
3. Implementation of sustainable practices.
4. Monitoring and evaluation of environmental performance.

2.2Green Toll Road

A green road refers to environmentally friendly road infrastructure that is designed and maintained to minimize environmental damage caused by land transportation, such as carbon emissions from traffic, greenhouse gas emissions, air pollution, and habitat destruction. Green roads can also contribute positively to environmental conservation by improving transportation efficiency, reducing fuel consumption, supporting sustainable land use, and promoting the use of public transportation (Din et al., 2023).

A green toll road is a toll road managed by the government that aims to provide high-quality transportation services, reduce costs, lower carbon emissions, and promote environmental sustainability. This can be achieved by integrating carbon emission reduction strategies into operational and financial models, as well as evaluating the effectiveness and potential of environmental policies (Shang et al., 2024).

2.3Green Toll Road Indonesia

The concept of a green road in Indonesia refers to sustainable road development practices that prioritize environmentally friendly and sustainable approaches in road design, construction, and maintenance. This concept represents roads designed and built in accordance with sustainability criteria, utilizing environmentally friendly technologies (Lawalata, 2014).

The Green Toll Road Indonesia (GTRI) framework applies the green concept to toll roads by incorporating sustainability principles to mitigate environmental impacts such as air pollution, noise pollution, and urban heat effects. This approach aims to minimize negative environmental impacts and enhance the overall sustainability of toll road development (Raharjo et al., 2021).

GTRI specifically focuses on reducing carbon emissions from toll road development. In collaboration with the Ministry of Public Works and Housing, the Indonesian government seeks to provide the best service to the public through toll roads, particularly by adopting green toll road principles nationwide. Failure to implement green principles in toll road projects may result in higher carbon emissions and a lack of environmentally friendly infrastructure. Therefore, the integration of green concepts in toll road development is crucial to mitigating environmental impacts and promoting sustainability (Mairizal et al., 2023).

The Green Toll Road Indonesia certification is awarded to toll roads that successfully achieve sustainability standards for a given project. Sustainability achievements are classified into several levels, each defined by specific requirements of the GTRI framework, criteria for each level, and the number of points needed to qualify (Lawalata, 2014).

2.4Related Works

As the urgency of sustainable infrastructure development increases, various studies have been conducted to examine the application of green concepts in toll roads, both in Indonesia and globally. Shang et al. (2024) highlighted the importance of implementing the green toll concept in China, focusing on operational cost optimization and the need for a framework that incorporates carbon emissions into decision-making. Their approach emphasizes the significance of policy interventions and a systemic transition toward low-carbon infrastructure.

In the Indonesian context, Rahmat et al. (2023) employed a multiple linear regression model to evaluate factors influencing the implementation of green policy. This study identified six key factors—ranging from pavement technology and material life cycles to environmental management—as determinants of successful green projects. Meanwhile, Mairizal et al. (2023) applied Structural Equation Modeling (SEM) to assess relationships among sustainability factors, underscoring the importance of project manager competence and environmental accountability systems in reducing emissions and improving energy efficiency.

On the other hand, quantitative approaches based on multi-criteria decision-making (MCDM) have been increasingly adopted to address sustainability system complexities. Taghavi et al. (2021) employed a DEMATEL–ANP hybrid method to evaluate the implementation of Green Supply Chain Management (GSCM) in construction, demonstrating the effectiveness of this approach in mapping interrelationships and prioritizing external factors.

Furthermore, Asy'Ary & Utomo (2020) and Djalante et al. 2020) evaluated the application of green concepts through descriptive and cluster analysis, respectively, focusing on managerial dimensions and comparative achievements among road segments. These studies provide valuable insights into the social, technical, and environmental dimensions of green road development.

However, most previous studies have not specifically evaluated the implementation of green policy in toll road projects based on the official GTRI indicators, nor have they comprehensively assessed its

application across the planning, construction, and operational stages. This research addresses that gap by examining green policy implementation with reference to GTRI indicators and evaluating three key aspects across the toll road project life cycle. The assessment is conducted through a scoring system based on measurable indicators relevant to field conditions. This approach also compares projects that have adopted GTRI standards with those that have not, to identify gaps, challenges, and improvement opportunities. The findings of this study are expected to strengthen strategies for developing green policies in sustainable toll road infrastructure.

