

Green infrastructure strategies for sustainable coastal tourism: A SWOT–AHP analysis

I Wayan Thariqy Kawakibi Pristiwasa^{1*}, I Nyoman Budiarta², Mohd Raziff Jamaluddin³, Gina Alcoriza⁴

^{1,2} Batam Tourism Polytechnic, Kepulauan Riau, Indonesia

³ Universiti Teknologi Mara, Selangor, Malaysia

⁴ University of the Philippines Diliman, Manila, Philippines

kawakibithariqy@gmail.com

*Corresponding Author Email

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ABSTRACT

The Riau Archipelago in Indonesia possesses significant coastal and marine ecosystems that underpin tourism development. However, these assets are increasingly threatened by climate change, fragmented spatial planning, and unequal infrastructure provision. Grounded in sustainable tourism development theory, green infrastructure planning, and strategic management theory, this study aims to identify and prioritize green infrastructure-based strategies that enhance climate resilience and long-term tourism sustainability. Using a mixed-methods approach, primary data were collected through in-depth interviews, focus group discussions, and structured questionnaires involving 15 purposively selected stakeholders from government agencies, tourism operators, and environmental organizations. Secondary data were obtained from regional planning documents, tourism statistics, and environmental reports. SWOT analysis was applied to systematically identify internal strengths and weaknesses as well as external opportunities and threats related to green infrastructure integration. Subsequently, the analytical hierarchy process was employed to assign weights and rank 20 alternative strategies based on stakeholder judgments. The analysis produced an IFAS score of 2.71 and an EFAS score of 2.47, indicating a moderately favorable strategic position. The results highlight mangrove restoration and hybrid coastal protection as top priorities, while expanding the theoretical contribution by positioning green infrastructure as a crucial asset for destination competitiveness.

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1. Introduction

Coastal tourism has long been recognized as a key driver of regional economic growth and livelihood development, particularly in island and archipelagic regions. At the same time, the rapid expansion of tourism-related infrastructure, urbanization, and coastal land-use conversion has generated significant environmental pressures, including mangrove deforestation, coral reef degradation, shoreline erosion, and declining ecosystem services



(Baloch et al., 2022; Baltranaitė et al., 2025). These pressures are increasingly exacerbated by climate-related hazards such as sea-level rise, coastal flooding, and extreme weather events, which threaten both fragile coastal ecosystems and the socio-economic stability of coastal communities (Das & Swain, 2024; Hernández-Delgado, 2024). In parallel, global tourism demand has shifted toward destinations that emphasize authenticity, low environmental impact, and sustainability, encouraging policymakers and destination managers to reconsider conventional mass-tourism development models (Kharbanda et al., 2025; Kashif et al., 2026).

Within this context, green infrastructure (GI) has emerged as a strategic planning concept that integrates ecological systems into development frameworks to simultaneously deliver environmental protection, economic value, and social benefits (Mell, 2017; Monteiro et al., 2020). GI refers to a strategically planned network of natural and semi-natural areas, ecological corridors, and nature-based or hybrid infrastructure designed to provide multiple ecosystem services (Gijsman et al., 2021; van Rees et al., 2023). In coastal environments, GI encompasses mangroves, coral reefs, seagrass meadows, wetlands, coastal greenbelts, and hybrid shoreline systems that combine ecological elements with engineered structures (Roberts et al., 2017; Kawata, 2022). These systems play a critical role in shoreline stabilization, wave attenuation, sediment retention, biodiversity conservation, and recreational enhancement, thereby directly supporting coastal tourism functions.

Empirical evidence consistently demonstrates the effectiveness of GI in reducing coastal risks and enhancing destination resilience. Coral reefs can dissipate up to 97 percent of incoming wave energy, substantially reducing flood risk for beaches and coastal infrastructure (Storlazzi et al., 2025). Mangroves provide measurable protection against flooding and erosion while delivering climate mitigation benefits through carbon storage (Alongi, 2008; Menéndez et al., 2020). Seagrass meadows stabilize sediments and improve water clarity, supporting fisheries and nature-based tourism activities (Rifai et al., 2023). Beyond risk reduction, GI enhances tourism attractiveness and competitiveness by preserving natural assets that underpin recreational activities such as snorkeling, diving, and ecotourism, which generate substantial economic value (Spalding et al., 2017; Arkema et al., 2021). Compared to conventional grey infrastructure, nature-based and hybrid GI solutions also offer lower lifecycle costs and co-benefits for biodiversity and local livelihoods (Beck et al., 2018; Silver et al., 2019; Paxton et al., 2024).

Despite these demonstrated benefits, the integration of GI into strategic tourism planning remains uneven and under-theorized, particularly in archipelagic and developing-country contexts. From a theoretical perspective, this study is grounded in sustainable tourism development, strategic management, and GI planning. Sustainable tourism theory emphasizes the balance between economic growth, environmental integrity, and social equity. In contrast, strategic management theory emphasizes aligning internal resources and capabilities with external opportunities and threats to achieve long-term competitiveness. GI, in this regard, can be conceptualized as a strategic resource and capability that enhances destination resilience, reduces environmental risk, and strengthens market positioning. However, existing studies have largely treated GI as an ecological or spatial planning issue rather than as a strategic asset embedded within tourism management and decision-making frameworks.

The Riau Archipelago in Indonesia illustrates these challenges acutely. Strategically located between the Strait of Malacca and the South China Sea, the province serves as a maritime gateway and a growing tourism hub, supported by strong cross-border connectivity with Singapore and Malaysia. Tourist arrivals and passenger flows have increased significantly, reflecting the region's economic potential (Irewati, 2020). The province also hosts extensive blue-carbon ecosystems, including over 79,000 ha of mangrove forests that provide critical climate mitigation and coastal protection functions (Nugroho et al., 2021). However, coral reef conditions remain poor, with live coral cover averaging only 5–29 percent,

indicating high vulnerability to warming seas and anthropogenic pressures (Yunanto et al., 2020). Rapid maritime and port development, uneven tourism infrastructure across islands, mangrove degradation near urban centres, weak waste management, and increasing marine debris further compound environmental and governance challenges (Purba et al., 2019; Afdal et al., 2022).

While previous studies in Indonesia and Southeast Asia have generated valuable insights into coastal ecosystem conservation, blue-carbon assessments, and spatial planning, they remain largely sectoral and fragmented, with limited integration into tourism-oriented strategic planning (Beck et al., 2018). Academically, there is a lack of studies that position GI within strategic management and decision-making frameworks for tourism development, particularly in complex archipelagic settings characterized by spatial fragmentation, multi-level governance, and competing land-use interests (Grabowski et al., 2022; O'Donnell, 2022). Methodologically, many planning approaches lack systematic and transparent prioritization tools, making it difficult for policymakers to align ecological objectives with economic and social goals in a replicable manner (Anelli et al., 2026).

Accordingly, this study focuses on identifying the key internal and external factors that influence the integration of GI into coastal tourism development in the Riau Archipelago, Indonesia, examining how GI can be strategically positioned to enhance climate resilience and tourism competitiveness in an archipelagic context, and determining priority GI-based strategies for sustainable coastal tourism development using a multi-criteria decision-making framework. By integrating sustainable tourism theory, strategic management perspectives, and GI planning within a combined strength, weakness, opportunity, threat (SWOT) and analytic hierarchy process (AHP) approach, this research contributes conceptually and methodologically to coastal tourism scholarship. Practically, it offers a structured decision-support tool for policymakers to systematically embed GI into strategic planning processes, thereby strengthening environmental resilience, economic sustainability, and destination competitiveness in the Riau Archipelago, Indonesia.

2. Literature Review

This study adopts an integrated strength, weakness, opportunity, threat (SWOT), analytic hierarchy process (AHP) framework by Saaty (2008) grounded in the resource-based view (RBV) by Barney (1991), the natural resource-based view (NRBV) by Hart (1995), and the dynamic capabilities theory (DCT) by Teece et al. (1997). From the RBV perspective, GI is conceptualized as a strategic resource that can generate sustainable competitive advantages for coastal tourism destinations by effectively leveraging unique ecological, social, and infrastructural assets. Extending this logic, the NRBV emphasizes that environmentally oriented capabilities, such as ecosystem conservation, climate adaptation, and sustainable resource management, constitute critical organizational and regional competencies that support long-term environmental and economic performance. Furthermore, the DCT highlights the ability of coastal tourism stakeholders to integrate, reconfigure, and adapt GI strategies in response to environmental uncertainty, climate risks, and evolving tourism demands in archipelagic regions.

