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# Balancing Ecology, Economy, and Community: An Analytic Network Process (ANP) Framework for Sustainable Ecotourism Development

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**ABSTRACT**

Sustainable ecotourism development requires balancing ecological, economic, and community interests; however, integrated prioritization frameworks remain underdeveloped, particularly in emerging regions. Addressing this gap, this study employs the Analytic Network Process (ANP) to evaluate and rank sustainable ecotourism strategies in North Aceh, Indonesia. Data were collected from 12 key stakeholders, including government officials, academics, and community leaders, through structured pairwise comparisons based on a developed ANP model comprising three clusters and nine sub-strategies. Consistency ratios were verified, and Super Decisions software was utilized for limit matrix convergence. Results indicate that Community-Based Ecotourism Development is the top priority (global priority = 0.188401), followed by Economic Empowerment and Social Equity (0.141022), Technology-Based Ecotourism Development and Environmental Management (0.126867), while Ecotourism Digitalization ranked lowest (0.009748). Sensitivity analysis confirmed the robustness of these rankings. The findings offer actionable insights for policymakers and stakeholders, providing a replicable and adaptable framework for sustainable ecotourism planning in regions with similar socio-ecological dynamics, thus contributing to achieving SDGs 8, 12, and 15.

## 1. INTRODUCTION

Ecotourism has emerged as a pivotal strategy for sustainable development, particularly in regions endowed with rich natural resources and cultural heritage [1]. Defined as responsible travel to natural areas that conserves the environment and enhances the well-being of local communities [2], ecotourism aligns with the United Nations SDGs, particularly SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land). The global ecotourism market is projected to grow significantly, driven by increasing environmental awareness and a shift towards sustainable travel practices [3]. However, traditional tourism models often lead to environmental degradation, socio-economic disparities, and cultural erosion, highlighting the urgent need for innovative and sustainable alternatives [4].

Despite the growing body of literature on ecotourism, several critical gaps remain. First, while community-based ecotourism has been widely studied, there is limited research on integrated strategies that simultaneously address environmental conservation, economic empowerment, and technological innovation [5]. Second, existing studies often focus on macro-level analyses, neglecting the micro-level dynamics of ecotourism development in specific regions, particularly in developing countries [6]. Third, there is a lack of comprehensive decision-making frameworks that prioritize ecotourism strategies based on multi-criteria analysis, such as the Analytic Network Process (ANP), which is essential for balancing ecological, economic, and social factors [7]. These gaps underscore the need for localized studies that provide actionable insights while contributing to the broader discourse on sustainable tourism.

While previous research has emphasized sustainable tourism strategies, limited efforts have been made to systematically prioritize them by integrating ecological, economic, and community dimensions, especially within the context of emerging regions. This study fills this gap by proposing a comprehensive ANP-based prioritization framework tailored for North Aceh, Indonesia.

Accordingly, this study aims to address these gaps by exploring and evaluating sustainable and innovative ecotourism development strategies in North Aceh, Indonesia, using the ANP. The ANP model was selected for its ability to handle complex interdependencies among ecological, economic, and social factors, making it particularly suitable for prioritizing ecotourism strategies in a holistic manner [7]. Specifically, the research seeks to: (1) identify the key factors influencing ecotourism development in North Aceh, (2) prioritize ecotourism strategies based on their impact on sustainability and community well-being, and (3) provide actionable recommendations for policymakers and

stakeholders.

North Aceh, a district in Aceh Province, Indonesia, was selected as the research setting due to its unique ecological and socio-economic characteristics. The region boasts diverse ecotourism potential, including mountains, waterfalls, rivers, and beaches, which are underutilized despite their significant economic and environmental value [8]. Additionally, many regions in developing countries face challenges such as limited access to financing, low environmental awareness, and inadequate infrastructure, which hinder the development of sustainable ecotourism [9], including North Aceh, Indonesia. By focusing on North Aceh, this study contributes to the broader discourse on ecotourism in developing regions and provides a replicable model for similar contexts.

Theoretically, this study advances the understanding of ecotourism development by integrating Multi-criteria decision-making (MCDM) models, such as the ANP, to prioritize strategies that balance ecological, economic, and social objectives. Practically, the findings offer actionable insights for policymakers, local communities, and stakeholders to develop ecotourism in a way that enhances environmental conservation, economic growth, and social equity. Additionally, this study highlights the importance of community participation and technological innovation in achieving sustainable tourism outcomes [10].

## 2. LITERATURE REVIEW

### 2.1 The concept of sustainable ecotourism

Sustainable ecotourism is a multifaceted concept that integrates environmental conservation, socio-economic development, and community empowerment. Ecotourism is defined as "responsible travel to natural areas that conserves the environment, sustains the well-being of local people, and involves interpretation and education" [2]. This definition underscores the three pillars of sustainable ecotourism: environmental preservation, community well-being, and educational value. Recent studies emphasize that sustainable ecotourism goes beyond mere environmental conservation; it also involves fostering socio-economic benefits for local communities. For instance, ecotourism can generate economic value through visitor expenditures while simultaneously promoting mental health and well-being, thereby creating a positive feedback loop between conservation and community development [4].