3. METHOD

3.1 Research Stage

This research was carried out through a series of systematic stages to evaluate the implementation of green policy on Indonesian toll roads and formulate data-driven policy enhancement recommendations. The research stages are structured as follows:

1. Identification of Problems and Research Objectives

The research began by identifying the main issues related to the suboptimal implementation of the green policy concept in toll road development in Indonesia. These issues were then formulated into objectives, which include evaluating the level of implementation and formulating policy recommendations.

2. Literature Review and Theoretical Strengthening

A literature review was conducted to strengthen the theoretical foundation related to environmentally friendly policies, the Green Toll Road Index (GTRI) system, and the framework for evaluating policy implementation. This literature serves as the basis for developing assessment indicators and analysis strategies.

3. Development of Conceptual Framework and Evaluation Indicators

The conceptual framework was developed based on an evaluative approach and adopted GTRI indicators, covering aspects of planning, construction, construction materials, accessibility, feasibility, service, energy efficiency, water efficiency, environmental aspects, and regional cooperation.

4. Data Collection

Data were collected through in-depth interviews with toll road operators. In addition, project data were gathered to support the assessment process and validate the findings.

5. Evaluation of Green Policy Implementation Level

The results from interviews and documents were analyzed using a qualitative approach to assess the extent to which each indicator has been implemented. The assessment was conducted descriptively to illustrate the level of green policy adoption.

6. Comparative Analysis

The study compared the implementation of green policy on GTRI-certified toll road sections with those that are uncertified. This analysis aimed to identify implementation gaps, inhibiting factors, and best practices that could be replicated.

7. Formulation of Green Policy Strengthening Recommendations

Based on the results of the evaluation and comparative analysis, recommendations were developed to strengthen the comprehensive implementation of green policy. The recommendations focus on policy reinforcement, technical capacity improvement, financial support, and multi-stakeholder collaboration.

3.2 Data Collection Techniques

The data collection in this research was carried out using two main approaches: in-depth interviews and document studies, in order to obtain relevant and comprehensive data regarding the implementation of green policy in toll road projects.

1. In-depth Interviews

In-depth interviews were conducted in a semi-structured manner with parties directly involved in the construction and management of toll roads. The informants were selected based on their involvement in planning, implementation, and supervision processes. One key informant in this study was the Operations Director of one of the Toll Road Regulatory Bodies (BPJT), who plays a strategic role in the management and implementation of sustainability policies in toll road projects.

The interviews aimed to explore information regarding:

a. The level of implementation of GTRI indicators in each toll road section,
b. Challenges and obstacles in implementing green policy,
c. Best practices successfully applied,

d. Perceptions of sustainability in toll road projects.

2. Document Study

Data obtained from document studies were used as the basis for developing evaluation indicators and understanding the context of green policy implementation in the field.

3.3 Data Analysis Technique

The data analysis in this research was conducted using a qualitative descriptive approach and an assessment based on the GTRI indicators. Data were collected through in-depth interviews and document studies, then analyzed to evaluate the level of green policy implementation in each toll road section.

As part of the assessment process, the researcher also conducted brainstorming sessions with four professionals who have knowledge and experience in sustainability and toll road infrastructure. These four professionals were not categorized as interview informants but were specifically involved to provide assessments of the GTRI indicator implementation.

The brainstorming sessions focused on the evaluation and analysis of data obtained from in-depth interviews and document studies. The objectives were to:

1. Align understanding of the GTRI indicators,
2. Provide input on the findings,
3. Help strengthen the evaluation direction before the final analysis was carried out by the researcher.

The results of these brainstorming sessions were used as additional considerations in evaluating each toll road section, ensuring that the assessment was more targeted, consistent, and not solely dependent on a single point of view.

4. RESULT

This study examines six toll road sections, consisting of two sections certified under the GTRI program and four uncertified sections. The selection of these six toll roads takes into account the diversity of regional characteristics, ranging from those located in densely populated urban areas to intercity sections crossing provincial boundaries, as well as varying levels of sustainability principle implementation.