SWOT analysis enables the systematic identification of internal strengths and weaknesses as well as external opportunities and threats associated with GI-based coastal tourism development, consistent with strategic management scholarship (Kurttila et al., 2000). The AHP complements this framework by quantitatively weighting strategic criteria and prioritizing alternative development strategies based on stakeholder preferences and contextual conditions (Wind & Saaty, 1980). Although the SWOT-AHP approach has been widely applied in tourism and environmental planning studies, its integration with RBV or NRBV and DCT in the context of GI-based coastal tourism planning within Indonesian

archipelagic regions remains underexplored. Therefore, this study contributes theoretically by extending strategic management perspectives into sustainable coastal tourism research and contributes contextually by providing a decision-making framework tailored to the unique ecological and socio-spatial characteristics of the Riau Archipelago, Indonesia.

3. Research Methods

This study employs a mixed-method research approach that integrates qualitative and quantitative techniques to examine the strategic integration of GI in sustainable coastal tourism development in the Riau Archipelago, Indonesia. The mixed-method approach is adopted to capture both in-depth stakeholder perspectives and structured, measurable priorities that support strategic decision-making. This approach is consistent with decision-oriented planning research, where qualitative insights are systematically translated into quantitative evaluations to inform policy and management strategies.

3.1. Research Design

The study adopts an exploratory–descriptive research design, drawing on strategic management and multi-criteria decision-making frameworks, particularly those that combine SWOT analysis with the AHP for strategy formulation (Wind & Saaty, 1980; Kurttila et al., 2000). The exploratory dimension allows the identification of context-specific factors influencing GI integration, while the descriptive component systematically evaluates and prioritizes strategic alternatives. This design is widely applied in tourism planning and environmental management studies to address complex, multi-stakeholder problems characterized by uncertainty and competing objectives. The research is structured into three integrated phases: data collection, data analysis, and strategy formulation. The data collection phase gathers primary and secondary data to establish a comprehensive situational understanding. The data analysis phase applies SWOT analysis to identify internal and external strategic factors, followed by AHP to quantitatively prioritize GI-based strategies. The final phase synthesizes qualitative findings and quantitative results into a ranked set of strategic recommendations for sustainable coastal tourism planning in the Riau Archipelago.

3.2. Informants and Sampling Technique

Purposive sampling was employed to select informants who possess relevant expertise, direct involvement, and decision-making capacity in tourism development, environmental management, and coastal governance. This sampling strategy is appropriate for exploratory strategic studies where information richness and contextual knowledge are more critical than statistical generalization.

Table 1. Composition of Key Informants

Category of Informants	Number of Informants	Description
Local Government Officials	5	Representatives from tourism, environmental, and spatial planning agencies at the provincial and district levels
Tourism Destination Managers and Private-Sector Operators	4	Managers and business owners involved in coastal and marine tourism activities
Community Tourism Awareness Groups	3	Representatives of local community groups supporting sustainable tourism initiatives
Academic Experts and Non-Government Organization Practitioners	3	Experts and practitioners in coastal conservation and sustainable tourism
Total	15	

Table 1 presents the distribution of 15 informants selected through purposive sampling across policy, operational, community, and knowledge domains. Government officials contribute regulatory and planning perspectives; tourism operators provide practical insights into market dynamics and infrastructure needs; community tourism groups reflect local participation and social acceptance; and academics and practitioners from non-governmental organizations contribute scientific and conservation-oriented viewpoints. The inclusion of 15 informants aligns with qualitative research standards for achieving thematic saturation, where additional interviews are unlikely to generate substantially new insights, particularly in focused, policy-oriented studies. This multi-stakeholder composition enhances analytical depth and reduces single-perspective bias in strategy formulation.

3.3. Data Collection

Secondary data were collected through document review of official tourism statistics, environmental datasets, academic publications, and policy documents. These data were used to contextualize primary findings, validate stakeholder perceptions, and support the strategic assessment of GI potential in the region. Table 2 summarizes the categories, sources, and purposes of primary and secondary data used to support the analysis of GI integration in coastal tourism.

Table 2. Types and Sources of Data

Data Type	Source	Purpose
Primary Data	In-depth interviews with 15 key informants	Explore challenges, opportunities, and perceptions regarding GI integration in coastal tourism
Primary Data	Focus Group Discussions	Capture community engagement perspectives and collaborative governance mechanisms
Primary Data	Structured surveys for tourism managers and stakeholders	Collect quantitative assessments of infrastructure, environmental services, and strategic priorities
Secondary Data	Tourism statistics from the Central Bureau of Statistics in the Riau Archipelago and provincial tourism offices	Assess performance indicators such as tourist arrivals, infrastructure development, revenue, and employment
Secondary Data	Environmental datasets from the Ministry of Environment, Bio Conferences reports, and academic studies	Analyze mangrove cover, coral reef health, and coastal changes relevant to GI potential
Secondary Data	Strategic planning and policy documents from local and national government frameworks	Examine policy alignment and regulatory support for sustainable tourism and coastal zone management

This study uses both primary and secondary data sources to ensure comprehensive coverage of the environmental, socio-economic, and institutional dimensions of GI integration in coastal tourism. Primary data collection employed the following instruments:

1. Semi-structured interview guidelines, designed to explore informants' perceptions of GI functions, existing challenges, policy constraints, institutional coordination, and strategic opportunities for coastal tourism development.
2. Focus group discussion (FGD) guidelines, used to facilitate group-level discussions, focusing on community engagement, local environmental issues, tourism impacts, and

collaborative governance mechanisms.

3. Structured survey questionnaires, developed using Likert-scale items to quantify stakeholder assessments of GI performance, environmental services, feasibility, economic impact, and strategic priority criteria required for AHP analysis.

3.4. Data Analysis

Data analysis followed a sequential and integrated SWOT–AHP procedure in which qualitative data from interviews and FGDs were first transcribed and thematically coded to identify recurring patterns related to strengths, weaknesses, opportunities, and threats associated with GI integration. Internal factors were derived from governance capacity, existing infrastructure, ecosystem conditions, and stakeholder readiness, while external factors reflected market trends, climate risks, regulatory frameworks, and regional development pressures; these were synthesized into internal factor analysis summary (IFAS) and external factor analysis summary (EFAS) matrices with weights and ratings assigned based on stakeholder consensus and empirical relevance. Subsequently, the AHP was applied to prioritize GI-based strategic alternatives generated from the SWOT matrix by constructing a hierarchical structure consisting of the overall goal (sustainable coastal tourism development through GI), evaluation criteria (economic impact, environmental sustainability, feasibility, and community support), and alternative strategies.

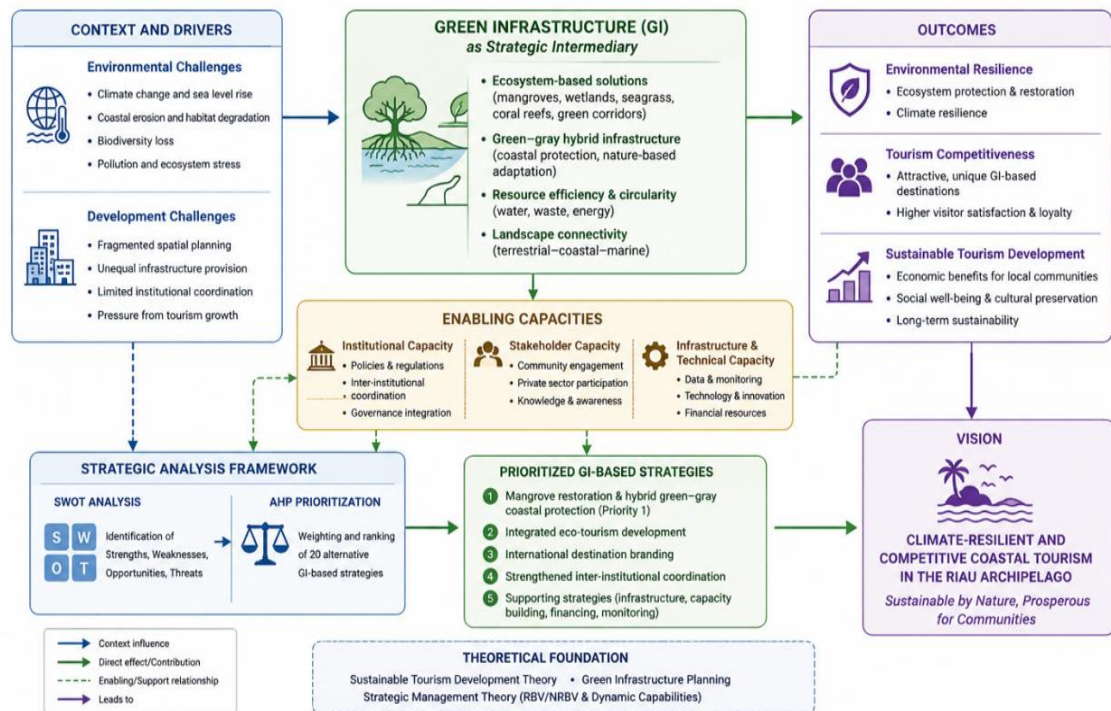


Figure 1. Conceptual Model Figure

Figure 1 illustrates the sequential and integrated SWOT–AHP analytical framework used to identify strategic factors, prioritize GI-based alternatives, and support sustainable coastal tourism planning. Pairwise comparisons were conducted using survey responses; relative weights were calculated using the eigenvalue method; and consistency ratios (CRs) below 0.10 were used to confirm logical consistency and quantitative reliability. Research rigor was ensured through triangulation across interviews, FGDs, surveys, and secondary data, member checking with selected informants to confirm

