Journal of Social Economics Research
2025 Vol. 12, No. 2, pp. 144-160
ISSN(e): 2312-6264
ISSN(p): 2312-6329
DOI: 10.18488/35.v12i2.4337

Strategic insights for sustainable conservation area development in TN Babul: SWOT and TOWS analysis approach

Safri Arif[1]
Harsuko Riniwati[2+]
Gatot Ciptadi[3]
Hasnidar[4]
Reny Tiarantika[5]

[1,5]*Department of Environment Sciences, Graduate School, Universitas Brawijaya, Malang, 65145, Indonesia.*
[1]*Email: asenfri@gmail.com*
[5]*Email: rtiarantika027@gmail.com*
[2]*Faculty of Fisheries and Marine Science, Universitas Brawijaya, Malang, 65145, Indonesia.*
[2]*Email: riniwatisepk@ub.ac.id*
[3]*Faculty of Animal Science, Universitas Brawijaya, Malang, 65145, Indonesia.*
[3]*Email: ciptadi@ub.ac.id*
[4]*Faculty of Fisheries and Marine Science, Universitas Muslim Indonesia, Makassar, 90231, Indonesia.*
[4]*Email: hasnidar.yasin@umi.ac.id*


(+ Corresponding author)

Article History
Received: 28 April 2025
Revised: 30 June 2025
Accepted: 15 July 2025
Published: 1 August 2025

Keywords
Bantimurung-Bulusaraung National Park
Biodiversity
Diversification strategy
Green infrastructure
Road development
Sustainable conservation
SWOT-TOWS.

JEL Classification:
F64; O44; Q01; Q56.

ABSTRACT

The construction of the Maros–Watampone national road, which passes through the Bantimurung-Bulusaraung National Park (TN Babul), reflects a dilemma between the need for infrastructure development and environmental conservation in a tropical protected area. This area holds high ecological value as a habitat for various endemic and protected species, yet it is also targeted as part of a national strategic project. This study offers a strategic approach that combines SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis and the TOWS Matrix to develop adaptive and sustainable conservation area management strategies. SWOT analysis identifies internal and external factors in area management. The TOWS Matrix helps create practical and relevant strategic combinations. The analysis shows that TN Babul is in Quadrant II of the SWOT matrix. This highlights the need for diversification strategies to reduce internal weaknesses and capitalize on external opportunities. The novelty of this research lies in combining ecological, social, and institutional data to create evidence-based conservation strategies. The resulting strategies include adding green infrastructure to road design, improving data-driven biodiversity monitoring systems, supporting and educating local communities, and strengthening regulations and conflict risk management between people and wildlife. This approach not only provides technical solutions to the impacts of development but also proposes a transformation toward more participatory and inclusive conservation governance. This research makes a significant contribution to the development of data-based conservation policy models for protected areas under pressure from infrastructure development in Indonesia.

Contribution/Originality: This study offers an original strategic framework by integrating ecological, social, and institutional dimensions using a combined SWOT–TOWS approach to address conservation challenges in infrastructure-impacted protected areas. Unlike previous studies, it formulates diversification strategies that are evidence-based, participatory, and tailored for sustainable development planning in biodiversity-rich zones.

1. INTRODUCTION

One of the main objectives of Indonesia's national development agenda is the development of infrastructure (Rizal, Apriliani, & Permana, 2020). The foundation of interregional connectivity is provided by roads, particularly

in eastern Indonesia, which has long struggled with isolation. It is anticipated that better transportation routes will speed up the delivery of goods and services and provide local communities with new avenues for economic growth. Nonetheless, conservation areas and other places of high ecological value are frequently the sites of infrastructure development (Anggraini et al., 2023; Doan et al., 2024). As a result, there is a conflict between the need for development and environmental preservation. The upgrading project of the Maros-Watampone national road, which passes through the Bantimurung-Bulusaraung National Park (TN Babul), is one instance of this problem. TN Babul is a unique tropical karst area known for its high biodiversity and national protection status. The road construction project in this area poses serious ecological risks that require careful examination (Arsyad et al., 2023).

Numerous endemic species, such as the primate Tarsius fuscus and hundreds of regionally distinctive butterfly species, can be found in Bantimurung-Bulusaraung National Park. In addition to its abundant biodiversity, the park features karst geological landscapes that are highly susceptible to disturbance. Road construction, in particular, can cause habitat fragmentation, altered water flow, noise pollution, and easier access for humans, all of which may lead to illicit exploitation. This road development affects neighboring communities on social and economic levels, in addition to its ecological impacts (Dassir, Paembonan, Arsyad, Sadapotto, & Nadira, 2021; Muis, Hiola, Syamsiah, & Khatima, 2023). Better welfare is possible, but there is also a greater chance of running afoul of national park officials. To fully understand the effects of road construction in conservation areas, this research is essential. Research that ignores ecological effects in favor of focusing solely on economic gains could lead to unsustainable policies. TN Babul requires particular consideration in all development decisions because it is one of Indonesia's megabiodiversity zones.

The effects of road construction in conservation areas have been the subject of numerous studies conducted worldwide. Prior research has mostly concentrated on theoretical studies or spatial analysis of biodiversity loss without integrating full economic valuation models (Liu et al., 2019). While some studies explore the trade-offs between infrastructure development and conservation, they often do not include quantitative assessments of biodiversity loss in monetary terms (Nugroho, Pramukanto, Negara, Purnomowati, & Wulandari, 2016; Wardana et al., 2021). This gap in the literature presents an opportunity to investigate not only the ecological consequences of road expansion but also the associated economic costs, thereby enabling a more informed decision-making process.