4.1 Estimation of Green Policy Implementation Levels on Toll Road Sections

1. Gempol–Pandaan Toll Road

The estimated level of green policy implementation on the Gempol–Pandaan section was based on an analysis of the GTRI assessment indicators developed by GPCI. The evaluation covered eight main aspects: planning, construction, construction materials, access and service, energy efficiency, water efficiency, environment, and regional cooperation. As shown in Table 4.1, this toll road achieved an estimated score of 96 out of 100, indicating a very high level of sustainability integration. This result aligns with its GTRI Gold certification, which signifies comprehensive integration of sustainability aspects throughout the infrastructure lifecycle. Among the eight indicators, the environmental aspect contributed the highest proportion at 21%, followed by access, feasibility, and service at 20%. This reflects a strong emphasis on environmental impact management as well as user comfort and safety. The construction materials aspect contributed 13%, followed by construction at 11%, and energy efficiency at 10%, indicating the application of efficiency principles and sustainable resource utilization. Planning and water efficiency each contributed 9%, showing attention to early-stage design and water resource management. Lastly, regional cooperation accounted for 3%, suggesting the need for stronger interregional coordination in green infrastructure development. Overall, these results illustrate that the Gempol–Pandaan Toll Road demonstrates excellent performance in implementing green infrastructure principles and serves as a benchmark for promoting green policy adoption across other toll road sections in Indonesia.

Tabel 4.1 Estimated Level of Green Policy Implementation

No.	Assessment	Weight(%)	Target	Gempol - Pandaan (Gold Certified)		Kunciran - Serpong (Gold Certified)		Pekanbaru - Dumai (Non-Certified)		TBPPKA (Non-Certified)		Medan - Binjai (Non-Certified)		JORR-S (Non-Certified)	
				Verification Results	Total (%)	Verification Results	Total (%)	Verification Results	Total (%)	Verification Results	Total (%)	Verification Results	Total (%)	Verification Results	Total (%)
1	Planning	8	30	32	9	31	8	15	4	15	4	14	4	7	2
2	Construction	13	50	43	11	49	13	19	5	22	6	19	5	36	9
3	Construction Materials	10	62	81	13	87	14	54	9	65	10	53	9	83	13
4	Access, Affordability, and Service	23	294	257	20	220	17	115	9	149	12	105	8	142	11
5	Energy Efficiency	11	47	44	10	42	10	13	3	37	9	11	3	19	4
6	Water Efficiency	11	110	85	9	68	7	7	1	10	1	3	0	40	4
7	Environment	21	136	137	21	114	18	52	8	67	10	23	4	32	5
8	Regional Cooperation	3	22	22	3	10	1	15	2	21	3	8	1	10	1
Total overall value		**100**	**751**	**701**	**96**	**621**	**88**	**290**	**40**	**386**	**55**	**236**	**33**	**369**	**50**

2. Kunciran–Serpong Toll Road

Based on the GTRI indicators from GPCI, the Kunciran–Serpong Toll Road achieved a total score of 88%, indicating a high and consistent level of green policy implementation across most assessment aspects. The detailed results for each aspect are presented in Table 4.1. This toll road has also officially obtained a GTRI Gold certification, reinforcing the validity and appropriateness of its sustainability efforts.

The planning and construction aspects both achieved their maximum possible scores, reflecting the integration of sustainability considerations from the early stages of development. The construction materials aspect even exceeded its weighting, indicating significant use of eco-friendly or recycled materials. Access, feasibility, and service scored 17%, showing adequate attention to user comfort and accessibility, although there is still room for improvement. Energy efficiency was implemented well at 10%, while water efficiency scored 7%, indicating the need for enhanced water conservation systems. The environmental aspect scored 18%, reflecting strong environmental management, including emissions control and vegetation conservation. Overall, the Kunciran–Serpong Toll Road can be categorized as one of the most sustainable toll roads in Indonesia and serves as a successful example of green policy implementation.