interpretive accuracy, pre-testing of survey instruments to enhance reliability, and AHP consistency testing, while ethical standards were upheld through informed consent, anonymity, and exclusive use of data for academic purposes. Overall, the integrated mixed-methods and SWOT–AHP framework provides a systematic, transparent, and replicable approach to embedding GI into strategic coastal tourism planning, ensuring coherence among research objectives, analytical procedures, and policy-relevant outcomes, while offering contextual novelty in the Indonesian archipelagic setting.

4. Results and Discussion

4.1. Overview of the Study Area

The Riau Archipelago, Indonesia, occupies a strategic maritime position between the Strait of Malacca and the Natuna Sea, serving as both a gateway for international shipping and a coastal tourism hub connecting Indonesia with Singapore and Malaysia. The province spans approximately 251.810,71 km², with 96% of the area being marine, around 1.350 islands, and its capital is Tanjungpinang. Its coastal tourism potential is supported by rich ecosystems, including 67.417 ha of mangroves, coral reefs in eastern Bintan with an average live coral cover of 43.82% (± 9.38), and productive seagrass meadows that store up to 348.26 MgC ha⁻¹ of sediment carbon. Socioeconomic indicators show a growing tourism sector, with 3.49 million domestic tourist trips and 143.245 international arrivals recorded in 2024, alongside a hotel occupancy rate of 59.92%. Batam accounts for around 66% of the province's gross regional domestic product (GRDP), supported by its logistics and tourism connectivity. Meanwhile, welfare data show a poverty rate of 4.78% and a Gini ratio of 0.357. The regional development agenda emphasizes sustainable tourism through the Regional Tourism Development Master Plan and the establishment of marine conservation areas, ensuring that coastal ecosystem services remain the foundation for tourism growth. Table 3 summarizes the province's key spatial and administrative features, including total area, the proportion of marine area, the number of islands, the capital city, and administrative divisions.

Table 3. Geographic and Administrative Characteristics of Riau Archipelago

Indicator	Value
Total Area	251.810,71 km ²
Percentage of Marine Area	96% of the Total Area
Number of Islands	1.350 Islands
Capital City	Tanjungpinang
Administrative Divisions	5 Regencies and 2 Municipalities

Table 4 presents the main coastal and marine ecosystem assets of the Riau Archipelago, including mangroves, coral reefs, and seagrass meadows that support blue-carbon functions and sustainable tourism development. The Riau Archipelago has extensive blue-carbon ecosystems that provide critical ecological services. Mangroves cover over 67.000 ha, coral reefs in eastern Bintan show moderate live coral cover, and seagrass meadows demonstrate high carbon storage capacity. These ecosystems represent significant natural capital for both climate mitigation and sustainable tourism development.

Table 4. Selected Coastal and Marine Resource Potentials

Component	Key Indicator	Value
Mangrove	Ecosystem area	67.417 ha
Coral Reefs	Average live coral cover in eastern Bintan	43.82% \pm 9.38
Seagrass Meadows	Sediment carbon stock in Pengudang, Bintan	~348.26 MgC/ha

Table 5 highlights recent tourism, economic, and welfare indicators that reflect the province's development context and readiness for sustainable coastal tourism initiatives. The tourism sector in the Riau Archipelago shows steady recovery and growth, with millions of domestic visitors and a significant number of international arrivals, supported by strong hotel occupancy rates. Batam remains the economic engine of the province, while poverty and inequality indicators are relatively moderate, providing a stable socio-economic foundation for tourism and environmental initiatives.

Table 5. Latest Socio-Economic and Tourism Indicators

Indicator	2024	Remarks
Domestic Tourists	3.49 Million Trips	January–December 2024
International Tourists	143.245 Arrivals	September 2024
Hotel Occupancy Rate	59.92%	December 2024
Batam's GRDP Contribution	~66% of Provincial GRDP	Year 2024
Poverty Rate	4.78%	September 2024
Gini Ratio	0.357	September 2024

4.2. Existing Conditions of Green Infrastructure in Coastal Areas

4.2.1. Distribution and Condition of Natural Ecosystems (Mangroves, Coral Reefs, and Seagrass)

Coastal natural ecosystems in the Riau Archipelago play a crucial role in supporting ecosystem services, sustaining marine biodiversity, and providing strategic assets for the development of nature-based tourism. Three key components of natural GI mangrove forests, coral reefs, and seagrass meadows are distributed across the province's islands, exhibiting varied ecological conditions depending on location and human pressures. Recent official reports and scientific studies show that these ecosystems cover extensive areas and provide significant ecological functions, though several sites are experiencing degradation due to coastal development and environmental changes.

Table 6. Distribution and Condition of Natural Coastal Ecosystems in Riau Archipelago

Ecosystem	Extent / Key Indicator	Main Locations	Ecological Condition
Mangroves	± 67.417 ha	Coastal areas of Bintan, Lingga, Karimun, Natuna	Generally in good condition; localized degradation near urban centers (Batam, Tanjungpinang)
Coral Reefs	Average Live Coral Cover 43.82% ± 9.38	Eastern Bintan Conservation Areas	Moderate condition; impacted by sedimentation and uncontrolled tourism activities
Seagrass Meadows	Sediment Carbon Stock ± 348.26 MgC/ha	Pengudang Waters, Bintan	Largely intact ecosystems; important for blue carbon storage and marine habitat function

Table 6 demonstrates that the Riau Archipelago hosts extensive and ecologically valuable coastal ecosystems that provide both environmental protection and economic opportunities. Mangrove forests cover more than 67.000 ha and act as natural coastal buffers, carbon sinks, and critical habitats for fisheries. Coral reefs in eastern Bintan exhibit moderate ecological health, with an average live coral cover of 43.82%, indicating significant restoration potential if managed properly. Seagrass

meadows in Pengudang are important blue carbon reservoirs and contribute to water clarity and biodiversity, enhancing the attractiveness of marine tourism activities such as snorkeling and diving. However, these ecosystems face increasing pressures from coastal development, sedimentation, and unregulated tourism. Integrated conservation and strategic planning are therefore essential to sustain their ecological functions and tourism value in the long term.

4.2.2. Green Open Spaces and Coastal Ecological Networks

Table 7. Existing Green Open Spaces and Coastal Ecological Networks in Riau Archipelago

Type of Green Infrastructure	Key Characteristics	Main Locations	Current Status / Issues
Coastal Green Belts	Narrow Vegetated Buffer Zones Along Urban Shorelines, Providing Erosion Protection	Batam, Tanjungpinang Urban Coasts	Present But Fragmented; Limited Continuity Due to Coastal Development Pressures
Urban Coastal Parks And Waterfront Areas	Designed Public Spaces Integrating Recreation And Ecological Functions	Tepi Laut Park (Tanjungpinang), Batam Waterfront	Developed In Selected Urban Areas; Maintenance and Ecological Design Vary
Natural Ecological Corridors	Mangrove Belts, Wetland-Dune Linkages, And Riparian Buffers Connecting Habitats	Bintan, Lingga, Natuna Islands	Existing Naturally but Poorly Integrated Into Formal Spatial Planning; Vulnerable To Land-Use Change
Community-Managed Green Spaces	Small-Scale Green Zones Managed by Local Communities for Tourism Activities	Bintan and Lingga Rural Communities	Emerging Initiatives; Limited Capacity and Funding For Scaling Up

Green open spaces (GOS) and ecological networks in the coastal areas of the Riau Archipelago play a dual role: they serve as recreational public spaces and ecological corridors connecting fragmented habitats. Although urban areas such as Batam and Tanjungpinang have begun incorporating coastal green belts and waterfront parks into spatial planning, the distribution of GOS across islands remains uneven. Many small islands and remote coastal settlements lack well-designed ecological green spaces. Strengthening coastal ecological networks is essential for supporting biodiversity conservation, maintaining landscape connectivity, and enhancing the quality of tourism experiences in coastal destinations.