Several scientists have investigated the relationship between biodiversity conservation and infrastructure development. For example, studies by Yandi, Rakhman, Martan, and Sidabutar (2023) emphasize how expanding roads can increase wildlife mortality rates, divide habitats, and alter ecological interactions. Simultaneously, studies on sustainable infrastructure development, such as those conducted by Li, Liu, Liu, and Ren (2025) and Prapti (2021), demonstrate how some adverse effects can be minimized by considering ecological factors during road design. Case studies on TN Babul remain limited, particularly those integrating ecological and economic perspectives. This study aims to provide a comprehensive evaluation in response to the increasing demand for road development in TN Babul. One of the primary challenges in developing effective mitigation strategies is the lack of such methods. This highlights a research gap in fully understanding the impacts of road development in Indonesian conservation areas. Therefore, there is an urgent need for research that addresses this gap using a more contextual and systemic approach. Besides the absence of multifaceted methodologies, previous research has rarely employed quantitative techniques capable of assigning objective weights to each variable. The urgency of this research also stems from the escalating threats to conservation areas in Indonesia caused by large-scale development projects. Over the past two decades, conservation areas across various provinces have suffered degradation due to road construction, mining, and land encroachment (Anda et al., 2024; Kinseng, Mahmud, Hamdani, & Hidayati, 2019). In many cases, development has not only damaged ecosystems but also weakened conservation governance. These experiences show that development will continue to sacrifice critical areas without strong research interventions.

The environmental effects of infrastructure development in conservation areas have been the subject of numerous studies (Helldin, 2019; Morán-López, Guzmán, Casildo, & Tolosa, 2017; Sharma, Rimal, Stork, Baral, &

Dhakal, 2018) However, most of these studies Brown, Strickland-Munro, Kobryn, and Moore (2017) and Meraj, Singh, Kanga, and Islam (2022) have focused on spatial mapping or qualitative assessments without incorporating comprehensive economic valuation models. Notwithstanding their value, these approaches usually fail to accurately calculate the economic cost of biodiversity loss, which limits their capacity to effectively inform trade-offs in policy. Additionally, previous research often lacks an integrated, multifaceted analysis that simultaneously considers ecological, social, economic, and institutional factors within a single framework (Atasoy, 2020). There are not many empirical case studies that assess road development in TN Babul from a systemic and strategic planning standpoint. As a result, decision-makers often lack sufficient data-driven strategies, which can lead to policies that undermine conservation goals. This study aims to fill these significant gaps by organizing strategic planning using SWOT and TOWS analysis.

This study aims to address significant gaps by providing a comprehensive evaluation of the ecological and economic impacts of road development in TN Babul, utilizing SWOT and TOWS analyses to facilitate strategic planning. It emphasizes a cross-sectoral and participatory approach, integrating ecological data with institutional and community perspectives, contrasting with previous studies that are often top-down and sector-specific. Additionally, this research offers valuable insights for policymakers and conservation managers, along with methodological innovation through the proposal of adaptive strategies based on a structured SWOT-TOWS framework. The contribution of this paper lies in its ability to connect ecological concerns with strategic development planning, an approach that has been underutilized in Indonesia's conservation management literature.

2. LITERATURE REVIEW

2.1. Grand Theory: Sustainable Development Theory

This study is based on the Sustainable Development Theory (Figure 1), which focuses on balancing ecological, economic, and social aspects in the development process (Brundtland, 1987). According to this theory, development that disregards the carrying capacity of the environment will lead to long-term harm and the depletion of natural resources. This theory emphasizes the need for conservation strategies that support management institutions and enhance the well-being of local communities, in addition to protecting biodiversity. As a result, the TN Babul conservation area's development plan needs to address both ecological issues and human demands simultaneously.

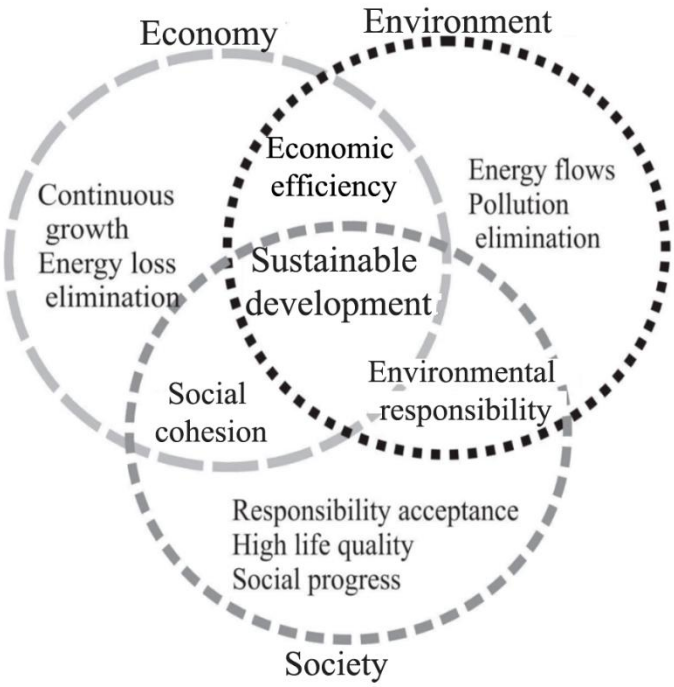

Figure 1. Sustainable development theory.

2.2. Concept of Conservation Areas and Sustainable Development

Conservation areas are defined as legally protected regions aimed at preserving their ecological, cultural, and social values (Westera, 2000). In Indonesia, this concept is reinforced by Law No. 5 of 1990. The sustainability of conservation areas relies not only on nature protection but also on inclusive and adaptive management mechanisms. Oladeji, Awolala, and Alabi (2022) and Riniwati, Harahab, and Abidin (2019) emphasize that conservation must be based on scientific data and consider anthropogenic pressures. Meanwhile, sustainable development prioritizes the synergy between conservation and long-term economic benefits for surrounding communities.