3. Pekanbaru–Dumai Toll Road

The 131 km Pekanbaru–Dumai Toll Road passes through environmentally sensitive areas, such as forests and peatlands. Based on the GTRI indicators by GPCI, it scored a total of 40%, reflecting a relatively low level of green policy implementation compared to optimal standards. The detailed breakdown for each aspect is also presented in Table 4.1. This result shows that while some sustainability aspects have been addressed, there is significant room for improvement, particularly in water efficiency (1%), energy efficiency (3%), and regional cooperation (2%). The highest scores were recorded for construction materials (9%), access, feasibility, and service (9%), and environment (9%), indicating some attention to user comfort and environmental preservation. Overall, this score suggests that the implementation of sustainability principles in this toll road section is still in the early stages of progressing toward comprehensive sustainable toll road practices.

4. Terbanggi Besar–Pematang Panggang–Kayu Agung Toll Road (TBPPKA)

The TBPPKA section forms part of the main Trans-Sumatra Toll Road, connecting Lampung Province with South Sumatra. Stretching 189 km, it has been operational since 2019. Based on the GPCI indicators, the estimated level of green policy implementation is 55%, as shown in Table 4.1. This score indicates that most sustainability aspects have been reasonably accommodated, particularly access, feasibility, and service (12%), construction materials (10%), and environment (10%). However, water efficiency remains low at 1%, and regional cooperation at 3%, highlighting the need for improvements in resource management and interregional collaboration. Overall, this result shows that TBPPKA has significant potential to achieve higher sustainability standards through continuous improvement in its lower-performing aspects.

5. Medan–Binjai Toll Road

The 17 km Medan–Binjai Toll Road is part of the network connecting Medan City to the western areas of North Sumatra Province. As an urban toll road, it supports both intra-city and interregional connectivity. Based on the GPCI indicators, this toll road scored only 33%, as shown in Table 4.1, indicating a relatively low level of green policy implementation. The highest scores came from construction materials (9%) and access, feasibility, and service (8%), suggesting some efforts in material selection and accessibility. However, most other aspects remain low, with water efficiency scoring 0%, planning and environment each scoring 4%, construction scoring 5%, energy efficiency scoring 3%, and regional cooperation scoring 1%. These findings indicate that sustainability management in the Medan–Binjai Toll Road remains limited and requires greater emphasis on environmental aspects and resource efficiency.

6. Jakarta Outer Ring Road Section S (JORR-S)

JORR-S is part of the urban toll road network in Jakarta, playing a critical role in reducing congestion and improving interregional connectivity within the capital. The estimated green policy implementation level for this section is 50%, or half of the maximum possible score, based on the GPCI indicators outlined in Table 4.1. The highest score was recorded in construction materials (13%), reflecting attention to the use of more environmentally friendly materials. Access, feasibility, and service also performed fairly well at 11%, indicating improvements in user service quality. However, aspects such as planning (2%),

regional cooperation (1%), and environment (5%) remain relatively low, showing that there is still room for further improvement to enhance sustainability in urban toll road management.

4.2 Evaluation of the Level of Green Policy Implementation on Toll Road Sections

Based on the assessment of the six toll road sections examined in this study, a clear gap in sustainability performance is evident between those that have obtained GTRI certification and those that have not. For the uncertified toll roads, most sustainability indicators have yet to meet the established targets, whether in the planning stage, construction implementation, or operational and maintenance phases. To gain a deeper understanding of the underlying causes of these gaps, an evaluation was conducted on the factors influencing the performance of each indicator. The 5M+1E framework—comprising Man, Machine, Method, Material, Money, and Environment—was employed to identify the root causes that hinder the adoption of green policies in toll road projects. The key findings for each category are summarized as follows:

1. Man (Human Resources)

There is a general lack of competence and awareness among both operational and managerial personnel regarding concepts of green infrastructure, green construction, and sustainability. Training and certification related to sustainable planning, construction, and operations including occupational health and safety management system, green procurement, energy and water efficiency, and environmental management—remain limited. No mandatory requirements are imposed by operators or government bodies to enhance green-related capabilities. Internal initiatives and environmental awareness tend to be low unless driven by regulatory pressure, and dedicated personnel for monitoring sustainability and environmental issues are scarce.

2. Machine (Equipment and Technology)

The adoption of green technologies in construction, operations, and public facilities is minimal. This includes the limited use of low-emission heavy equipment, energy-efficient lighting, and energy monitoring systems. Supporting facilities such as energy-saving sensors, water recycling systems, and waste management infrastructure are either unavailable or unevenly distributed. Additionally, there is no systematic performance monitoring of equipment related to energy, water, or environmental quality. Technological capacity for on-site reuse/recycling of construction materials and waste management is also lacking.