However, the concept of sustainable ecotourism is not without its paradoxes. Higham and Lück [11] argue that ecotourism often faces a tension between conservation goals and the economic imperatives of tourism development. They suggest that achieving a balance requires innovative governance and stakeholder collaboration. Similarly, Fennell [12] critiques the notion of sustainable development within ecotourism, arguing that it often serves as a rhetorical device rather than a practical framework. He calls for a more nuanced understanding of sustainability that considers local contexts and power dynamics.

Community participation is a critical component of sustainable ecotourism. Involving local communities in ecotourism planning and management not only enhances the sustainability of tourism projects but also ensures that economic benefits are equitably distributed [9]. This aligns with the principles of community-based tourism (CBT), which prioritizes local ownership and control over tourism resources [10]. Furthermore, education and awareness-raising are essential for fostering a sense of environmental stewardship among both tourists and local communities [13]. Weaver [14] adds that ecotourism should be seen as a tool for transformative learning, where both tourists and locals engage in meaningful interactions that promote sustainability.

Innovative approaches to ecotourism, such as the integration of green technology and digital platforms, are increasingly recognized as essential for enhancing sustainability. For example, the role of digital marketing and data analytics in promoting ecotourism destinations and optimizing resource management [15]. These technological advancements not only improve operational efficiency but also enhance the visitor experience, thereby contributing to the overall sustainability of ecotourism initiatives. Coghlan and Gooch [16] further emphasize the importance of transformative learning frameworks in sustainable tourism, suggesting that ecotourism can serve as a platform for educating tourists about environmental and social issues.

In summary, sustainable ecotourism is a holistic approach that balances environmental conservation, socio-economic development, and community empowerment. By integrating these elements, ecotourism can serve as a powerful tool for achieving SDGs, particularly in regions rich in natural and cultural resources [17].

### 2.2 Challenges in sustainable ecotourism development

Sustainable ecotourism development faces numerous challenges, particularly in developing regions where resources are limited, and socio-economic conditions are often precarious. One of the primary challenges is the lack of financial resources and access to capital, which hinders the development of infrastructure and the implementation of sustainable practices. Many ecotourism projects in developing countries struggle to secure funding due to limited government support and the absence of private sector investment [18]. This financial constraint often results in inadequate facilities and services, reducing the attractiveness of ecotourism destinations.

Another significant challenge is the limited environmental awareness and education among local communities and tourists. Pham and Khanh [19] emphasize that without proper education on environmental conservation, both tourists and local residents may engage in practices that degrade natural resources, such as littering, overfishing, or deforestation. This lack of awareness undermines the sustainability of ecotourism initiatives and can lead to long-term ecological damage. Hall [20] further highlights the challenge of biodiversity conservation in tourism, arguing that tourism activities often exacerbate habitat destruction and species loss.

Technological limitations also pose a barrier to sustainable ecotourism development. Many ecotourism destinations, especially in remote areas, lack access to modern technologies that could enhance sustainability, such as renewable energy systems, waste management solutions, and digital platforms for marketing and visitor management. Gössling and Peeters [21] discuss the challenges of water resource management in tourism, noting that many ecotourism destinations face water scarcity due to overuse and poor management. They suggest that innovative technologies and governance frameworks are needed to address these issues.

Stakeholder conflicts further complicate ecotourism

development. Differing interests among local communities, government agencies, private sector actors, and non-governmental organizations (NGOs) can lead to disputes over resource allocation, land use, and revenue sharing. Bramwell and Lane [22] argue that effective stakeholder collaboration is essential for the success of ecotourism projects, but achieving consensus is often challenging due to conflicting priorities and power imbalances. Simpson et al. [23] add that climate change poses an additional challenge, as many ecotourism destinations are vulnerable to rising temperatures, sea-level rise, and extreme weather events.

Finally, socio-economic challenges, such as poverty and inequality, exacerbate the difficulties of sustainable ecotourism development. In many developing regions, local communities rely heavily on natural resources for their livelihoods, making it difficult to balance conservation goals with economic needs [24]. Without alternative income sources, communities may resist ecotourism initiatives that restrict access to natural resources, even if these initiatives promise long-term benefits. Mowforth and Munt [25] further argue that tourism development in the Global South often perpetuates inequalities, as the benefits of tourism are rarely equitably distributed.

In summary, the challenges in sustainable ecotourism development are multifaceted, encompassing financial constraints, limited environmental awareness, technological barriers, stakeholder conflicts, and socio-economic issues. Addressing these challenges requires a holistic approach that integrates financial support, education, technology, stakeholder collaboration, and community empowerment [22].

### 2.3 Innovative approaches to ecotourism development

Innovative approaches to ecotourism development are increasingly recognized as essential for addressing the challenges of sustainability, particularly in the face of growing environmental and socio-economic pressures. One of the most promising innovations is the integration of green technology into ecotourism operations. The use of renewable energy sources [26], such as solar and wind power, in ecotourism facilities not only reduces carbon footprints but also enhances the resilience of tourism operations in remote areas. Similarly, Chan et al. [9] highlight the importance of eco-friendly infrastructure, such as wastewater treatment systems and energy-efficient buildings, in minimizing the environmental impact of tourism activities.

Another innovative approach is the adoption of digital platforms and data analytics to optimize ecotourism management. Gretzel and Koo [27] demonstrate how smart tourism technologies, such as mobile applications and real-time data analytics, can enhance visitor experiences while minimizing environmental impacts. Buhalis and Sinarta [28] further emphasize the role of digital transformation in tourism, particularly in improving operational efficiency and customer engagement. They argue that digital platforms can facilitate real-time communication between tourists and service providers, leading to more personalized and sustainable tourism experiences.