2.3. Strategic Approaches in Conservation Area Management

Managing conservation areas requires strategic approaches that consider social, economic, and environmental dynamics. Abecasis, Schmidt, Longnecker, and Clifton (2013) state that management strategies must be participatory and evidence-based to ensure long-term resilience. Godet (2000) emphasizes that local community involvement and advocacy for their interests are crucial aspects of conservation success. A strategy-based approach enables the identification of policies that are not only responsive to threats but also proactive in managing opportunities.

3. RESEARCH METHOD

3.1. Research Location

Babul National Park (TN Babul) is part of an important conservation region in Indonesia and is situated in an area with a high level of biodiversity. Located across a variety of ecosystem types, including lowland forests, peat swamps, and tropical rivers, this area consists of a core zone, utilization zone, and rehabilitation zone (Figure 2). Since TN Babul has significant potential as a conservation area and is also facing various development issues and human pressures, including deforestation, unregulated tourism, and land disputes with nearby communities, it was chosen as the study site (Muis et al., 2023). The research was conducted between June 2024 and February 2025.

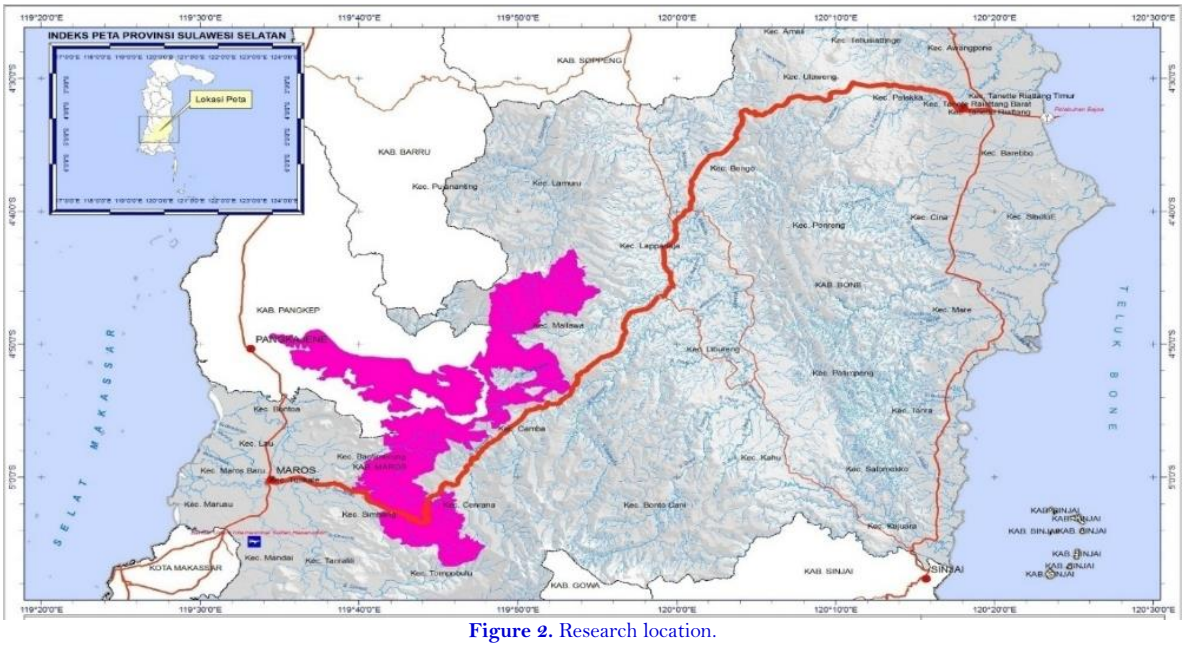

Figure 2. Research location.

3.2. Key Informant Study

The key informant study approach gathered detailed information from stakeholders with knowledge, experience, and direct involvement in road development and conservation in the Bantimurung-Bulusaraung National Park (TN Babul) area (Forje & Tchamba, 2022; Su, Wall, & Ma, 2014). Key informants were selected

based on specific criteria such as their involvement in area management, decision-making capacity, and understanding of the ecological and social aspects of the area. The categories of informants included national park managers from the TN Babul Office, local government officials from environmental and public works agencies, local community representatives, academics, and members of environmental non-governmental organizations (NGOs). Semi-structured interview techniques provided flexibility in exploring information while remaining aligned with the SWOT and TOWS analysis frameworks (Tajer & Demir, 2022).

The informants' opinions regarding the effects of road construction on the environment, the efficiency of conservation governance, community involvement, and the potential and difficulties of sustainable area development were the main subjects of the interviews. To determine internal (strengths and weaknesses) and external (opportunities and threats) factors for SWOT and TOWS analysis, the gathered data were compiled, categorized, and qualitatively examined. Focused group discussions were also used to validate the interview results in order to establish strategic agreement among different actors and validate preliminary findings. Triangulation was carried out by contrasting the findings of interviews, direct observations, and secondary data to ensure the validity of the data. To confirm initial findings, reduce interpretation bias, and promote agreement on strategic directions, focus group discussions (FGDs) were also held with stakeholders. This approach ensures that the strategies formulated are relevant, participatory, and capable of addressing the realities on the ground comprehensively.

3.3. Data Collection Method

This study uses two types of data: primary data and secondary data. Primary data were collected through direct observation, interviews with stakeholders, and field surveys. Observations focused on identifying the condition of the roads and the characteristics of plants and animals around the research site (Hussain & Ingole, 2020). Interviews were conducted with national park managers, academics, and local communities to understand their perspectives on the effects of road development. To examine the affected routes and document the species present along the extended road segments, an exploratory methodology was employed during field surveys. Secondary data sources included official government documents, academic research, environmental reports, and thematic maps covering topography, geology, demographics, and ecosystems. Primary data were obtained from the Bantimurung Bulusaraung National Park Office, the Central Bureau of Statistics (BPS), and previous research on the impact of road development on conservation ecosystems. All participants provided informed consent prior to the interviews. The study adhered to ethical research standards, ensuring voluntary participation, confidentiality, and respondent anonymity.