Table 7 shows that coastal green open spaces and ecological networks in the Riau Archipelago remain concentrated in urban centers, while rural and small-island areas remain underdeveloped in structured green planning. Urban coastal parks, such as Tepi Laut Park in Tanjungpinang, provide both recreational and limited ecological functions but face challenges with long-term maintenance and landscape connectivity. Natural ecological corridors, such as mangrove belts and riparian buffers, are ecologically important but not yet fully integrated into provincial spatial planning, making them vulnerable to land-use changes. Community-managed green spaces are emerging as promising bottom-up initiatives, particularly in rural tourism areas, but

require stronger institutional and financial support to scale up. Strengthening and expanding these ecological networks is essential to enhance coastal resilience, improve habitat connectivity, and provide added value for eco-tourism development.

4.2.3. Environmentally Friendly Built Infrastructure

Environmentally friendly built infrastructure represents an essential component of GI in supporting coastal resilience and sustainable tourism development in the Riau Archipelago, Indonesia. Several urban coastal areas, particularly in Batam and Tanjungpinang, have begun adopting eco-engineering approaches, such as sustainable drainage systems, coastal parks, and bioengineering techniques, to reduce environmental impacts and improve tourism amenities. However, these initiatives remain localized and limited in scale, with varying levels of technical design, implementation, and long-term maintenance.

Table 8. Environmentally Friendly Built Infrastructure in Coastal Areas of Riau Archipelago

Type of Infrastructure	Key Features	Main Locations	Current Status / Issues
Sustainable Drainage Systems (Suds)	Use of permeable surfaces, vegetated swales, and retention ponds to manage runoff and reduce flooding	Selected urban districts in Batam and Tanjungpinang	Pilot implementations; limited coverage and integration with broader urban drainage systems
Coastal Parks and Waterfront Green Infrastructure	Urban recreational areas that combine leisure spaces with shoreline protection and aesthetic value	Tepi Laut Park (Tanjungpinang), Batam waterfront	Functional and popular tourist spots; variability in ecological design quality and maintenance
Bioengineering Shoreline Protection	Use of vegetated slopes, coastal planting, and soft engineering techniques to stabilize shorelines	Several sites in Bintan and Batam	Applied at small scale for erosion control; potential to complement mangrove restoration but requires technical support
Hybrid Infrastructure Projects	A combination of grey and green infrastructure (e.g., seawalls with mangrove belts)	Batam industrial coastline	Limited demonstration projects; promising for industrial-tourism interface but needs regulatory and planning integration

Table 8 indicates that the adoption of environmentally friendly built infrastructure in the Riau Archipelago remains in an early, localized stage, concentrated mainly in urban coastal zones. Pilot sustainable drainage systems (SuDS) have been implemented to address urban runoff and flooding, but have not yet been scaled up to cover entire drainage basins. Coastal parks and waterfront developments, such as Tepi Laut Park, serve dual functions as tourist attractions and shoreline buffers, though their ecological design standards vary by location. Bioengineering methods, including vegetated coastal stabilization, are applied at small scales and show promise for integrating soft engineering with mangrove rehabilitation. A hybrid infrastructure that combines grey and green elements has been piloted in Batam's

industrial areas, offering opportunities for multifunctional coastal protection and tourism enhancement. Overall, these initiatives illustrate emerging awareness and experimentation with GI solutions, but stronger technical planning, policy support, and inter-agency coordination are needed to scale them effectively across the archipelago.

4.2.4. The Role of Green Infrastructure in Coastal Protection and Tourism Attraction

GI plays a critical role in enhancing coastal resilience and strengthening the natural tourism appeal of the Riau Archipelago, Indonesia. Mangrove forests, coral reefs, and seagrass meadows function synergistically as natural wave barriers, sediment filters, and key habitats for diverse marine species, supporting ecotourism activities such as snorkeling, diving, and recreational fishing. In addition, coastal parks and green belts provide scenic landscapes and recreational spaces that are increasingly valued by both domestic and international tourists. Beyond ecological and aesthetic functions, GI also delivers significant indirect economic benefits by protecting coastal infrastructure and tourism assets from erosion and flooding, thus contributing to the long-term sustainability of the tourism industry.

Table 9. Roles of Green Infrastructure in Coastal Protection and Tourism in the Riau Archipelago

GI Component	Main Functions	Tourism Relevance
Mangrove forests	Reduce wave energy, stabilize shorelines, trap sediments, support fisheries	Provide scenic ecotourism sites (boardwalks, kayaking), and act as natural coastal protection for tourism facilities
Coral reefs	Dissipate 90–97% of incoming wave energy, maintain clear waters, support high biodiversity	Key attraction for diving and snorkeling; maintain beach quality and nearshore water clarity
Seagrass meadows	Stabilize sediments, store blue carbon, and provide nursery habitats for marine species	Enhance underwater tourism experiences; contribute to ecosystem services that support fisheries-based tourism
Coastal parks and green belts	Provide aesthetic landscapes, recreation space, and buffer zones between land and sea	Improve visitor experience; increase tourism site attractiveness and recreational diversity
Hybrid infrastructure	Combine natural ecosystems with built elements to protect infrastructure and tourism assets	Protect resorts, waterfronts, and roads from erosion and flooding, reducing maintenance costs

Table 9 highlights that GI contributes both ecological protection and economic value to the coastal tourism sector in the Riau Archipelago, Indonesia. Mangroves, coral reefs, and seagrass meadows provide crucial natural defense functions by reducing wave energy, stabilizing sediments, and maintaining water quality, thereby protecting tourism infrastructure from climate-related hazards. At the same time, these ecosystems are major attractions for nature-based tourism, offering activities such as kayaking through mangrove forests, snorkeling in coral reefs, and observing diverse marine life in seagrass meadows. Coastal parks and green belts further enrich

tourism experiences by providing scenic and recreational spaces along urban shorelines. Hybrid GI solutions, which combine natural features with engineered structures, are increasingly recognized as cost-effective measures for safeguarding tourism assets while maintaining ecological benefits. To maximize these functions, stronger integration between ecological planning and destination development is required, including expanding marine protected areas, restoring degraded habitats, and strengthening cross-sector governance.

Overall, the findings indicate that GI presents both significant opportunities and persistent challenges for coastal tourism development in the Riau Archipelago. While GI offers strong protective, economic, and experiential benefits, its effectiveness is constrained by fragmented planning, uneven infrastructure distribution, and limited institutional coordination. These dual conditions underscore the need for a structured strategic assessment to systematically evaluate internal capacities and external pressures. Accordingly, the following SWOT analysis synthesizes these opportunities and constraints to inform priority-setting for GI-based coastal tourism strategies.

4.3. SWOT Analysis of Green Infrastructure for Sustainable Coastal Tourism in Riau Archipelago

4.3.1. Internal Factor Analysis of Green Infrastructure

The internal analysis focuses on identifying strengths and weaknesses that influence the integration of GI in supporting sustainable coastal tourism in the Riau Archipelago. The province possesses rich ecological assets such as mangroves, coral reefs, and seagrass meadows, combined with strategic maritime connectivity that supports tourism growth. These are key strengths for GI-based tourism. However, challenges such as uneven infrastructure development, fragmented spatial planning, and weak community capacity limit GI's full potential to support sustainable tourism. The IFAS matrix evaluates these factors based on their average value, weight, rating, and total score to determine the relative significance of each factor.

Table 10, which yields a total score of 2.707, demonstrates that the internal environment supporting the development of GI-based sustainable coastal tourism in the Riau Archipelago is moderately strong, with strengths slightly exceeding weaknesses. The province's key strengths are rooted in its rich ecological assets, such as extensive mangrove forests, coral reefs, and seagrass meadows, combined with strategic maritime connectivity that enhances accessibility and tourism flows. These natural and locational advantages are further reinforced by emerging community-based tourism initiatives, cultural richness, and the establishment of marine conservation areas that provide an enabling ecological framework. However, several significant weaknesses persist, including poor transportation infrastructure on remote islands, fragmented integration of ecological and tourism spatial planning, inadequate waste management systems, and limited human resource capacity for GI maintenance and eco-tourism management. Additionally, weak tourism branding, regulatory gaps, and institutional fragmentation reduce policy coherence and implementation effectiveness. To maximize the potential of GI, these internal barriers must be strategically addressed through targeted investments in infrastructure, integrated spatial and environmental planning, capacity-building programs, and strengthened governance to support sustainable growth in coastal tourism.