CBT models are another innovative approach that empowers local communities to take an active role in ecotourism development. Scheyvens and Cheer [10] argue that CBT not only ensures equitable distribution of economic benefits but also fosters a sense of ownership and responsibility among local residents. This approach has been successfully implemented in various regions, such as the community-managed ecotourism initiatives in Vietnam [5] and the participatory conservation programs in Ethiopia [24]. Hjalager [29] adds that innovation in tourism should focus on creating value for local communities, rather than merely maximizing profits for external stakeholders.

Public-private partnerships (PPPs) have emerged as a viable strategy for overcoming financial and technical barriers in ecotourism development. Bhutio et al. [30] highlight that PPPs can leverage the resources and expertise of both sectors to implement large-scale ecotourism projects, such as the development of eco-lodges and nature reserves. These partnerships also facilitate knowledge transfer and capacity building, enabling local communities to participate more effectively in ecotourism activities. Sigala [31] further discusses the role of innovation in post-COVID-19 tourism recovery, suggesting that ecotourism can benefit from digital transformation and sustainable practices.

Finally, education and awareness-raising are critical components of innovative ecotourism approaches. Mondino and Beery [13] stress the importance of environmental education programs for both tourists and local communities, as they promote sustainable practices and foster a deeper appreciation for natural and cultural heritage. Kimbu and Ngoasong [32] highlight the role of digital tools, such as gamified learning platforms, in enhancing environmental education and engagement.

In summary, innovative approaches to ecotourism development, such as green technology, digital platforms, community-based models, public-private partnerships, and educational initiatives, offer promising solutions to the challenges of sustainability. By integrating these approaches, ecotourism can achieve a balance between environmental conservation, economic growth, and social equity [27].

### 2.4 Multi-criteria decision making in ecotourism

MCDM models have become increasingly important in ecotourism development, as they provide a systematic framework for evaluating and prioritizing strategies that balance ecological, economic, and social objectives. Among the various MCDM approaches, the ANP is particularly well-suited for ecotourism due to its ability to model complex interdependencies among factors such as environmental sustainability, economic viability, and community well-being [7]. ANP allows decision-makers to assess the relative importance of different criteria and alternatives, facilitating more informed and balanced decision-making.

One of the key advantages of MCDM in ecotourism is its ability to integrate stakeholder perspectives into the decision-making process. Saaty [33] highlights that ANP is particularly effective in capturing the interdependencies among various factors, making it a powerful tool for complex decision-making in tourism. Zavadskas et al. [34] further emphasize that MCDM methods, such as ANP, can help decision-makers evaluate trade-offs between competing objectives, such as economic growth and environmental conservation.

Another critical application of MCDM in ecotourism is the evaluation of environmental impacts. Mardani et al. [35] demonstrate how MCDM models can be used to assess the ecological footprint of tourism activities and identify strategies for minimizing environmental degradation. By incorporating criteria such as biodiversity conservation, carbon emissions, and waste management, MCDM enables decision-makers to

prioritize ecotourism initiatives that align with sustainability goals. Shen et al. [36] add that MCDM can be used to evaluate the long-term sustainability of tourism projects, particularly in regions with limited resources.

Economic considerations also play a central role in MCDM models for ecotourism. Rezaei [37] argues that MCDM can help balance short-term economic gains with long-term sustainability objectives. For instance, by evaluating the economic benefits of ecotourism against potential environmental costs, decision-makers can identify strategies that maximize economic returns while minimizing ecological harm. This approach is particularly relevant in developing regions, where economic development is often a top priority.

In addition, MCDM models are valuable for addressing social equity in ecotourism development. Scheyvens and Cheer [10] argue that MCDM can be used to ensure that the benefits of ecotourism are equitably distributed among local communities, particularly marginalized groups. By incorporating criteria such as community participation, capacity building, and fair revenue sharing, MCDM models can promote more inclusive and socially just ecotourism initiatives.

Finally, the integration of technology and innovation into MCDM models is an emerging trend in ecotourism research. Go et al. [15] highlight the potential of digital tools, such as geographic information systems (GIS) and data analytics, to enhance the accuracy and efficiency of MCDM processes. These technologies enable real-time data collection and analysis, providing decision-makers with up-to-date information on environmental conditions, visitor behavior, and economic performance.

In summary, MCDM models, particularly ANP, offer a powerful tool for addressing the complex and interrelated challenges of ecotourism development. By integrating environmental, economic, and social criteria, MCDM enables more holistic and sustainable decision-making, ensuring that ecotourism initiatives contribute to long-term conservation and community well-being [34].

## 3. METHODS

### 3.1 Research framework

This study adopts a MCDM framework, specifically the ANP, to evaluate and prioritize sustainable ecotourism development strategies in North Aceh, Indonesia. The ANP model is chosen for its ability to handle complex interdependencies among various factors, such as environmental sustainability, economic viability, and social equity [7]. The framework is structured around four main clusters: Community Participation, Environmental Management, Innovation and Technology, and Economic Empowerment. Each cluster consists of several sub-clusters that capture the key dimensions of ecotourism development, ensuring a comprehensive analysis of the interrelationships among these factors [9].