3.4. The SWOT and TOWS Analysis

SWOT analysis is one of the methods used to develop conditions and evaluate a problem, project, or business concept based on internal (within) and external (outside) factors, namely strengths, weaknesses, opportunities, and threats. This method is most often used in business evaluation to identify strategies to be implemented. SWOT analysis only depicts the current situation, not just solving the problem (Nainggolan, Aritonang, Ginting, Sihotang, & Gea, 2021). SWOT analysis consists of four factors:

- Strengths: These are the conditions of strengths within the organization, project, or business concept. The strengths analyzed are factors existing within the organization, project, or business concept itself that is, what strengths the tourism sector has. By knowing these strengths, tourism can be developed to be more resilient, able to survive in the market, and capable of competing for further development related to tourism.
- Weaknesses: These are the conditions of weaknesses within the organization, project, or business concept. The weaknesses analyzed are factors existing within the organization, project, or business concept itself, namely all factors that are disadvantageous or detrimental to the development of tourism objects.

- Opportunities: These are conditions for growth opportunities that may occur in the future. These conditions originate externally to the organization, project, or business concept itself, such as competitors or policies.
- Threats: These are threatening conditions from the outside. These threats can disrupt the organization, project, or business concept itself.

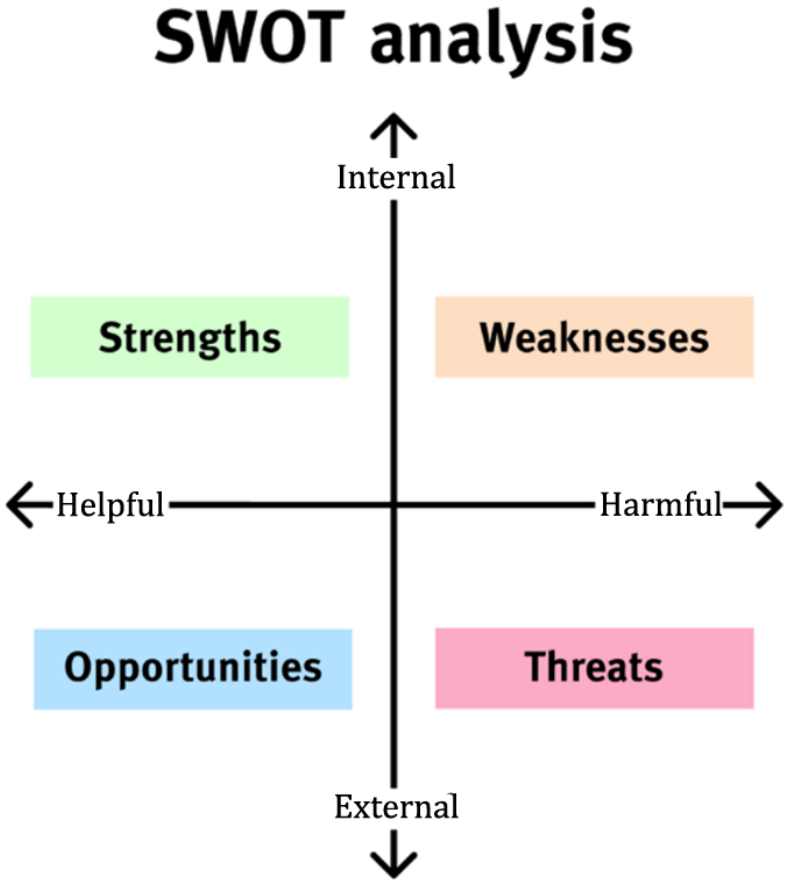

Figure 3. SWOT analysis.

To conduct a SWOT analysis, you need to follow several steps. This includes preparing data and identifying key internal and external factors. You can collect data using different methods such as interviews, surveys, observations, literature reviews, or focus group discussions with stakeholders. After gathering the data, analysts group the findings into the four SWOT components (Rahantoknam, 2024). This process typically involves collaborating with decision-makers or experts to ensure that each factor is relevant and accurately reflects the situation. Once all components are identified, they are organized into a SWOT matrix to analyze the relationships between internal strengths and weaknesses and external opportunities and threats.

According to Nainggolan et al. (2021), SWOT analysis is the systematic identification of various factors to formulate strategies expected to solve a problem. This analysis is based on logic that can maximize strengths and opportunities, while jointly minimizing weaknesses and threats. In preparing strategic factors, the SWOT matrix is used as shown in Figure 3. This matrix clearly illustrates how external opportunities and threats can be matched with internal strengths and weaknesses.

Generally, SWOT analysis is used to identify internal and external factors and build a foundational position for an organization, institution, or region (Jeelani & Shah, 2024). In the context of managing conservation areas such as Babul National Park (TN Babul), SWOT analysis is used to evaluate strengths, weaknesses, opportunities, and threats based on stakeholders' perceptions. However, to translate the results of SWOT analysis into applicable strategies, this study is complemented by a TOWS analysis. TOWS is a conceptual framework developed by

Weihrich (1982) to develop strategies based on logical combinations of SWOT factors. TOWS focuses on how an organization or region can:

- Use its strengths to exploit opportunities (SO strategy).
- Overcome weaknesses by leveraging opportunities (WO strategy).
- Use its strengths to avoid threats (ST strategy).
- Minimize weaknesses to avoid threats (WT strategy).

According to Weihrich (1982), TOWS strategies result from a logical combination of factors to generate tactical and actionable responses. This process allows stakeholders to formulate conservation policy directions based on actual conditions on the ground. Therefore, in this study, factors from qualitative SWOT analysis (obtained through interviews and focus group discussions) are then mapped into the TOWS matrix to formulate development strategies that are contextual, participatory, and adaptive (Figure 4). The strategies derived from TOWS are then used as the basis for drafting policy recommendations for the sustainable development of the TN Babul conservation area.