Table 10. IFAS Matrix of Green Infrastructure for Sustainable Coastal Tourism in Riau Archipelago

Component	Statement	Average Value	Weight	Rating	Total Score
Strengths					
Ecological Assets	Extensive mangrove ecosystems (±67.417 ha) act as natural buffers, sediment traps, and carbon sinks, providing both ecological functions and tourism appeal.	4	0.098	4	0.390
Biodiversity & Marine Attractions	Coral reefs with 43.82% average live cover and rich seagrass meadows support diving, snorkeling, and fisheries-based tourism.	3	0.073	4	0.293
Strategic Location	Situated between Singapore–Malaysia maritime routes, the archipelago benefits from high tourist mobility and international access.	3	0.073	4	0.293
Economic Contribution	Coastal tourism plays a significant role in GRDP; Batam alone contributes around 66% of the provincial economy, boosting tourism infrastructure and logistics.	3	0.073	3	0.220
Cultural & Community Assets	Strong local culture and emerging local groups (e.g., in Bintan and Lingga) support authentic and community-based eco-tourism experiences.	2	0.049	3	0.146
Conservation Policy Support	Marine conservation areas (e.g., Bintan Timur MPA, SK 1050/2019) provide legal frameworks and ecological protection supporting GI integration.	2	0.049	3	0.146
GI Tourism Appeal	Coastal parks, waterfront green belts, and eco-landscapes enhance scenic value and visitor experiences, supporting GI-based tourism branding.	2	0.049	3	0.146
Total Strengths			0.463		1.634
Weaknesses					
Infrastructure Limitations	Poor road access, uneven tourism infrastructure distribution, and inadequate basic facilities on outer islands reduce accessibility and visitor comfort.	4	0.098	2	0.195
Fragmented Spatial Planning	Lack of integration between ecological planning and tourism development, particularly in small islands, leads to inefficient land-use and resource conflicts.	4	0.098	2	0.195
Waste Management	Inadequate waste treatment systems and increasing marine debris problems threaten ecosystem health and tourism site quality.	3	0.073	2	0.146
Limited GI Implementation	Sustainable drainage systems, bioengineering, and hybrid infrastructure remain at pilot stages and are not yet scaled up across coastal areas.	3	0.073	2	0.146
Human Resource Capacity	Limited local expertise in GI maintenance, eco-tourism management, and environmental monitoring constrains effective program implementation.	2	0.049	2	0.098
Promotion & Branding	Weak international marketing efforts and the absence of clear GI-based tourism branding hinder competitiveness with neighboring destinations.	2	0.049	2	0.098
Institutional Coordination	Overlapping mandates and limited cross-sectoral coordination among agencies slow down planning and execution of GI–tourism initiatives.	2	0.049	2	0.098
Regulatory Gaps	Absence of integrated regulatory frameworks linking GI and tourism at the provincial level limits policy coherence and implementation.	2	0.049	2	0.098
Total Weaknesses			0.537		1.073
Total IFAS		41	1		2.707

4.3.2. EFAS Analysis of Green Infrastructure GI for Sustainable Coastal Tourism in Riau Archipelago

Table 11. EFAS Matrix of Green Infrastructure for Sustainable Coastal Tourism Development in Riau Archipelago

Component	Statement	Average Value	Weight	Rating	Total Score
Opportunities					
Global Eco-Tourism Demand	Rising global interest in sustainable and nature-based tourism creates strong market potential for GI-based destinations in Southeast Asia.	4	0.133	3	0.40
National Policy Alignment	Alignment with Indonesia's green economy and blue carbon strategies (e.g., RPJMN, SDGs, climate commitments) supports GI integration in tourism development.	3	0.100	3	0.30
Climate Finance and Donor Support	Availability of international climate funds, blue carbon initiatives, and non-government organization support provides financial opportunities for GI restoration and tourism infrastructure.	3	0.100	4	0.40
Cross-Border Connectivity	Proximity to Singapore and Malaysia facilitates international tourism flows, investments, and partnerships that can strengthen GI-based tourism models.	3	0.100	3	0.30
Technological Innovation	Advancements in green engineering, coastal monitoring, and eco-tourism technologies offer tools to support effective GI planning and promotion.	2	0.067	3	0.20
Total Opportunities			0.500		1.60
Threats					
Climate Change Impacts	Sea level rise, increased storm surges, and coral bleaching threaten coastal ecosystems and tourism infrastructure.	4	0.133	2	0.27
Uncontrolled Coastal Development	Rapid expansion of ports, industries, and settlements causes habitat degradation and conflicts with GI functions and tourism assets.	4	0.133	2	0.27
Competition from Neighboring Destinations	Well-developed eco-tourism in Singapore, Malaysia, and Thailand poses competitive pressure on Riau's Archipelago positioning in the regional market.	3	0.100	2	0.20
Policy & Institutional Inconsistency	Inconsistent national-provincial policies and limited enforcement capacity hinder sustainable coastal planning and GI implementation.	2	0.067	1	0.07
Environmental Degradation Trends	Overfishing, mangrove clearing, and pollution continue to undermine ecosystem services critical to tourism resilience.	2	0.067	1	0.07
Total Threats			0.500		0.87
Total EFAS		30	1.00		2.47

The external factor analysis examines the opportunities and threats influencing the implementation of GI for sustainable coastal tourism development in the Riau Archipelago. As a maritime region with rich ecological resources and strategic geographic positioning, the province faces both promising external opportunities such as rising global eco-tourism demand, supportive national policies, and climate financing and significant external threats, including climate change impacts, environmental degradation, and competition from neighboring destinations. Understanding these external dynamics is crucial for formulating effective strategies to leverage strengths and opportunities while mitigating potential risks.

Table 11 analysis yields a total score of 2.47, indicating that the external environment for developing GI-based sustainable coastal tourism in the Riau Archipelago offers favorable opportunities, though significant threats must be

managed carefully. Key opportunities include the global rise in eco-tourism demand (0.40), national policy alignment with sustainable development goals (0.30), and access to climate finance and donor support (0.40), all of which provide strong momentum for implementing GI strategies. Cross-border connectivity with Singapore and Malaysia also enhances market access and investment potential, while technological innovation offers practical tools for environmental monitoring and green engineering. However, serious external threats persist, particularly climate change impacts and uncontrolled coastal development (each scoring 0.27), which threaten both ecological stability and tourism infrastructure. Additionally, regional competition, policy inconsistency, and environmental degradation pose strategic risks that could undermine long-term sustainability. To capitalize on opportunities while mitigating these threats, Riau Archipelago must adopt a proactive strategy that integrates international partnerships, climate adaptation measures, stronger regulatory enforcement, and regional branding to position itself competitively as a sustainable coastal tourism destination.

4.3.3. Internal-External Matrix Analysis of Green Infrastructure for Sustainable Coastal Tourism in Riau Archipelago Province

The internal-external (IE) matrix analysis is conducted to determine the strategic position of GI for sustainable coastal tourism development in the Riau Archipelago Province, based on the results of the IFAS and EFAS. This analysis plots the IFAS and EFAS total scores in a two-dimensional matrix to determine whether GI-based tourism development is in a growth, stability, or retrenchment strategy zone. Table 12 presents the strategic positioning framework used to classify GI-based sustainable coastal tourism development into growth, stability, or retrenchment strategy zones based on the total weighted scores of IFAS and EFAS.

Table 12. Internal-External Matrix

EFAS Score	Strong 3.0-4.0	Medium 2.0-2.99	Weak 1.0-1.99
High 3.0-4.0	I	II	III
Medium 2.0-2.99	IV	V	VI
Low 1.0-1.99	VII	VIII	IX

Horizontal Axis (X) = IFAS Total Weighted Score

Vertical Axis (Y) = EFAS Total Weighted Score

IFAS Score = 2.707

EFAS Score = 2.470

Thus, the coordinates of the IE Matrix position are:

$$(X; Y) = (2.707; 2.470)$$

Based on these coordinates, GI-based sustainable coastal tourism development in the Riau Archipelago is positioned in Cell V of the IE Matrix, representing a hold-and-maintain strategy. The positioning in Cell V indicates that the region possesses moderate internal strength and moderate external attractiveness. This suggests that the development of GI-based sustainable coastal tourism has adequate capacity and opportunities for continued growth; however, strategic improvements and adaptive management are still required to enhance competitiveness and sustainability. The strategic implications are as follows:

1. Strengthen existing internal capacities by improving the quality of GI, environmental governance, tourism facilities, and institutional coordination among stakeholders.
2. Optimize ecological and geographical advantages, including coastal ecosystems,

marine biodiversity, and the strategic location of the Riau Archipelago, Indonesia, as a cross-border tourism gateway.