The development of the ANP research framework was informed by an extensive literature review and refined through expert consultations to ensure contextual relevance. The clustering and sub-strategy structure were synthesized from prior studies on sustainable ecotourism development [3, 4] and validated through stakeholder discussions with government officials, academic experts, and community leaders in North Aceh. This hybrid approach enhanced the validity and applicability of the ANP model.

The Community Participation cluster focuses on the active involvement of local communities in ecotourism planning and management, including sub-clusters such as community engagement, capacity building, and communication. The Environmental Management cluster addresses actions to preserve the environment while supporting tourism, including nature conservation, environmental policies, and awareness-raising initiatives. The Innovation and Technology cluster explores the use of green technology and digital platforms to enhance sustainability, while the Economic Empowerment cluster emphasizes local business development, access to capital, and entrepreneurship training [10].

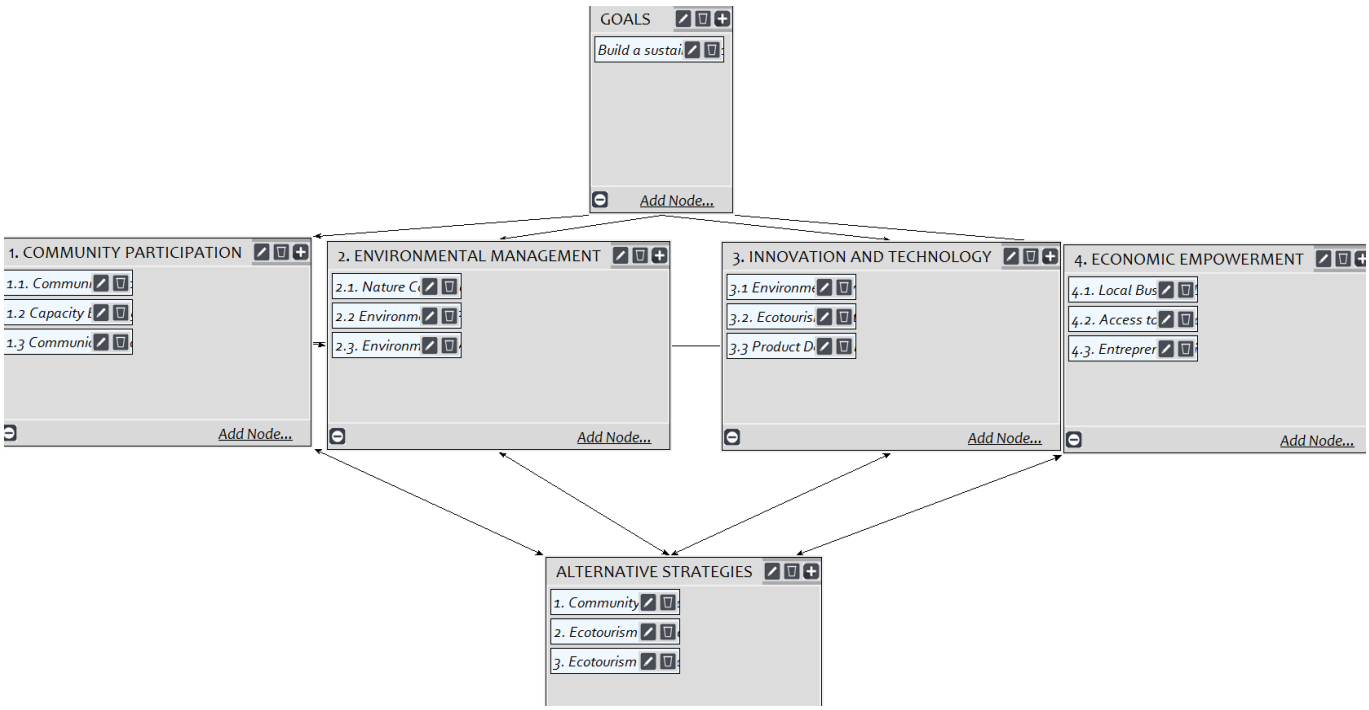


**Figure 1.** Research conceptual framework

**Table 1.** Main cluster and sub-cluster

| Main Cluster | Sub-Cluster | Description |
|---|---|---|
| **Community Participation** | Community Engagement | Training programs, collaboration with NGOs, and establishment of community discussion forums to enhance participation. |
| | Capacity Development | Management training, ecotourism management workshops, and technical assistance programs for local communities. |
| | Communication and Information | Development of integrated information platforms, including social media, websites, and community newsletters. |
| **Environmental Management** | Nature Conservation | Implementation of reforestation projects, waste management systems, recycling initiatives, and community-based tree planting programs. |
| | Environmental Policies | Development of environmental conservation regulations, incentives for eco-friendly practices, and ongoing monitoring mechanisms. |
| | Environmental Awareness | Organization of environmental campaigns, educational programs, and community clean-up activities to foster awareness. |
| **Innovation and Technology** | Eco-friendly Technology | Deployment of renewable energy systems, wastewater treatment solutions, and eco-friendly transportation infrastructure. |
| | Ecotourism Digitalization | Establishment of online reservation platforms, virtual tours, and tourism guide applications to enhance visitor experiences. |
| | Product Development | Development of local handmade products, diversification initiatives, and adoption of eco-friendly packaging. |
| **Economic Empowerment** | Local Business Development | Development of community cooperatives, establishment of business incubation centers, and support for local product markets. |
| | Access to Capital | Provision of microcredit programs, access to government funding, and establishment of partnerships with private sector entities. |
| | Entrepreneurship Training | Implementation of business workshops, mentorship programs, and entrepreneurship seminars targeting local communities. |

Figure 1 illustrates the research conceptual framework, highlighting the relationships between the main clusters and sub-clusters. The framework emphasizes the integration of environmental conservation, economic empowerment, and technological innovation to achieve sustainable ecotourism development.