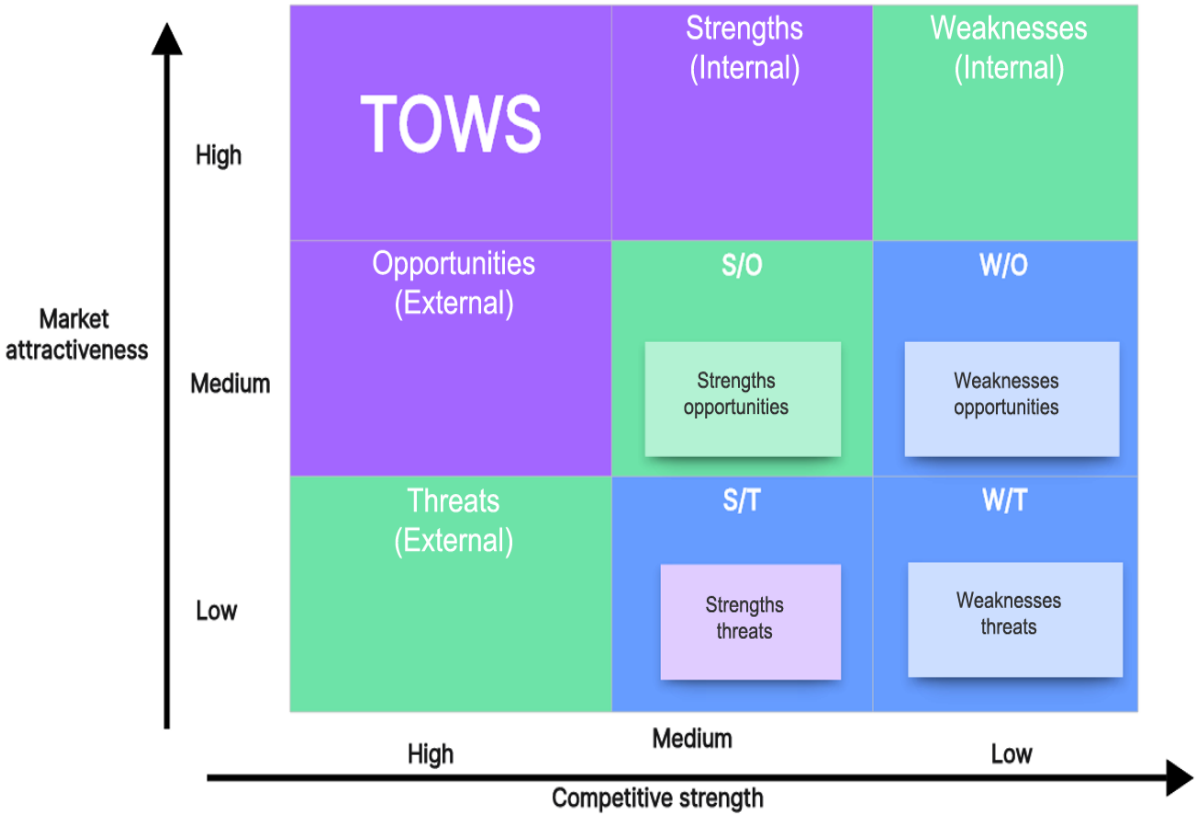

Figure 4. TOWS matrix.

4. RESULT AND DISCUSSION

4.1. SWOT Mapping

SWOT mapping (Strengths, Weaknesses, Opportunities, Threats) is a strategic approach used to analyze the internal and external conditions of an activity or project, in this case, road construction. This analysis aims to identify the strengths and weaknesses inherent within the internal system, as well as the opportunities and threats arising from the external environment (Table 1). This mapping is carried out based on the results of identifying sensitive attributes. Then, these factors are analyzed and plotted into the SWOT matrix to determine the strategic position and formulate appropriate follow-up strategies.

Table 1. SWOT Mapping.

Strengths	Weaknesses	Opportunities	Threats
Community participation in biodiversity conservation	The number of flora and fauna species decreased after development.	Potential economic value of affected species	Economic losses due to disruption of ecosystem services
Community involvement in road development planning	The area of remaining natural vegetation cover	Availability or potential for the development of wildlife corridor policies.	Environmental rehabilitation costs due to road construction.
Changes in conservation knowledge/education in the community	The level of habitat fragmentation	Innovation in green infrastructure technology and design (green roads)	Human-wildlife conflict due to habitat fragmentation.
	The existence of endemic or protected species that are threatened with disruption	Support from national/international conservation agencies	Negative community perceptions of the impacts of road construction
	Changes in local community livelihoods due to negative impacts	Increased public awareness and trends towards sustainable development	Lack of community involvement in planning and monitoring stages.
	The effectiveness of development supervision on ecological impacts is low	Opportunities for developing environmentally friendly drainage systems.	Lack of effective biodiversity monitoring policies and systems
	The availability of wildlife corridors or crossing routes is minimal	Opportunities for creating data-based biodiversity monitoring systems	Land conversion without adequate ecological impact assessments
	The distance of roads to core conservation areas is too close	Opportunities for integrating environmentally friendly road designs in the future	
	The absence of environmentally friendly road designs (Green-road infrastructure).		
	The drainage system has not been designed to prevent pollution of the surrounding environment.		
	The absence of a data-based biodiversity monitoring system		

4.2. Calculate IFAS EFAS

To formulate a sustainable and environmentally conscious development strategy, a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was conducted as a tool to assist strategic decision-making (Helmi & Ali, 2020). This analysis began with the preparation of two main matrices, namely the Internal Factor Analysis Summary (IFAS) (Table 2) and the External Factor Analysis Summary (EFAS) (Table 3). Both are used to identify and evaluate key factors influencing the success or failure of an activity or policy, in this case, road construction and its impacts on the environment and society.