3. Method (Processes and Procedures)

There are no standard operating procedures (SOPs) or internal guidelines integrating sustainability principles from the planning stage through to maintenance. Design, construction, and operational processes remain conventional, with limited adoption of reuse, recycling, eco-design, or green engineering approaches. Environmental documents such as Environmental Management Plan/ Environmental Monitoring Plan and Environmental Impact Assessment are often treated as formalities rather than operational references. Regular audits and evaluations for energy, water, and environmental performance are absent, and environmental risk management is not systematically embedded into the toll road lifecycle.

4. Material

Environmentally friendly materials are often unavailable in project regions, including certified green materials that comply with domestic content requirements (TKDN). Material selection is largely driven by short-term cost considerations rather than long-term sustainability benefits. There is no centralized database or internal policy for green materials, and reuse/recycling of construction materials is not implemented systematically. Materials used for public facilities—such as lighting, concrete, and landscaping—do not always follow green construction principles.

5. Money (Funding and Incentives)

Budgets dedicated to capacity building, green technology, and procurement of sustainable materials are limited. Green policy implementation is often perceived as an additional cost rather than a long-term investment. There are no incentive schemes or bonuses for projects that adopt sustainability measures. Financial priorities remain focused on core infrastructure rather than green-supporting facilities, and funding for CSR initiatives and community empowerment around toll roads is minimal.

6. Environment (Regulatory and Organizational Context)

Sustainability regulations are not universally mandatory across toll road projects, with certifications such as GTRI remaining optional. Regulatory enforcement is weak, particularly for inter-provincial routes. Government incentives for projects adopting green policies are minimal. Organizational culture does not

prioritize sustainability in day-to-day operations, and public participation from communities around the toll roads is low due to limited engagement and transparency. Furthermore, the physical environment of offices and rest areas is often not designed according to green principles, such as natural ventilation, daylighting, or rainwater infiltration.

Based on the identification of root causes using the 5M+1E framework, it is evident that the main challenges in implementing green policies in toll road projects encompass human resources, technology, procedures, materials, financing, and the broader regulatory and organizational context. These issues are interconnected, forming systemic barriers that hinder the achievement of sustainability targets. Therefore, a comprehensive and integrated strategy is required to address these root causes. This strategy should not only resolve existing weaknesses but also drive transformation towards the sustainable implementation of green policies throughout the toll road life cycle—from planning and construction to operation and maintenance.

1. Man (Human Resources)

Capacity building is essential through regular training and certification programs focused on green infrastructure, sustainable construction, energy and water efficiency, and environmental management. Sustainability competencies should be embedded into recruitment criteria, career promotion requirements, and contractual agreements. Dedicated sustainability teams or Green Officers should be established within each toll road management unit to monitor sustainability indicators. In addition, environmental awareness can be enhanced through internal campaigns, toolbox meetings, and recognition programs for employees who excel in applying green policies.

2. Machine (Equipment and Technology)

The adoption of low-emission, energy-efficient heavy equipment should be prioritized, alongside the installation of energy, water, and environmental quality monitoring systems in management offices, rest areas, and public facilities. Supporting infrastructure such as energy-efficient LED lighting, automated sensors, water recycling systems, and waste management facilities should be provided. Technical capabilities for the on-site reuse or recycling of construction materials should also be strengthened.

3. Method (Processes and Procedures)

Standard Operating Procedures (SOPs) must integrate sustainability principles from the planning stage through to maintenance. Environmental documents should be used as operational references rather than mere formalities. Periodic audits of energy efficiency, water conservation, and environmental performance should be conducted, and environmental risk management should be embedded into every phase of the project, including design, construction, and operations.

4. Material (Resources)

Internal policies should prioritize the use of environmentally friendly and TKDN-certified materials. A database of suppliers offering green building materials—including recycled and low-carbon products—should be developed. Standard procedures for the reuse and recycling of construction materials should be implemented, and sustainable materials should be used for public facilities, including lighting, furniture, and landscaping.