Table 1 presents a structured overview of the main clusters and their corresponding sub-clusters, each representing critical dimensions for sustainable ecotourism development. The Community Participation cluster focuses on grassroots involvement and empowerment strategies; the Environmental Management cluster emphasizes preservation, regulatory frameworks, and awareness initiatives; the Innovation and Technology cluster highlights technological adaptation to enhance sustainability; and the Economic Empowerment cluster addresses financial and entrepreneurial capacity-building. This categorization ensures a comprehensive prioritization of factors, aligned with both theoretical foundations and stakeholder-driven realities.

### 3.2 Sampling and data collection

The study employs a quantitative approach for data collection and analysis. Primary data were collected through in-depth interviews with 12 purposively selected key stakeholders, including government officials, academics, ecotourism practitioners, community organizations, local businesses, and NGO workers. The purposive sampling technique ensures that the perspectives of diverse stakeholders are represented, enhancing the validity and reliability of the findings [38].

Participants in this study were selected using purposive sampling to ensure relevance and expertise. The inclusion criteria for stakeholders required (1) a minimum of five years of professional experience related to ecotourism development, environmental management, community development, or tourism policymaking; (2) direct involvement in ecotourism projects or policy formulation in North Aceh; and (3) willingness to participate in expert-based decision-making processes. To enhance diversity, the sample included representatives from different sectors, namely government agencies, academic institutions, local communities, and tourism-related businesses. Efforts were made to ensure gender diversity and to capture a wide range of professional perspectives and experiences relevant to sustainable ecotourism development.

### 3.3 ANP methodology

The ANP model is used to analyze the data and prioritize ecotourism development strategies. The pairwise comparison method was employed to gather judgments from stakeholders, where each criterion and sub-criterion was compared relative to others using Saaty's 1-9 fundamental scale. A consistency ratio (CR) was calculated for each respondent to ensure the logical consistency of judgments, with a threshold CR value of $\leq 0.1$ considered acceptable. To validate the questionnaire design and ensure clarity, a pilot test was conducted involving two experts prior to the main data collection. All computations, including the construction of unweighted, weighted, and limit supermatrices, were performed using Super Decisions software version 2.8.0.

The ANP process involves the following steps:

1) Developing a Network Model: A network model was constructed to identify the key elements, including objectives, main clusters, sub-clusters, and alternatives. This model captures the interdependencies among factors such as community engagement, environmental awareness, and access to finance.
2) Constructing the Supermatrix: An unweighted supermatrix was developed to establish the direct relationships between elements without adjusting for overall influence. This initial matrix highlights critical factors such as community engagement, environmental awareness, and access to finance.
3) Weighting the Supermatrix: A weighted supermatrix was constructed to illustrate more complex

relationships between elements and clusters. This step involves adjusting the weights based on stakeholder input to reflect the relative importance of each factor.

4) Calculating the Limit Supermatrix: The limit supermatrix was generated to determine the global priorities for each element in sustainable ecotourism development [7]. This step provides a comprehensive ranking of strategies based on their overall impact on sustainability and community well-being.

### 3.4 Justification for methodology

The use of ANP in this study is justified by its ability to address the multi-criteria nature of ecotourism development, which involves balancing ecological, economic, and social objectives. By incorporating stakeholder perspectives and prioritizing strategies based on their overall impact, ANP provides a robust framework for decision-making in complex and dynamic environments [26]. Furthermore, the integration of qualitative and quantitative data ensures that the findings are both comprehensive and actionable, contributing to the development of effective and sustainable ecotourism strategies.

### 3.5 Data analysis

The data analysis process begins with the development of an unweighted supermatrix, which establishes the direct relationships between elements without adjusting for overall influence. This initial matrix highlights the critical factors across strategies, such as community engagement, environmental awareness, and access to finance. Next, a weighted supermatrix is constructed to illustrate more complex relationships between elements and clusters. Finally, a limit supermatrix is generated to determine the global priorities for each element in sustainable ecotourism development [7]. The study adheres to ethical research practices, including obtaining informed consent from all participants, ensuring confidentiality, and avoiding any form of coercion or harm. Ethical approval for the study was obtained from the relevant institutional review board.

## 4. RESULTS

The results of this study are derived from the ANP analysis, which prioritizes sustainable ecotourism development strategies in North Aceh, Indonesia. The analysis is based on the input from 12 key stakeholders, including government officials, academics, ecotourism practitioners, community organizations, local businesses, and NGO workers. The findings are presented in Table 2, which summarizes the normalized weights (relative importance within clusters) and global priorities (overall importance across clusters) for each strategy and sub-cluster.

### 4.1 Prioritization of ecotourism development strategies

As shown in Table 2, the Community-Based Ecotourism Development Strategy has the highest priority with a normalized weight of 0.41290 and a global priority of 0.188401. This indicates that active community participation is the most critical factor for sustainable ecotourism development in North Aceh. The second priority is Ecotourism Development Based on Economic Empowerment & Social Equity with a normalized weight of 0.30906 and a global priority of 0.141022, highlighting the importance of economic empowerment and equitable benefit distribution. The third priority is Technology-Based Ecotourism Development and Environmental Management with a normalized weight of 0.27804 and a global priority of 0.126867, emphasizing the role of technology and environmental management in enhancing sustainability. Meanwhile, Ecotourism Digitalization ranked lowest with a normalized weight of 0.02134 and a global priority score of 0.009748, indicating that technology initiatives alone are perceived as less critical without strong community and environmental integration.