Table 2. Internal factor analysis summary.

Strategic factor		Total	Weight	Total	Ratings	Score
Strengths	Community participation in biodiversity conservation	30	0.06	37	3.70	0.22
	Community involvement in road development planning.	39	0.08	40	4.00	0.31
	Changes in conservation knowledge and education within the community.	39	0.08	38	3.80	0.30
			0.22			0.84
Strategic factor		Total	Weight	Total	Ratings	Score
Weaknesses	The number of flora and fauna species decreases after development.	38	0.08	40	4.00	0.31
	The area of remaining natural vegetation cover.	38	0.08	30	3.00	0.23
	The level of habitat fragmentation	35	0.07	40	4.00	0.28
	The existence of endemic or protected species that are threatened with disruption	33	0.07	29	2.90	0.19
	Changes in local community neighborhoods due to negative impacts.	33	0.07	40	4.00	0.27
	Low effectiveness of development supervision on ecological impacts	34	0.07	40	4.00	0.27
	Minimal availability of wildlife corridors or crossing routes	35	0.07	30	3.00	0.21
	The distance of roads to core conservation areas is too close	36	0.07	40	4.00	0.29
	The absence of environmentally friendly road designs (Green Road Infrastructure).	36	0.07	36	3.60	0.26
	The drainage system has not been designed to prevent pollution of the surrounding environment.	38	0.08	30	3.00	0.23
	The absence of a data-based biodiversity monitoring system.	32	0.06	29	2.90	0.19
			496.00			2.73
			0.78			-1.89
			1.00			

Table 3. External factor analysis summary.

Strategic factor		Total	Weight	Total	Ratings	Score
Opportunities	Potential economic value of affected species	36	0.07	38	3.80	0.26
	Availability or potential for the development of wildlife corridor policies.	37	0.07	33	3.30	0.23
	Technological innovation and green infrastructure design (green roads).	39	0.07	40	4.00	0.30
	Support from national and international conservation agencies.	37	0.07	40	4.00	0.28
	Increased public awareness and trends toward sustainable development.	38	0.07	37	3.70	0.27
	Opportunities for the development of environmentally friendly drainage systems	37	0.07	30	3.00	0.21
	Opportunities for creating data-based biodiversity monitoring systems	31	0.06	30	3.00	0.18
	Opportunities for integrating environmentally friendly road designs in the future.	38	0.07	37	3.70	0.27
			0.56			2.00
Strategic factor		Total	Weight	Total	Ratings	Score
Threats	Economic losses due to disruption of ecosystem services	40	0.08	33	3.30	0.25
	Cost of environmental rehabilitation due to road construction.	36	0.07	34	3.40	0.23
	Human-wildlife conflict due to habitat fragmentation	30	0.06	35	3.50	0.20
	Negative community perception of the impacts of road construction.	29	0.06	38	3.80	0.21
	Non-community involvement in the planning and monitoring stages	30	0.06	32	3.20	0.18
	Lack of effective biodiversity monitoring policies and systems.	30	0.06	40	4.00	0.23
	Land conversion without adequate ecological impact assessments.	35	0.07	36	3.60	0.24
			523.00			1.55
			0.44			0.45
			1.00			

IFAS focuses on internal factors that reflect the strengths and weaknesses of the system under analysis. Meanwhile, EFAS describes external factors, including opportunities and threats, which are external conditions beyond direct control but have a significant influence (Jeelani & Shah, 2024). Through this approach, each factor is assessed based on its level of importance (weight) and its impact (rating), which are then calculated into a final score. The results from these two matrices provide an overview of the strategic position of the system analyzed and serve as the basis for formulating strategies that are aligned with the actual conditions in the field.

Based on the results of the IFAS and EFAS matrix calculations, a coordinate point of (-1.89; 0.45) was obtained, indicating that the system's position lies in Quadrant II of the SWOT matrix. This position shows that internally, the system has more weaknesses than strengths, as reflected by the negative IFAS value. However, externally, there are still opportunities that can be utilized, although not very dominant, as indicated by the positive EFAS value. The system's presence in Quadrant II indicates that the appropriate approach is to apply a diversification strategy. This strategy aims to reduce internal weaknesses by optimizing external opportunities. In sustainable road development, the diversification strategy can be realized through strengthening institutional regulations, involving the community in planning and conservation, and implementing green infrastructure technology. Although the system faces several limitations, such as human-wildlife conflicts, habitat fragmentation, and weak ecological supervision, there is still potential for policies and infrastructure to be developed to improve these conditions. This approach will serve as the foundation for designing adaptive, participatory, and sustainability-based strategic steps.

4.3. Strategy for Improving the Sustainability Status of TN Banbul

Based on the results of the SWOT analysis visualized in the TOWS matrix, the strategic coordinate position is in Quadrant II with values of X = -1.89 and Y = 0.45. This indicates that the management condition or the impact of road construction on the Bantimurung–Bulusaraung National Park area is in a position that presents opportunities but is also overshadowed by significant internal weaknesses.