5. Money (Financing and Incentives)

A dedicated budget should be allocated for implementing green technologies, training programs, and procuring environmentally friendly materials. Incentive schemes or bonuses should be provided for projects that meet or exceed sustainability targets. Life cycle costs and long-term savings should be considered as key factors in budget planning. Corporate Social Responsibility (CSR) funds can be optimized to support community empowerment and environmental preservation programs in areas surrounding the toll roads.

6. Environment (Regulatory and Organizational Context)

The adoption of the GTRI certification or other sustainability standards should be mandated rather than optional. Coordination with both local and central governments should be strengthened to ensure regulatory compliance across provinces. An organizational culture that places sustainability as a core value must be cultivated. Public engagement can be increased through consultation forums, environmental reporting, and transparent data sharing. Finally, office buildings and TIPs should be designed in accordance with green building principles, such as maximizing natural lighting, applying cross ventilation, and utilizing rainwater harvesting systems.

4.3Strengthening Recommendations for Green Policy Practices on Toll Roads

The recommendations for strengthening green policy practices on toll roads are designed comprehensively, covering the planning, construction, and operation & maintenance phases. Each stage plays a crucial role in ensuring that the green policy is not merely an administrative concept, but truly implemented in ways that deliver tangible impacts. This approach aligns with the GTRI sustainability indicators, which emphasize the importance of integrating environmentally friendly principles from the outset of a project through to its long-term operations. The following are the recommendations for strengthening green policy practices on toll roads in Indonesia.

1. Integrating sustainability principles from the planning stage

The planning phase plays a critical role in ensuring that sustainability principles are integrated from the very beginning of toll road development. The preparation of feasibility studies and technical designs should refer to green indicators such as those outlined by GTRI, so that the resulting plans genuinely reflect an environmentally friendly approach. Key aspects to consider include the selection of sustainable materials, efficiency in energy and water use, and more comprehensive environmental impact assessments, including social factors and climate change adaptation measures.

To support the tangible implementation of green policies, dedicated budget allocations should be embedded in cost plans as a strategic commitment, rather than as an additional expense. In addition, internal company policies and external regulations that support environmental principles will further strengthen the direction of sustainable development. Stakeholder involvement from the earliest stages—through mapping and consultation processes—also becomes a critical factor in building cross-sector synergy to ensure project continuity and sustainability.

2. Implementing green construction

The construction phase plays a vital role in bringing green policy into real-world practice. Sustainable principles can be applied by establishing mandatory green construction SOPs for all contractors and subcontractors, including hazardous and non-hazardous waste management, reuse of water from concrete curing processes, and energy efficiency during project execution. The selection of construction materials should prioritize certified eco-friendly products, locally sourced materials, and low-carbon options.

Supporting facilities for green policy should be built from the start of the project, such as infiltration wells, water-saving toilets, and segregated waste bins. These can help reduce the ecological impact of construction activities. To ensure consistent implementation of sustainability practices, regular training on occupational health, safety, and environmental aspects should be provided to all project workers. Furthermore, protecting the surrounding ecosystems and implementing reforestation within the construction area should be a top priority. All activities should be regularly monitored using digital technologies to enable automatic and transparent reporting.

3. Promoting sustainable operations and maintenance

In the operation and maintenance phase, sustainability principles should be implemented through efficient resource use and internal policies that support environmentally friendly practices. The adoption of energy- and water-saving technologies such as solar panels, automated sensors, and wastewater biofilter systems is an important step for operational offices, toll gates, and rest areas TIP. Green operational policies can also be reinforced through internal SOPs, such as restrictions on single-use plastics, temperature control for air conditioning, and operational vehicle efficiency. An integrated waste management system should be established, covering waste from rest areas food services to vehicle oil waste, to prevent environmental pollution. The involvement of local communities in landscape maintenance and toll road cleanliness can also be a key element—through initiatives like park adoption programs and environmental education. Regular environmental monitoring and audits must be conducted as part of performance evaluation systems, with results used for continuous improvement. Sustaining operational sustainability requires incentive policies that encourage green programs, supported by adequate funding commitments from toll road operators.