**Table 2.** Matrix priority

| Name | Normalized by Cluster | Limiting |
|---|---|---|
| 1. Community-Based Ecotourism Development | 0.41290 | 0.188401 |
| 2. Technology-Based Ecotourism Development and Environmental Management | 0.27804 | 0.126867 |
| 3. Ecotourism Development Based on Economic Empowerment & Social Equity | 0.30906 | 0.141022 |
| 1.1. Community Involvement | 0.44033 | 0.050230 |
| 1.2. Capacity Development | 0.25952 | 0.029604 |
| 1.3. Communication and Information | 0.30015 | 0.034239 |
| 2.1. Nature Conservation | 0.30194 | 0.045924 |
| 2.2. Environmental Policy | 0.14489 | 0.022037 |
| 2.3. Environmental Awareness | 0.55317 | 0.084135 |
| 3.1. Environmentally Friendly Technology | 0.71550 | 0.081619 |
| 3.2. Ecotourism Digitalization | 0.08510 | 0.009748 |
| 3.3. Product Development | 0.19939 | 0.022745 |
| 4.1. Local Business Development | 0.29268 | 0.047844 |
| 4.2. Access to Capital | 0.58224 | 0.095177 |
| 4.3. Entrepreneurship Training | 0.12508 | 0.020447 |

### 4.2 Sensitivity analysis

In order to assess the robustness of the prioritization results, a sensitivity analysis was conducted by introducing minor variations in the cluster weights. The findings confirmed that these variations did not significantly alter the ranking of the ecotourism development strategies. This indicates that the prioritization outcomes are stable and reliable, reinforcing the validity of the model.

### 4.3 Key elements within each cluster

Within the Community Participation cluster, Community Involvement is the most crucial sub-cluster with a normalized weight of 0.44033 and a global priority of 0.050230, underscoring the importance of engaging local communities in decision-making processes. In the Environmental Management cluster, Environmental Awareness has the highest priority with a normalized weight of 0.55317 and a global priority of 0.084135, indicating the need for increased environmental education and awareness-raising initiatives.

In the Innovation and Technology cluster, Environmentally Friendly Technology is prioritized with a normalized weight of 0.71550 and a global priority of 0.081619, reflecting the significance of green technology in improving sustainability. Conversely, Ecotourism Digitalization has the lowest priority with a normalized weight of 0.08510 and a global priority of

0.009748, suggesting that digitalization initiatives play a secondary role relative to other sustainability drivers.

Within the Economic Empowerment cluster, Access to Capital is the most critical sub-cluster with a normalized weight of 0.58224 and a global priority of 0.095177, highlighting the need for improved access to financing for local communities. Local Business Development also has significant importance with a normalized weight of 0.29268 and a global priority of 0.047844, emphasizing the role of local enterprises in driving economic growth.

Overall, while Ecotourism Digitalization is acknowledged as part of innovation strategies, it remains less prioritized compared to initiatives centered on community engagement, environmental awareness, and economic empowerment.

## 5. DISCUSSION

### 5.1 Identifying key factors

The findings of this study identify four key factors influencing ecotourism development in North Aceh: community participation, environmental management, innovation and technology, and economic empowerment. These factors collectively align with the principles of sustainable ecotourism, which emphasize the integration of environmental conservation, socio-economic development, and community well-being [2].

Community participation emerges as the most critical factor, with the Community-Based Ecotourism Development Strategy receiving the highest global priority score (0.188401). This finding underscores that sustainable tourism initiatives must be grounded in robust community engagement to ensure both legitimacy and effectiveness. Community ownership fosters a stronger sense of stewardship and responsibility, leading to better conservation outcomes. This conclusion aligns with previous studies in Vietnam.

Community participation emerges as the most critical factor, with the Community-Based Ecotourism Development Strategy receiving the highest global priority score (0.188401). This finding underscores that sustainable tourism initiatives must be grounded in robust community engagement to ensure both legitimacy and effectiveness. Community ownership fosters a stronger sense of stewardship and responsibility, leading to better conservation outcomes. This conclusion aligns with previous studies in Vietnam [5] and Ethiopia [24], which emphasize the critical role of community-led initiatives in enhancing the sustainability of ecotourism ventures.

Environmental management also stands out as a key pillar, highlighted by the prioritization of Environmental Awareness (global priority = 0.084135). This result underlines the necessity of foundational environmental education to cultivate sustainable practices. In contexts like North Aceh, environmental education campaigns, such as community clean-up initiatives and conservation workshops, are essential for instilling conservation values. Without a strong base of environmental consciousness, even technically sophisticated ecotourism projects may fail to meet long-term sustainability goals [4].