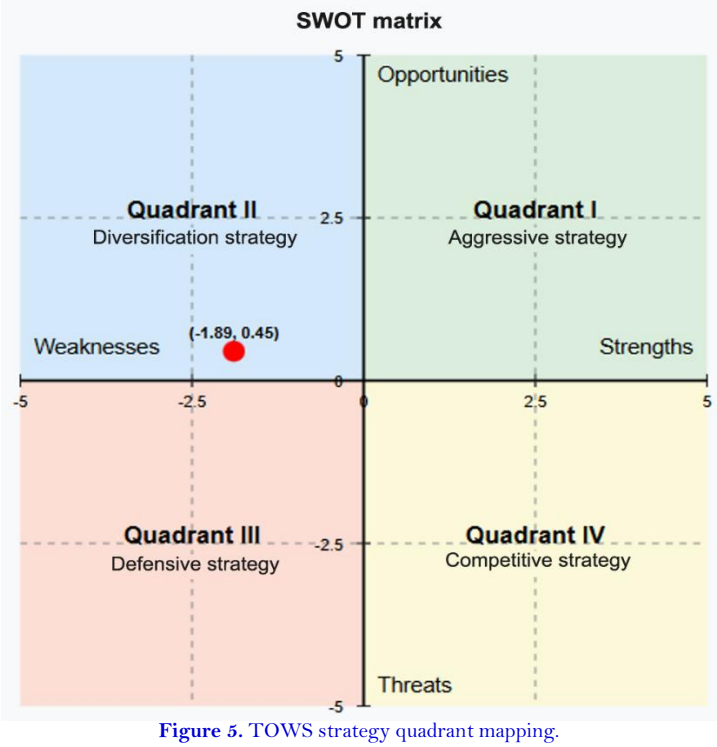

Figure 5. TOWS strategy quadrant mapping.

The position shown in Figure 5 places the strategy within a diversification approach, which is a strategy that utilizes existing external opportunities to overcome or minimize internal weaknesses (Alimoradiyan, Hajinezhad, Yousefi, & Giampietro, 2024; Thanh, Le Van Thuy, Anh, Nguyen, & Hieu, 2021). Weaknesses such as the suboptimal biodiversity monitoring system, lack of environmentally friendly road infrastructure design, minimal wildlife crossing corridors, and low effectiveness of ecological impact supervision are major challenges. However, these conditions still provide opportunities for developing strategies, such as support from national and international conservation agencies, trends in sustainable development, opportunities to develop green infrastructure technology, and increasing public awareness of the importance of conservation.

The strategy that needs to be developed is the diversification of programs and approaches, such as redesigning road construction with a green infrastructure approach, creating safe wildlife corridor pathways, enhancing education and community involvement in conservation, and building a participatory data-based monitoring system. The diversification strategy aims not only to reduce the negative impacts of road construction but also to optimize long-term ecological and socio-economic benefits sustainably. When implemented optimally by maximizing opportunities and improving weaknesses, this strategy is expected to improve the sustainability status index of Bantimurung–Bulusaraung National Park.

4.4. Implementation of Diversification Strategy

The purpose of the diversification strategy is to overcome internal weaknesses by utilizing external opportunities, ensuring that road construction continues while minimizing negative impacts on biodiversity and communities. Table 4 summarizes the implementation strategy of the diversification strategy, based on the results of SWOT and TOWS mapping, which are determined through the calculation of the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS).

Table 4. Implementation strategy.

Strategy	Implementative action	Success indicators
Integration of environmentally friendly infrastructure	Redesigning roads with green infrastructure principles and wildlife crossings.	Number of green infrastructure points installed and the existence of active wildlife corridors.
Strengthening biodiversity monitoring systems	Installation of camera traps, community involvement in monitoring, digitization of species data	Availability of biodiversity database, active involvement of residents in reporting.
Empowerment and education of local communities	Conservation education programs, community training, and the development of educational ecotourism.	Number of educational activities, increasing community understanding of conservation
Improvement of conservation governance and regulations.	Advocacy of wildlife corridor policies, formation of independent monitoring teams, integration into Environmental Impact Assessment (EIA).	Existence of local policies that support conservation, regular monitoring reports.
Management of social risks and wildlife conflicts	Counseling on wildlife conflict risks, replacement of productive trees, and public complaint forums.	Reduction in reports of wildlife conflicts, the amount of compensation received by the community.

4.4.1. Integration of Environmentally Friendly Infrastructure

The strategy of integrating environmentally friendly infrastructure is a response to internal weaknesses in road construction that can potentially damage ecosystems, while also leveraging external opportunities such as the trend of sustainable development, advances in green infrastructure technology, and support from various national and international conservation agencies (Hajimi, Fauzi, & Salbiah, 2024; Susila & Hukom, 2023). This approach aims to reduce ecological pressure from physical development, especially on biodiversity along the Maros–Watampone road segment crossing Bantimurung–Bulusaraung National Park. Implementation involves redesigning the road segment to comply with green road infrastructure principles, including using porous pavement that allows water

infiltration, planting shading vegetation in the road median to maintain a cool microclimate, and providing dedicated lanes for bicycles and low-emission electric vehicles. Additionally, constructing a closed drainage system is critical, designed to filter waste and prevent contaminated runoff from entering the natural habitat, which serves as a life corridor for local flora and fauna. One of the most crucial elements of this strategy is the provision of wildlife corridors, such as underground tunnels and green bridges built at animal crossing points. This infrastructure allows wildlife to move between habitats without crossing the road directly, thereby reducing the risk of animal accidents and maintaining ecosystem connectivity. Thus, this strategy supports not only the technical aspect of development but also makes a tangible contribution to environmental conservation and ecological sustainability within the conservation area.

4.4.2. Strengthening Biodiversity Monitoring Systems

The strategy to improve data-driven biodiversity monitoring systems addresses essential opportunities to ensure that road construction considers biodiversity protection. This strategy takes advantage of external opportunities, especially new technologies in monitoring, such as the Internet of Things (IoT), drones, and Geographic Information Systems (GIS). It also includes active participation from research institutions and environmental NGOs (Jupiter et al., 2017; Rajamanickam et al., 2023). As a result, biodiversity monitoring is no longer conducted manually or in reaction to events; it now depends on real-time data that form the basis for flexible and predictive policies. The implementation involves creating an integrated monitoring system. This system uses camera traps to observe wildlife near construction routes, drones to map changes in vegetation and habitats and online platforms for community members to report wildlife sightings. Communities participate as citizen scientists. They receive training and support to help collect data on local species (Addison et al., 2018). This participation not only improves the data collected but also raises awareness about the importance of wildlife conservation. Observations and reports are compiled into a database of protected and endemic species affected by construction. This database becomes a crucial tool for developing policies based on evidence, such as conservation planning, evaluating environmental impacts, and making timely and accurate interventions. With this plan, biodiversity management shifts from assumptions to smart, community-driven, and sustainable monitoring systems.

