

## **A MULTI- CRITERIA DECISION-MAKING ANALYSIS OF VOLCANIC TOURISM USING THE ANALYTIC HIERARCHY PROCESS AND QFD: A CASE STUDY OF SIAU TAGULANDANG BIARO REGENCY**

Jozef Richard Raco

Universitas Katolik De La Salle Manado, Indonesia  
[jraco@unikadelasalle.ac.id](mailto:jraco@unikadelasalle.ac.id)

Yulius Raton

Universitas Katolik De La Salle Manado, Indonesia  
[yration@unikadelasalle.ac.id](mailto:yration@unikadelasalle.ac.id)

Tryadi Wilhelmus Tumewu

Universitas Katolik De La Salle Manado, Indonesia  
[ttumewu@unikadelasalle.ac.id](mailto:ttumewu@unikadelasalle.ac.id)

Ronaldo Ferdi Ignatius Rottie

Universitas Katolik De La Salle Manado, Indonesia  
[rrottie@unikadelasalle.ac.id](mailto:rrottie@unikadelasalle.ac.id)

Angelia Melani Adrian

Universitas Katolik De La Salle Manado, Indonesia  
[madrian@unikadelasalle.ac.id](mailto:madrian@unikadelasalle.ac.id)

Ronald Albert Rachmadi

Universitas Katolik De La Salle Manado, Indonesia  
[rrachmadi@unikadelasalle.ac.id](mailto:rrachmadi@unikadelasalle.ac.id)

### **ABSTRACT**

The Siau Tagulandang Biaro Islands Regency (Sitaro) in Indonesia, rich in natural volcanic resources, presents significant potential for sustainable tourism development. However, post-COVID-19 tourism growth poses challenges in attracting visitors amidst stiff competition. This study aims to design a comprehensive, participatory tourism development strategy for the region, integrating community and expert insights. A mixed-methods approach was employed, combining Focus Group Discussions (FGD), SWOT analysis, and the Analytic Hierarchy Process (AHP) to prioritize key development factors. A sensitivity analysis was conducted to assess the stability and robustness of the results. Subsequently, this study utilized Quality Function Deployment (QFD) and the House of Quality (HoQ) methods to translate these prioritized factors into actionable strategies. The study identifies eight operational strategies; notably, citizens' awareness, performance, and institutional development emerged as the top priorities. These findings offer

valuable insights for policymakers and stakeholders aiming to foster resilient and inclusive tourism growth.

**Keywords:** sustainable tourism; volcanic tourism; participatory planning; AHP; QFD; community engagement; island sustainability

## **1. Introduction**

The tourism industry has experienced significant growth following the pandemic crisis, and this trend is expected to continue, driving economic expansion. Indonesia set ambitious targets for the tourism sector, aiming for tourism foreign exchange to reach US\$31-39 billion by 2024. Additionally, the sector aimed to contribute 5.5% to the country's GDP, create job opportunities for approximately 15 million individuals, attract 25-28 million foreign tourists, and welcome 350-450 million domestic tourist visits (Kusubandio, 2020). These ambitious targets for the tourism sector, particularly the goal of foreign exchange earnings were not realized by 2024 due to the pandemic. Consequently, the government revised this strategic plan and adjusted the targets accordingly for the 2025-2029 strategic plan with the target of \$31—39 billion remaining (Ministry of Health, Indonesia, 2025).

Indonesia, an archipelagic country with approximately 17,000 islands, and boasts remarkable potential for natural-based tourism. This abundant natural beauty represents one of the key development priorities for the country. As public perception shifts towards recognizing the additional benefits of nature, nature-based tourism is gaining popularity (Ghasemi et al., 2024). With the increasing demand for nature-based tourism, the competitiveness of a tourism destination is influenced by its 'green' branding and credentials (Torsney & Buckley, 2023).