Innovation and technology play an increasingly important, yet nuanced, role. The prioritization of Environmentally Friendly Technology (global priority = 0.081619) reflects a growing recognition of green technology's potential to enhance sustainability. However, the low priority assigned to Ecotourism Digitalization (global priority = 0.009748) reveals significant structural limitations in North Aceh. Limited digital infrastructure, low digital literacy, and a primary focus on addressing basic socio-environmental needs currently limit the feasibility of digital tourism innovations [15]. This finding suggests that efforts to promote digital tourism must be accompanied by broader investments in digital infrastructure and education, ensuring that technology complements, rather than displaces, human-nature connections.

Economic empowerment rounds out the key factors, with Access to Capital ranked highest within this cluster (global priority = 0.095177). This finding indicates that financial constraints represent the most immediate and critical barrier to sustainable ecotourism development. The prioritization of Access to Capital over Entrepreneurship Training suggests that while capacity building is valuable, it remains ineffective without adequate financial support [10]. Without access to credit or investment, even well-trained entrepreneurs face insurmountable barriers to initiating and scaling ecotourism projects. This result is consistent with findings from rural ecotourism development studies in Thailand and Ethiopia, where financial empowerment emerged as a prerequisite for successful CBT [24, 26]. Thus, facilitating microcredit programs and improving financial access should be prioritized alongside entrepreneurial education initiatives to foster truly sustainable and inclusive ecotourism growth in North Aceh.

### 5.2 Prioritizing ecotourism strategies

The ANP analysis provides a clear prioritization of ecotourism strategies based on their impact on sustainability and community well-being. The results reveal that Community-Based Ecotourism Development Strategy is the top priority, followed by Economic Empowerment & Social Equity, and Technology-Based Ecotourism Development and Environmental Management.

Community-based strategies are identified as the most critical, reflecting their potential to enhance local ownership, cultural preservation, and equitable benefit sharing [5]. These strategies are essential for ensuring that ecotourism development is inclusive and sustainable [5]. For instance, community-managed ecotourism organizations in North Aceh could ensure that revenues are reinvested in local development projects, such as schools and healthcare facilities. Strengthening community engagement is vital not only for distributing economic benefits but also for fostering stewardship and enhancing conservation outcomes, a pattern consistent with findings in Vietnam and Ethiopia [5, 24].

Economic empowerment strategies are ranked second in priority, highlighting the critical need to strengthen local economies through entrepreneurship training, access to capital, and the development of local businesses. The prioritization of Access to Capital over Entrepreneurship Training suggests that while skills development is important, the lack of financial resources presents a more immediate barrier to CBT initiatives. Without access to financing, even the most skilled entrepreneurs may struggle to implement ecotourism ventures [26]. In North Aceh, initiatives such as microcredit programs, local business incubators, and cooperative financing models could provide critical support to budding ecotourism entrepreneurs, helping reduce poverty and fostering greater social equity.

Technology and environmental management strategies form the third tier of priorities, emphasizing the supporting

role of innovation in achieving sustainability goals [39]. Environmentally friendly technologies are recognized for their ability to optimize resource use and minimize ecological impacts. However, the low prioritization of Ecotourism Digitalization (global priority = 0.009748) suggests that technological solutions are currently viewed as supplementary rather than central to sustainable ecotourism development. Limited digital infrastructure and digital literacy in North Aceh constrain the effective integration of digital tools into ecotourism operations [15]. Therefore, while investments in renewable energy and eco-friendly transportation systems are warranted, digital transformation initiatives should be pursued cautiously, ensuring that they enhance rather than overshadow community engagement and environmental stewardship.

In comparison with other regions, similar prioritization patterns have been observed. Studies conducted in Vietnam [5] and Ethiopia [24] similarly found that strengthening community engagement and economic empowerment takes precedence over technological interventions. This consistent trend across emerging regions suggests that policymakers and development practitioners must prioritize reinforcing foundational social and financial structures before advancing to technology-intensive solutions.

### 5.3 Providing actionable recommendations

Based on the findings, this study proposes several actionable recommendations for policymakers and stakeholders to enhance ecotourism development in North Aceh. These recommendations are directly aligned with the priority order revealed through the ANP analysis [5, 24], ensuring practical relevance and strategic focus.

First, enhancing community participation is essential. Establishing community-led ecotourism organizations that ensure local ownership and decision-making processes will empower communities and strengthen their commitment to sustainable tourism. Providing targeted training and capacity-building programs in tourism management, environmental conservation, and small business operations can further empower communities and promote local stewardship [2].

Second, strengthening environmental management is crucial for the long-term sustainability of ecotourism. Implementing environmental education programs targeted at both tourists and local residents will raise awareness about sustainable practices. Moreover, the development and enforcement of policies that incentivize eco-friendly practices—such as waste management, renewable energy adoption, and reforestation—are vital to preserving the ecological assets that form the foundation of ecotourism [4].

Third, promoting innovation and technology should be approached strategically. Investments in green technologies—such as renewable energy systems, eco-friendly infrastructure, and sustainable transport—can significantly reduce the environmental footprint of tourism activities [15, 39]. While digital platforms for marketing, reservation systems, and visitor management can enhance operational efficiency, their adoption should be tailored to local capabilities, ensuring that digital initiatives support, rather than replace, human-centered community engagement.

Fourth, supporting economic empowerment is vital to ensuring equitable distribution of ecotourism benefits. Facilitating access to microcredit, grants, and other forms of financial support for local entrepreneurs and ecotourism initiatives can stimulate economic growth. Establishing business incubation centers, cooperatives, and training programs can further enhance entrepreneurship, reduce poverty, and diversify income sources [26].