3. Capitalize on external opportunities such as the increasing global demand for eco-tourism, sustainable investment trends, climate financing schemes, and regional tourism cooperation.
4. Implement market penetration and product development strategies, including destination branding, diversification of eco-tourism attractions, and enhancement of digital tourism promotion.
5. Adopt adaptive and climate-resilient planning measures to mitigate environmental threats, including coastal degradation, climate change impacts, and competition from neighbouring tourism destinations.
6. Encourage collaborative partnerships between government, local communities, private sectors, and conservation organizations to support sustainable tourism governance and long-term regional resilience.

4.4. SWOT Matrix of Green Infrastructure for Sustainable Coastal Tourism in Riau Archipelago

The SWOT matrix serves as a strategic tool to formulate integrated development strategies for GI-based sustainable coastal tourism in the Riau Archipelago. By systematically combining internal factors (strengths and weaknesses) with external factors (opportunities and threats), this matrix helps identify strategic priorities that leverage ecological assets and growth opportunities while addressing structural weaknesses and mitigating environmental and policy-related threats. The strategies generated aim to guide decision-makers in strengthening the province's position as a competitive and resilient coastal tourism destination aligned with global sustainability trends.

Table 13 highlights that the Riau Archipelago possesses a strong ecological and geographic foundation for advancing GI-based sustainable coastal tourism. Strengths such as extensive mangrove ecosystems, rich marine biodiversity, strategic maritime location, and supportive conservation policies create a solid internal base. These strengths align well with external opportunities, including rising global demand for ecotourism, national green economy policies, the availability of climate finance, and technological advancements. Consequently, several S-O strategies focus on expanding eco-tourism products, improving digital marketing, and mobilizing green investment. However, the matrix also reveals critical structural weaknesses, particularly in infrastructure, waste management, spatial planning, human resource capacity, and institutional coordination, that must be addressed to reduce vulnerability to external threats, including climate change, uncontrolled coastal development, and competition in regional tourism. W-O and W-T strategies emphasize infrastructure upgrades, capacity building, regulatory reforms, and the adoption of innovation to overcome these barriers. Overall, the 20 integrated strategies demonstrate that, with strategic coordination and investment, the Riau Archipelago can capitalize on its natural advantages to become a leading model of sustainable coastal tourism in Southeast Asia, resilient to environmental and competitive pressures.

Table 13. SWOT Matrix

			Strength (S)	Weakness (W)
			<p>S1. Extensive mangrove ecosystems (±67.417 ha) with ecological and tourism functions.</p> <p>S2. Coral reefs and seagrass meadows support biodiversity and marine tourism.</p> <p>S3. Strategic location between Singapore and Malaysia routes.</p> <p>S4. Significant contribution of coastal tourism to GRDP (~66% from Batam).</p> <p>S5. Strong local culture and emerging local groups.</p> <p>S6. Marine conservation policies and protected areas.</p> <p>S7. Coastal parks and GI features enhance tourism appeal to support sustainable tourism.</p>	<p>W1. Poor road access and uneven infrastructure.</p> <p>W2. Fragmented spatial planning between ecological and tourism development.</p> <p>W3. Inadequate waste management and marine debris.</p> <p>W4. Limited GI implementation (SuDS, hybrid infra).</p> <p>W5. Low human resource capacity in eco-tourism and GI.</p> <p>W6. Weak branding and promotion internationally.</p> <p>W7. Institutional fragmentation.</p> <p>W8. Regulatory gaps in GI-tourism integration.</p>
Opportunities (O)	Strategi S-O	Strategi W-O		
<p>O1. Rising global demand for eco tourism.</p> <p>O2. Supportive national policies and blue carbon strategies</p> <p>O3. Access to climate finance and international donor support</p> <p>O4. Cross-border connectivity with Singapore and Malaysia</p> <p>O5. Technological innovation in green engineering and monitoring.</p>	<p>Develop integrated eco-tourism packages that combine mangrove, coral, and cultural attractions to tap into rising global eco-tourism demand (S1, S2, S5, O1).</p> <p>Strengthen green infrastructure investment through climate finance and donor partnerships, leveraging conservation zones and ecosystem assets (S1, S6, O2, O3).</p> <p>Promote the Riau Archipelago as a cross-border eco-tourism hub, leveraging its strategic location and connectivity with Singapore-Malaysia (S3, S4, O1, O4).</p> <p>Use marine biodiversity and GI assets to differentiate destination branding and attract the expanding sustainable tourism market (S2, S7, O1, O5).</p> <p>Enhance digital marketing and eco-tourism technologies to improve visitor experiences and expand international market reach (S4, S7, O5).</p>	<p>Mobilize climate finance and PPPs to upgrade road access and eco-friendly infrastructure on outer islands (W1, W4, O2, O3).</p> <p>Adopt green technology solutions to address waste management and marine debris issues in tourist areas (W3, O5).</p> <p>Implement integrated spatial planning using national green economy policy frameworks and technological innovation (W2, O2, O5).</p> <p>Launch international branding campaigns that highlight cross-border accessibility and GI's uniqueness (W6, O1, O4).</p> <p>Strengthen local human resource capacity through donor-supported training in eco-tourism and GI management (W5, O3, O5).</p>		
Threats (T)	Strategi S-T	Strategi W-T		
<p>T1. Climate change impacts (sea level rise, storms, coral bleaching).</p> <p>T2. Uncontrolled coastal development is degrading ecosystems.</p> <p>T3. Competition from neighboring destinations.</p> <p>T4. Policy inconsistency and weak enforcement.</p> <p>T5. Environmental degradation from overfishing and pollution.</p>	<p>Reinforce coastal protection by combining mangrove restoration and hybrid GI to adapt to sea level rise and storm risks (S1, S6, T1, T2).</p> <p>Promote conservation-based tourism regulations to prevent uncontrolled coastal development (S6, S7, T2, T5).</p> <p>Position Riau Archipelago as a differentiated eco-tourism destination based on biodiversity and cultural uniqueness to counter regional competition (S2, S5, T3).</p> <p>Develop disaster-resilient tourism infrastructure by leveraging strategic location and strong GI features (S3, S4, T1, T4).</p> <p>Strengthen marine conservation enforcement to reduce the impacts of environmental degradation on tourism (S1, S6, T5).</p>	<p>Upgrade transportation infrastructure and connectivity to reduce vulnerability to extreme weather and climate impacts (W1, T1).</p> <p>Strengthen regulatory frameworks for spatial planning and GI integration to address policy inconsistencies and development threats (W2, W8, T2, T4).</p> <p>Develop waste-to-energy or circular economy initiatives to reduce environmental degradation and improve resilience (W3, T5).</p> <p>Enhance institutional coordination mechanisms to respond more effectively to climate and policy uncertainties (W7, T1, T4).</p> <p>Implement targeted capacity-building programs to improve crisis management, disaster preparedness, and eco-tourism competitiveness (W5, W6, T3, T4).</p>		

4.5. AHP Analysis for Strategy Prioritization of Green Infrastructure-Based Sustainable Coastal Tourism in Riau Archipelago

The analytical hierarchy process (AHP) is used to prioritize the 20 SWOT-derived strategies for integrating GI into sustainable coastal tourism development in the Riau Archipelago. This method enables systematic weighting and ranking of strategic options based on expert judgments, capturing the relative importance of each strategy with respect to feasibility, impact, and urgency. The results guide policymakers in focusing on high-leverage strategies that maximize ecological assets, address structural weaknesses, and enhance resilience to external pressures.

Table 14. AHP Weighting and Ranking of GI-Based Tourism Strategies

Strategy Category	Strategy Code	Initial Code	Mean Weight	Eigen Value	Final Weight	Priority Rank
Strength-Opportunity (SO)	SO-1	S1	0.0822	1.8742	0.0832	2
Strength-Opportunity (SO)	SO-2	S2	0.0318	0.7134	0.0317	17
Strength-Opportunity (SO)	SO-3	S3	0.0412	0.9258	0.0411	14
Strength-Opportunity (SO)	SO-4	S4	0.0449	1.0192	0.0452	11
Strength-Opportunity (SO)	SO-5	S5	0.0306	0.6864	0.0305	18
Weakness-Opportunity (WO)	WO-1	S6	0.0268	0.6033	0.0268	20
Weakness-Opportunity (WO)	WO-2	S7	0.0303	0.6771	0.0300	19
Weakness-Opportunity (WO)	WO-3	S8	0.0334	0.7452	0.0331	16
Weakness-Opportunity (WO)	WO-4	S9	0.0819	1.8433	0.0818	3
Weakness-Opportunity (WO)	WO-5	S10	0.0354	0.7894	0.0350	15
Strength-Threat (ST)	ST-1	S11	0.0866	1.9551	0.0867	1
Strength-Threat (ST)	ST-2	S12	0.0615	1.3914	0.0617	4
Strength-Threat (ST)	ST-3	S13	0.0434	0.9671	0.0429	13
Strength-Threat (ST)	ST-4	S14	0.0493	1.1032	0.0489	9
Strength-Threat (ST)	ST-5	S15	0.0566	1.2698	0.0563	7
Weakness-Threat (WT)	WT-1	S16	0.0446	1.0017	0.0444	12
Weakness-Threat (WT)	WT-2	S17	0.0480	1.0725	0.0476	10
Weakness-Threat (WT)	WT-3	S18	0.0501	1.1473	0.0509	8
Weakness-Threat (WT)	WT-4	S19	0.0610	1.3816	0.0613	5
Weakness-Threat (WT)	WT-5	S20	0.0602	1.3727	0.0609	6
Total			1.0000	22.5400	1.0000	