The archipelagic area, characterized by small and secluded islands, offers tourists a captivating blend of beauty, intimacy, and exoticism. With its unique local culture, serene environments, and uncrowded spaces, the archipelago provides an appealing experience for many. Exoticism refers to the islands' extraordinary and distinctive nature, setting them apart from people's everyday environments. Islands are often characterized by their unique cultures, diverse wildlife, and picturesque landscapes rarely found elsewhere. This sense of exoticness adds an element of adventure to the experience, providing opportunities for exploration and discovery (Darma Putra et al., 2021).

The concept of remoteness underscores these islands' allure due to their distant and isolated nature. Many individuals find the prospect of traveling to a far-off and less-explored destination to be thrilling and full of adventure. The remoteness often translates to untouched natural beauty and the opportunity to escape the fast-paced urban life. This sense of remoteness embodies the idea of escape, allowing one to break free from daily routines and experience peace, tranquillity, and relaxation (Vu et al., 2024). Combining remoteness and exoticism in an island destination can provide tourists an intimate and immersive experience.

Island tourism faces numerous challenges, including environmental degradation, limited infrastructure, and socio-cultural tensions, all of which demand careful and sustainable planning. Island tourism is often considered a double-edged sword, bringing both economic benefits and significant challenges. Planning is critical for addressing these issues, ensuring that tourism development aligns with both the preservation of local culture and the natural environment. These challenges of tourism are particularly pronounced on islands, where resources are often limited and the impacts of tourism can be disproportionately high. The unique geographical, environmental, and socio-cultural characteristics of islands demand a distinct approach to tourism planning. These challenges include environmental degradation due to over-tourism, limited infrastructure, the fragility of ecosystems, and socio-cultural impacts on local communities. As such, effective tourism planning is crucial for ensuring that tourism benefits are maximized while minimizing negative impacts.

The Islands Regency of Siau Tagulandang Biaro (Sitaro), located in North Sulawesi, Indonesia, is an archipelago consisting of 47 islands, of which 12 are inhabited. The region is predominantly marine, with approximately 80% of its territory covered by sea, and it has an estimated coastline length of 98.6 km and a total area of 275.96 km<sup>2</sup> (Raco et al., 2023).

The natural tourism potential of this area encompasses various attractions, including the pristine white sandy beaches along the coast of Mahoro Island, a captivating heart-shaped lake nestled high on Makalehi Island, and the unique hot water beach of Lehi. Notably, this archipelago is home to the Karangetang Volcano or Api Siau, renowned as The Real Volcano due to its high activity level, erupting almost daily. The volcano's magma chamber burns continuously throughout the year, creating a mesmerizing and distinct spectacle, particularly at night. Sailors often utilize this volcano as a navigational landmark. Additionally, Tagulandang Island boasts a volcano called Ruang volcano that remains active. The Siau Tagulandang Biaro Islands are also known for their endemic wildlife, such as the Tersier-Siau and Celepuk Siau, also known as Otus Siauensis. The Celepuk Siau was previously declared extinct but was rediscovered in the forested areas of Siau Island in 2017. Furthermore, this region is renowned for producing the world's finest nutmeg, thanks to the Karangetang volcano's fertile volcanic ash soil.