Finally, fostering stakeholder collaboration is essential for the success of ecotourism initiatives. Building public-private partnerships can leverage additional resources and expertise for larger-scale projects. Additionally, establishing platforms for regular dialogue among government agencies, community groups, NGOs, and private investors can help align diverse interests, resolve conflicts, and ensure that ecotourism development remains inclusive, participatory, and sustainable [5].

Thus, by implementing these recommendations in alignment with the prioritized strategies identified through the ANP analysis, stakeholders can foster a more resilient, inclusive, and sustainable ecotourism model in North Aceh.

### 5.4 Implications for theory and practice

The findings of this study contribute meaningfully to the growing body of literature on sustainable ecotourism by demonstrating the effectiveness of the ANP model in prioritizing ecotourism strategies. The ANP model, with its capacity to handle complex interdependencies among ecological, economic, and social factors, offers a robust framework for decision-making in tourism development. By integrating community participation, economic empowerment, environmental management, and technological innovation, this study advances the understanding of sustainable tourism beyond traditional models. The prioritization of community-based strategies, while consistent with previous studies [5, 24], is enhanced by incorporating economic and technological dimensions, offering a replicable and context-sensitive framework for regions with similar ecological and socio-economic characteristics.

### 5.5 Implications for sustainable development

The results of this study have significant implications for achieving the United Nations SDGs, particularly SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land). By emphasizing community participation, environmental stewardship, and economic empowerment, ecotourism can function as a powerful catalyst for sustainable development in North Aceh and similar regions.

Ecotourism initiatives contribute to SDG 8 by creating decent work opportunities and stimulating local economic growth. Community-led tourism projects promote equitable benefit distribution and livelihood diversification through employment opportunities in guiding, hospitality, handicrafts, and conservation activities, reducing poverty and enhancing resilience.

In alignment with SDG 12, sustainable ecotourism encourages responsible consumption and production practices. The integration of green technology, renewable energy systems, and waste management initiatives reduces the environmental footprint of tourism operations. Environmental education programs for both visitors and residents further reinforce sustainable behaviors, ensuring the responsible use of natural resources.

Furthermore, ecotourism supports SDG 15 by protecting terrestrial ecosystems and biodiversity. Strategies such as reforestation, habitat restoration, and conservation policies

preserve the ecological assets that underpin the tourism sector. Fostering a culture of environmental stewardship among communities and visitors ensures the long-term sustainability of these critical ecosystems.

Additionally, stakeholder collaboration and inclusive policy frameworks are pivotal to maximizing ecotourism's contribution to sustainable development. Public-private partnerships and community-driven governance models offer pathways to amplify positive impacts while ensuring equitable access to resources and benefits.

### 5.6 Limitations and future research directions

This study acknowledges several limitations. The reliance on qualitative insights from a relatively small pool of stakeholders may constrain the generalizability of the findings. Future research should aim to expand the sample size and integrate quantitative validation methods to bolster the robustness of results.

While the ANP model effectively captures complex interdependencies, it may not fully encapsulate the dynamic and evolving realities of ecotourism development. Comparative studies utilizing alternative MCDM approaches, such as the Best-Worst Method [37], are recommended to further validate and refine the prioritization framework.

Given the specific contextual focus on North Aceh, the extent to which these findings are generalizable to other regions remains an open question. Comparative research across diverse socio-economic and ecological contexts could illuminate region-specific best practices and challenges.

Moreover, the role of digitalization in ecotourism development warrants deeper exploration. Future studies could investigate how digital innovations—such as mobile applications, virtual reality experiences, and smart tourism infrastructure—can enhance visitor engagement and operational sustainability, particularly in regions facing significant digital divides.

## 6. CONCLUSIONS

This study developed an ANP-based prioritization framework that holistically integrates community participation, environmental management, innovation and technology, and economic empowerment to support sustainable ecotourism development. Unlike traditional approaches that often treat these elements separately, the framework emphasizes their interdependence, recognizing that sustainable tourism outcomes require simultaneous advancements across social, environmental, technological, and economic domains.

The novel contribution of this research lies in contextualizing the ANP model to address the unique challenges and opportunities of emerging regions like North Aceh. By incorporating stakeholder perspectives from government agencies, academia, community organizations, and private sector actors, the model provides a more inclusive and actionable strategy formulation process. This multidimensional prioritization approach ensures that ecotourism initiatives are not only environmentally sound but also socially inclusive and economically viable.

Beyond its immediate application in North Aceh, the framework holds significant potential for adaptation in other regions with similar socio-economic and ecological conditions. Regions characterized by rich natural resources but facing financial constraints and limited digital infrastructure can particularly benefit from the model's emphasis on community empowerment and foundational capacity-building before technological intensification.

Practically, the study offers clear strategic guidance: prioritize strengthening community structures, foster environmental stewardship through education and policy, facilitate financial access for local entrepreneurs, and integrate technology thoughtfully to complement human-centric tourism experiences. By aligning with the United Nations SDGs (SDG 8, SDG 12, and SDG 15), the framework contributes to promoting inclusive economic growth, responsible resource use, and the conservation of terrestrial ecosystems.

Future studies could further enhance the framework by exploring its application across different socio-economic contexts and integrating dynamic elements such as technological advancements and climate change adaptation.

Overall, this study advances the discourse on sustainable ecotourism development by offering a theoretically grounded and practically viable framework that balances ecological preservation, economic development, and social equity.

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