The results in Table 14 show that S-T strategies dominate the top priorities, reflecting the critical need to strengthen coastal resilience against climate impacts while leveraging ecological assets. The highest-ranked strategy is S-T-1 (0.0867), which focuses on reinforcing coastal protection through mangrove restoration and hybrid GI to adapt to sea-level rise and storm surges. This is followed by S-O-1 (0.0832), which integrates eco-tourism packages around mangrove, coral, and cultural assets to capitalize on growing global demand. W-O-4 (S9, 0.0818), which promotes international branding, ranks third, underscoring the importance of strategic marketing in enhancing destination competitiveness. Lower-ranked strategies (e.g., W-O-1, W-O-2) are mainly infrastructure and waste management interventions that, while important, have lower relative strategic leverage.

Taken together, the AHP results indicate a coherent strategic direction that prioritizes resilience-building and ecological asset optimization over purely infrastructural or remedial interventions. The dominance of strategies that combine strong internal ecological assets with responses to external climate and market pressures suggests a shift toward adaptive, nature-based tourism development. This prioritization framework provides a clear roadmap for policymakers by distinguishing high-impact

strategic interventions from supportive but secondary actions, thereby strengthening strategic focus and the sequencing of implementation.

Table 15. Ranked Priority List of GI-Based Tourism Strategies

Strategy Code	Strategic Category	Strategy Description
ST-1	Strength-Threat (ST)	Reinforce coastal protection through mangrove restoration and hybrid GI systems to address sea-level rise and storm risks.
SO-1	Strength-Opportunity (SO)	Develop integrated eco-tourism packages combining mangrove, coral reef, and cultural attractions.
WO-1	Weakness-Opportunity (WO)	Launch international branding campaigns that emphasize cross-border accessibility and GI's uniqueness.
ST-2	Strength-Threat (ST)	Promote conservation-based tourism regulations to prevent uncontrolled coastal development.
WT-1	Weakness-Threat (WT)	Enhance institutional coordination to improve responses to climate and policy uncertainties.
WT-2	Weakness-Threat (WT)	Implement targeted capacity-building programs for crisis management and tourism competitiveness.
ST-3	Strength-Threat (ST)	Strengthen marine conservation enforcement to minimize the impacts of environmental degradation.
SO-2	Strength-Opportunity (SO)	Develop circular economy initiatives to improve environmental resilience and tourism sustainability.
ST-4	Strength-Threat (ST)	Develop disaster-resilient tourism infrastructure integrated with GI features.
WT-3	Weakness-Threat (WT)	Strengthen regulatory frameworks for integrated spatial planning and GI governance.
SO-3	Strength-Opportunity (SO)	Utilize biodiversity and GI assets for destination branding and market differentiation.
WT-4	Weakness-Threat (WT)	Upgrade transportation infrastructure to reduce climate-related vulnerability.
ST-5	Strength-Threat (ST)	Position the Riau Archipelago as a differentiated eco-tourism destination to address regional competition.
SO-4	Strength-Opportunity (SO)	Promote the Riau Archipelago as a cross-border eco-tourism hub by leveraging its strategic location.
WO-2	Weakness-Opportunity (WO)	Strengthen human resource capacity through professional training and donor-supported programs.
WO-3	Weakness-Opportunity (WO)	Implement integrated spatial planning based on national green policy frameworks.
WO-4	Weakness-Opportunity (WO)	Strengthen GI investment through climate finance mechanisms and donor partnerships.
SO-5	Strength-Opportunity (SO)	Enhance digital marketing and eco-tourism technologies to expand international outreach.
WO-5	Weakness-Opportunity (WO)	Adopt green technology solutions to improve waste management systems.
WO-6	Weakness-Opportunity (WO)	Mobilize climate finance and public-private partnerships (PPPs) to develop eco-friendly infrastructure in outer islands.

Table 15 clearly indicates that adaptive coastal protection (S11), integrated eco-tourism development (S1), and international branding (S9) are the three most strategic interventions for advancing GI-based sustainable tourism in Riau Archipelago Province. These strategies combine ecological enhancement with market positioning, making them high-impact and feasible priorities. Mid-ranked strategies focus on institutional

strengthening, regulatory improvements, and resilience-building, which are crucial enablers of long-term sustainability. Lower-ranked strategies, though less immediately impactful, address fundamental infrastructure and operational issues that must not be neglected, as they support the enabling environment for higher-ranked strategies. Overall, this prioritization reflects a balanced approach that integrates environmental protection, tourism development, and governance reforms to achieve sustainable coastal tourism goals.

4.6. Analytical Hierarchy Process Consistency Diagnostics

To ensure the reliability and consistency of stakeholder judgments in the pairwise comparison process, consistency testing was conducted using the AHP consistency indicators, namely the maximum eigenvalue (λ_{max}), consistency index (CI), random index (RI), and consistency ratio (CR). The results of the consistency diagnostics are presented in Table 16.

Table 16. Analytical Hierarchy Process Consistency Diagnostics

Indicator	Value	Description
Number of Criteria/Alternatives (N)	20	Total elements compared in the AHP matrix
Maximum Eigenvalue (λ_{max})	22.51	Principal eigenvalue of the comparison matrix
Consistency Index (CI)	0.13	Measure of judgment consistency
Random Index (RI)	1.59	Standard random consistency value for N = 20
Consistency Ratio (CR)	0.08	Ratio used to evaluate overall consistency

The CR value obtained is 0.08, which is below the acceptable threshold of 0.10 as suggested by Wind and Saaty (1980). This indicates that the pairwise comparisons made by respondents are sufficiently consistent and reliable for decision-making analysis. Therefore, the weighting and prioritization results generated through the AHP method can be considered valid and appropriate for determining strategic priorities in GI-based sustainable coastal tourism development in the Riau Archipelago.

4.7. Discussion

The prioritization results demonstrate that adaptive and ecosystem-based strategies constitute the core strategic pathway for GI-based tourism development in the Riau Archipelago. The highest-ranked strategy (S-T-1), namely strengthening coastal protection through mangrove restoration and hybrid GI systems, indicates that stakeholders perceive ecological resilience not merely as environmental protection, but as a strategic asset that underpins tourism competitiveness and long-term regional sustainability. This finding extends the RBV and NRBV perspectives by illustrating how coastal ecosystems serve as valuable, location-specific resources that can generate sustained competitive advantages for tourism destinations. In this context, mangroves, coral reefs, and coastal ecosystems provide multifunctional value by simultaneously reducing climate-related risks, preserving biodiversity, supporting fisheries, and enhancing destination attractiveness.

The findings also reinforce the DCT, particularly the capacity of regional governance systems to adapt, reconfigure, and integrate ecological and infrastructural resources in response to environmental uncertainty. Rather than relying solely on conventional gray infrastructure, prioritizing hybrid GI systems reflects a strategic shift toward adaptive governance mechanisms that combine ecological restoration with engineered coastal protection. This mechanism is particularly relevant in archipelagic regions where climate risks, spatial fragmentation, and resource dependency create high levels of environmental vulnerability. Previous studies have similarly emphasized the

protective role of mangroves and coral reefs in reducing flood risk, wave energy, and erosion while generating co-benefits for local livelihoods and ecosystem services (Hochard et al., 2019; Menéndez et al., 2020). Likewise, hybrid ecological-engineering approaches have been identified as more adaptive and cost-efficient than conventional hard infrastructure, especially in coastal and deltaic regions exposed to accelerating climate hazards (Pontee et al., 2016; Temmerman et al., 2023; Vargas-del-Río et al., 2023).