4. Strengthening support systems that connect all toll road project phases sustainably

This can be achieved through systemic and structural cross-phase approaches. One crucial step is integrating green policy principles into technical regulations and policies from the start, so they serve as a consistent reference from planning to operations. This can be implemented by developing sustainability-based internal SOPs, setting green criteria in tender requirements, and aligning with national policies such as those from the Ministry of Public Works and Housing. In addition, multi-stakeholder collaboration must be built and maintained consistently. The involvement of local communities, academics, local governments, and civil society organizations can strengthen accountability and the

effectiveness of green policy implementation throughout the project life cycle. Strengthening human resource capacity and organizational culture is also essential. Continuous training for workers, management, and operators is necessary to ensure sustainability principles are not only documented but internalized into daily work practices.

Monitoring, auditing, and certification systems should be designed as ongoing mechanisms—such as annual GTRI-based audits or digital reporting that enables real-time evaluation and improvement. Financial support is also a strategic, inseparable factor. Every stage requires additional investment for green principle implementation; therefore, government and corporate incentive schemes should be encouraged to stimulate the use of eco-friendly materials, energy efficiency, and other green innovations. Finally, communication and public outreach must not be overlooked. Positive branding of green toll roads through ongoing campaigns, media engagement, and sustainability performance publications can enhance public trust and encourage toll road users to participate in environmental preservation efforts

5. CONCLUSION

The findings of this study indicate that the level of green policy implementation across six toll road segments in Indonesia varies significantly based on GTRI indicators. Toll roads that have been certified, such as the Gempol–Pandaan Toll Road and the Kunciran–Serpong Toll Road, demonstrate more consistent application of sustainability principles from the planning stage through to operations. In contrast, non-certified toll roads still exhibit various weaknesses and inconsistencies in implementing sustainability aspects. These findings highlight the need for a more systematic and comprehensive approach to strengthen green policy practices throughout the entire lifecycle of toll road infrastructure in Indonesia.

Based on the evaluation of six toll road segments in Indonesia, a significant gap is found between GTRI-certified and non-certified segments. This gap spans all assessment aspects within the GTRI indicators, including planning, construction implementation, and regional cooperation. Certified toll roads such as Gempol–Pandaan and Kunciran–Serpong demonstrate more consistent application of sustainability principles, whereas non-certified roads face multiple challenges such as limited human resource capacity, absence of sustainability-oriented SOPs, low adoption of green technologies, weak regulatory frameworks, and minimal stakeholder collaboration.

Recommendations for strengthening green policy practices on toll roads in Indonesia must be designed comprehensively—covering planning, construction, and operation & maintenance—so that sustainability principles are not merely administrative formalities, but are genuinely realized in practice. In the planning stage, green principles should be integrated from the preparation of feasibility studies through regulatory support, dedicated budget allocation, and participatory stakeholder engagement. In the construction stage, key strategies include developing and implementing GTRI-based SOPs, using environmentally certified materials, ensuring energy and water efficiency, and providing occupational safety, health, and environmental training for workers, supported by monitoring technology and protection of surrounding ecosystems. The operational phase emphasizes measurable green policies, resource efficiency, waste management, community participation, and the execution of continuous audits and monitoring. To ensure cross-phase continuity, a robust support system is required, encompassing regulatory harmonization, integrated SOP development, multi-stakeholder collaboration, human resource capacity building, strengthening of eco-friendly material supply chains, GTRI-based auditing and reporting mechanisms, and green financing schemes. Through this approach, green policy serves as an integrative strategy that promotes efficient, adaptive, and sustainable toll road management.

Future research should focus on developing a more adaptive and measurable evaluation model to support the formulation of sustainable performance indicators. Comparative studies between toll road segments that have successfully implemented GTRI and those that have not, as well as benchmarking with countries that have effectively applied green policy concepts, are recommended to identify key success factors. Additionally, further investigation into organizational and stakeholder readiness to support green policy, including the integration of incentive systems and regulatory strengthening is essential. Exploring the integration of green policy with smart transportation technologies based on renewable energy and real-time data also presents a promising avenue. Lastly, conducting cost-benefit analyses or Life Cycle Cost Analysis would help demonstrate that green initiatives represent long-term investments rather than upfront financial burdens.

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