4.4.3. Empowerment and Education of Local Communities

The strategy for empowering and educating local communities is a vital pillar of sustainable development, especially in ecologically sensitive areas like Bantimurung–Bulusaraung National Park. This strategy capitalizes on external opportunities such as increasing public awareness of environmental issues and community participation enthusiasm in conservation efforts. Regarding road construction that may disturb flora and fauna habitats, community involvement is key so that conservation is not only structural but also arises from local awareness and collective action. Implementation involves organizing conservation education programs based in schools and communities, with relevant and practical content such as wildlife species identification, ecological functions of trees and home garden vegetation, and understanding the long-term impacts of development on local ecosystems (Mohammed, Osei-Fosu, & Yusif, 2017; Mondino & Beery, 2019). At the community level, activities such as village dialogues and participatory development deliberations are important spaces to build mutual understanding and ensure local aspirations and wisdom are accommodated in the development process. Besides educational approaches, the strategy encourages alternative conservation-based economic models as concrete empowerment efforts (Efani, Tiarantika, Manzilati, Sambah, & Riza, 2024). Examples include developing educational ecotourism where locals can serve as guides or homestay managers near the conservation area and cultivating medicinal or ecologically valuable home garden plants that support environmental preservation while supplementing family income. Through this strategy, communities are not mere spectators in development but active participants in sustainably managing and benefiting from their environment.

4.4.4. Improvement of Conservation Governance and Regulation

The strategy to improve governance and regulation aims to establish a strong institutional framework to anticipate and manage the ecological impacts of infrastructure development, especially in conservation areas like Bantimurung–Bulusaraung National Park. This strategy utilizes external opportunities such as existing national policies on wildlife corridors and active support from conservation agencies with authority, technical capacity, and cross-sector collaboration networks. Good governance is an essential prerequisite, ensuring that road construction is not sectoral or exploitative but aligned with conservation and sustainability principles (García et al., 2023). In practice, the initial step is to encourage local governments along with the Natural Resources Conservation Agency (BKSDA) to formulate technical regulations specific to mitigating construction impacts on wildlife. These regulations should govern procedures, technical standards, and project implementers' obligations to protect habitat and ecological connectivity. Furthermore, an independent cross-sector supervisory team involving government, academics, NGOs, and communities should be established. This team will directly oversee infrastructure projects in conservation zones and provide corrective recommendations in case of deviations or unforeseen impacts. Additionally, conservation aspects must be integrated into Environmental Impact Analysis (AMDAL) documents and spatial planning for infrastructure development (Sitepu & Manurung, 2021). Conservation should not be a reactive add-on but an integral part of all planning and implementation stages. With adaptive, collaborative, and data-driven governance and regulations, road development will not only minimize ecological risks but also strengthen social legitimacy and long-term sustainability commitments.

4.4.5. Management of Social Risks and Wildlife Conflicts

The strategy for managing social and ecological risks is designed to control threats such as negative public perceptions of development and human-wildlife conflicts, leveraging public participation opportunities and collaborative multi-stakeholder approaches. In the context of road construction crossing sensitive areas like Bantimurung–Bulusaraung National Park, failure to manage social-ecological perceptions and impacts can cause social resistance, habitat damage, and disruption to the local ecosystem balance. Therefore, this strategy aims to create open communication channels, adaptive solutions, and responsive mitigation mechanisms. One implementation approach is providing easily accessible public complaint mechanisms and regular dialogue forums involving contractors, government, and affected communities (Baynham-Herd, Redpath, Bunnefeld, Molony, & Keane, 2018). These forums serve as spaces for airing concerns, clarifying issues, and mediating social conflicts or dissatisfaction with the development process. Moreover, this strategy includes compensation and alternative solutions, such as replacing cut home garden trees with productive seedlings (e.g., fruit trees or medicinal plants) and providing environmental incentives for communities helping conserve areas around road projects (Jacinto, Sebastião, Reis, & Ferrão, 2023). From an ecological perspective, mitigating human-wildlife conflicts involves planting buffer zone plants disliked by wildlife along road edges to reduce animals entering development areas. Additionally, installing wildlife crossing warning signs at vulnerable points is necessary as a preventive step to avoid traffic accidents involving animals. With this approach, infrastructure development becomes not just a technical matter but also an adaptive, inclusive social and ecological process sensitive to local dynamics.

5. CONCLUSIONS

The construction of the Maros–Watampone national road, which passes through the Bantimurung-Bulusaraung National Park (TN Babul), poses significant challenges to the ecological and social sustainability of the conservation area. The results of the SWOT-TOWS analysis indicate that the current management condition falls into Quadrant II, characterized by significant internal weaknesses but with external opportunities that can still be optimized through diversification strategies. These strategies include the implementation of green infrastructure, strengthening of biodiversity monitoring systems, empowerment of local communities, as well as improvements in

governance and mitigation of human-wildlife conflict risks. The implications of this study highlight the importance of participatory and evidence-based approaches in formulating development policies in conservation areas to achieve a balance between environmental preservation and improved community welfare. Nevertheless, this study has several limitations, such as the dominance of subjective qualitative data, limited geographical coverage to a single area, and the absence of a comprehensive use of predictive quantitative models. Therefore, further and more in-depth research is needed to strengthen the foundation for sustainable conservation policymaking.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The study involved minimal risk and followed ethical guidelines for social science fieldwork. Formal approval from an Institutional Review Board was not required under the policies of Universitas Brawijaya, Indonesia. Informed verbal consent was obtained from all participants, and all data were anonymized to protect participant confidentiality.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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