Beyond identifying priority strategies, the SWOT-AHP integration contributes theoretically by operationalizing strategic management concepts within sustainable tourism planning. Existing GI and coastal tourism studies often remain descriptive and fragmented, addressing environmental protection, tourism development, and institutional reform as separate domains. In contrast, this study demonstrates how SWOT-AHP can function as an integrative decision-making mechanism that translates complex stakeholder preferences into measurable strategic priorities. The AHP process clarified trade-offs among ecological, economic, social, and governance dimensions, thereby revealing why ecosystem-based interventions achieved greater strategic leverage than isolated infrastructure expansion. This constitutes an important methodological contribution because the framework not only prioritizes actions but also exposes the strategic logic underlying stakeholder decision-making in climate-vulnerable tourism regions.

The second cluster of prioritized strategies highlights the strategic interaction between ecological conservation and tourism market positioning. Strategies S-O-1 (integrated eco-tourism development) and W-O-4 (international destination branding) indicate that environmental assets alone are insufficient to generate sustainable tourism competitiveness unless supported by effective market integration mechanisms. From a strategic management perspective, branding functions as a capability that transforms ecological resources into economic value by shaping destination identity, tourist perceptions, and regional differentiation. Eco-tourism based on mangroves, coral reefs, and local cultural heritage creates experiential value that aligns with shifting global tourism preferences toward authentic, low-impact, and sustainability-oriented destinations (Donohoe & Needham, 2016; Moussa et al., 2024).

The strategic mechanism underlying these findings lies in integrating conservation incentives with tourism value creation. Ecosystem preservation enhances destination attractiveness, while tourism revenues create incentives for continued environmental stewardship and community participation. Previous studies have shown that eco-tourism can simultaneously support conservation outcomes and local income generation when community participation and environmental governance are effectively integrated (Friess et al., 2019; Blanton et al., 2024). For the Riau Archipelago, geographical proximity to Singapore and Malaysia further strengthens its strategic positioning within regional tourism networks. However, capturing this advantage requires coordinated branding strategies, improvements in service quality, and stronger partnerships with tourism intermediaries and regional stakeholders (Kibria et al., 2021; Aziz et al., 2023).

Stakeholder engagement emerged as a critical mechanism shaping strategic prioritization. Importantly, local actors did not simply validate predefined policy agendas but actively influenced the weighting and framing of GI strategies. During focus group discussions, representatives from community tourism organizations emphasized that mangrove-based tourism and small-scale eco-tourism initiatives were more socially inclusive and economically feasible than large-scale resort development models. This finding highlights the importance of participatory governance within DCT, where adaptive capacity is strengthened through knowledge sharing, local stewardship, and collaborative decision-making. Community participation, therefore, functions not only as a social

component of sustainability but also as an institutional capability that improves implementation feasibility, policy legitimacy, and long-term resilience.

Infrastructure development and institutional reform strategies occupied medium priority, suggesting that stakeholders perceive them as enabling mechanisms rather than as primary drivers of sustainable tourism transformation. Strategies such as S-T-4 (disaster-resilient tourism infrastructure) and W-T-2 (strengthening regulatory frameworks) support GI effectiveness by improving coordination, reducing environmental risks, and facilitating integrated spatial planning. This finding is consistent with empirical evidence showing that infrastructure investments generate greater long-term value when ecological systems and governance structures remain functional and interconnected (Baloch et al., 2022; Herbeck et al., 2022). Conversely, excessive reliance on conventional hard infrastructure without ecosystem integration often leads to maladaptive outcomes, including ecosystem degradation, increased maintenance burdens, and stranded assets (Beck et al., 2018; Temmerman et al., 2023). Eco-sensitive infrastructure, aligned with integrated planning, therefore serves as a supporting mechanism that enhances both tourism quality and environmental resilience (Hochard et al., 2019; Shang et al., 2025).

Lower-ranked strategies, including climate finance mobilization (W-O-1) and green waste-management technologies (W-O-2), reveal persistent governance and institutional capacity constraints commonly experienced in archipelagic regions (Bennet & Satterfield, 2018; Mulyani et al., 2020; Rahman et al., 2022). However, their lower ranking should not be interpreted as a lack of importance. Instead, stakeholders appear to perceive these strategies as secondary mechanisms whose effectiveness depends on prior institutional strengthening and governance integration. This finding advances understanding of sequencing mechanisms in GI planning, where foundational governance capacity, inter-agency coordination, and community institutionalization must precede large-scale financing and technological expansion. Strengthening local organizations, such as local groups, therefore becomes strategically important because these institutions mediate communication, implementation, and collective action processes necessary for long-term GI governance (Lockwood et al., 2017; Alexander et al., 2019).

Overall, this study contributes both theoretically and methodologically to sustainable coastal tourism research. Theoretically, it extends RBV, NRBV, and DCT into the context of GI-based tourism planning by conceptualizing ecological systems as strategic resources and adaptive governance mechanisms. Methodologically, the integration of SWOT and AHP demonstrates how qualitative stakeholder perspectives can be transformed into transparent and quantifiable strategic priorities. The resulting strategic pathway for coastal protection, eco-tourism development, branding, institutional strengthening, and infrastructure support reflects not only global best practices but also the ecological and governance realities of archipelagic regions. Consequently, the study positions the SWOT-AHP framework not merely as a planning instrument, but as a strategic governance tool capable of improving adaptive decision-making, stakeholder alignment, and long-term sustainability in climate-vulnerable coastal tourism destinations.

5. Conclusion

This study provides a strategic assessment of GI integration for sustainable coastal tourism development in the Riau Archipelago, emphasizing the combined importance of ecological resilience, adaptive coastal protection, and strategic market positioning. The IFAS-EFAS and SWOT-AHP results demonstrate that mangrove restoration, hybrid GI-based coastal protection, and coastal ecosystem conservation constitute the most critical strategic priorities, given their dual roles in mitigating climate risks and enhancing the long-term attractiveness

of tourism destinations. In parallel, integrated ecotourism packaging and international branding are identified as key mechanisms to leverage the region's distinctive ecological and cultural assets and strengthen competitiveness in the global tourism market. These strategies are supported by enabling factors such as institutional coordination, regulatory coherence, and eco-sensitive infrastructure development, resulting in a balanced strategic pathway that aligns resilience, sustainability, and destination branding within contemporary coastal tourism governance and climate adaptation frameworks.

From a practical and policy perspective, this study offers several important benefits. It provides decision-makers with a structured, evidence-based prioritization of GI strategies to guide investment allocation, spatial planning, and coastal tourism development amid climate uncertainty. Policymakers are encouraged to prioritize funding for mangrove restoration and hybrid coastal protection as foundational measures to safeguard tourism assets. Collaboration between government agencies and the private sector is essential for developing integrated eco-tourism products and strengthening international branding initiatives. Furthermore, strengthening institutional capacity, regulatory alignment, and community participation is critical to addressing governance-related constraints and ensuring the long-term sustainability of GI-based tourism strategies. The proposed phased implementation approach, beginning with ecological strengthening, followed by branding and infrastructure development, and supported by continuous environmental and socio-economic monitoring, offers a practical roadmap for implementation.

In terms of academic contribution, this study contributes to the growing literature on sustainable coastal tourism by demonstrating the applicability of an integrated SWOT-AHP framework for prioritizing GI strategies within a climate-vulnerable tourism context. The findings extend existing research by linking ecological resilience strategies to market-oriented tourism development and governance considerations, thereby bridging perspectives on environmental planning and tourism competitiveness. Methodologically, the study demonstrates how multi-criteria decision analysis can translate qualitative strategic insights into actionable priorities, offering a replicable approach for similar coastal destinations.

However, several limitations must be acknowledged to enhance transparency and academic rigor. First, the analysis relies on expert judgment, introducing potential subjectivity into the SWOT and AHP weighting processes. Second, the sample size of experts is relatively limited, which may constrain the representativeness of the prioritization results. Third, the findings are context-specific to the Riau Archipelago and may not be directly generalizable to other coastal regions with different socio-ecological and institutional characteristics. Finally, the study focuses primarily on strategic prioritization and does not empirically quantify the long-term environmental or economic impacts of GI implementation.

Building on these limitations, future research can systematically extend the present study in several directions. Empirical studies employing larger, more diverse stakeholder samples could enhance the robustness of the weighting results. Methodological extensions that combine SWOT-AHP with spatial analysis, scenario modeling, or quantitative impact assessments would enable researchers to evaluate the long-term ecological, economic, and social outcomes of GI-based tourism strategies. Comparative or cross-regional studies could also examine the transferability of the proposed framework across different coastal tourism contexts. Additionally, future research could further refine the theoretical integration of GI, destination branding, and climate adaptation within tourism planning models, thereby advancing both methodological and conceptual development in sustainable tourism studies. Overall, by integrating strategic analysis, practical guidance, and theoretical reflection, this study positions the Riau Archipelago as a potential model for sustainable, climate-resilient

coastal tourism in Southeast Asia, while also providing a foundation for future scholarly inquiry and methodological advancement.

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