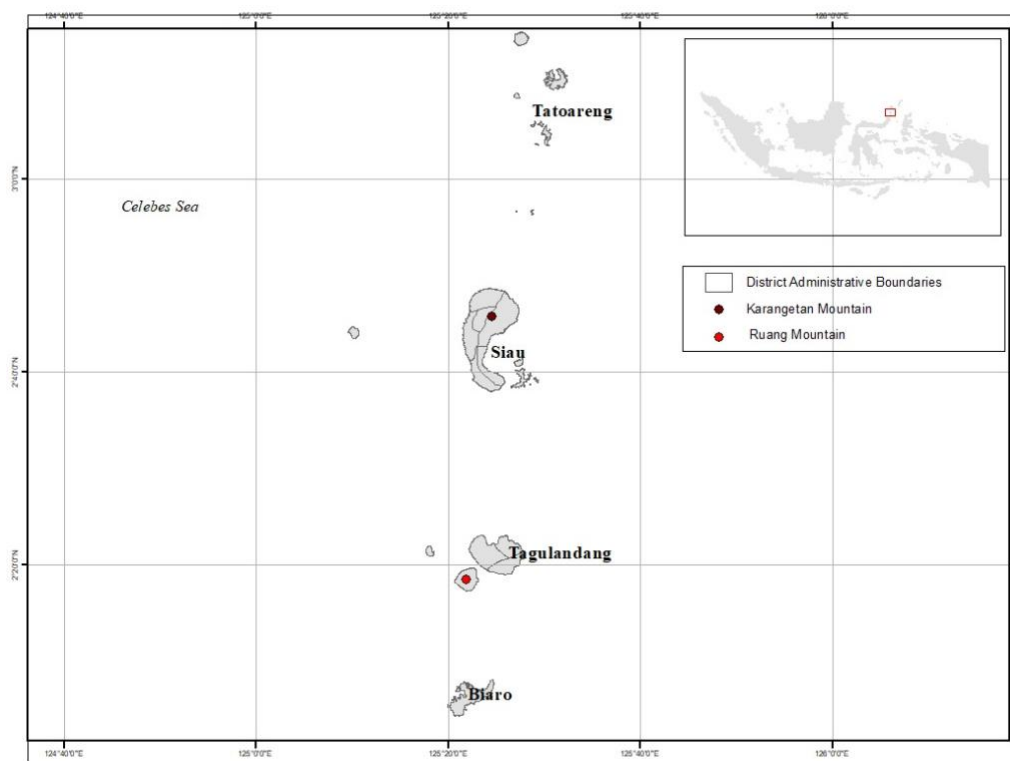


Figure 1 Map of Islands Regency of Siau Tagulandang Biaro

Figure 1 is an administrative boundary map of the Siau Tagulandang Biaro (Sitaro) Regency, North Sulawesi Province, Indonesia, which is the study area for this research. This map displays the location of Karangetang Volcano on Siau Island and Ruang Volcano on Ruang Island, Tagulandang District.

There is a prevailing view that research on island tourism remains limited and insufficiently developed. It is therefore important to conduct scientific studies focusing on island tourism to assist the government in preserving natural spaces, which are crucial for biodiversity conservation and the planet's overall ecological balance. Such research can also contribute to economic growth, poverty reduction through environmentally sustainable practices, resilience to external economic and environmental shocks, and the well-being of local communities and their cultural heritage.

This research uses the Siau Tagulandang Biaro Regency as a case study to explore these planning issues and to provide actionable insights for other island destinations. The case study illustrates the need for a strategic, participatory, and sustainable approach to tourism development, applicable not only to Siau Tagulandang Biaro but to other island destinations in Indonesia and globally. By focusing on a real-world context, this study moves beyond purely theoretical discussion and offers practical insights for addressing challenges in island tourism planning.

This study employs the Analytical Hierarchy Process (AHP) to prioritize tourism development strategies for Siau Tagulandang Biaro. The AHP is particularly suitable for tourism planning because it allows multiple development criteria – such as environmental sustainability, economic benefits, and community impacts – to be systematically evaluated. The method provides a transparent way to weigh stakeholder preferences, ensuring that all voices are considered in the decision-making process.

In addition to the AHP, Focus Group Discussions (FGD) and SWOT analysis were conducted with key stakeholders, including government officials, tourism operators, and local residents, to gather qualitative insights regarding tourism development challenges and opportunities in the region. These approaches reflect participatory planning practices commonly recommended in sustainable tourism development. The findings from the FGDs and SWOT analysis were subsequently used to inform the development of criteria and sub-criteria applied in the AHP model, while Quality Function Deployment (QFD) was applied to translate prioritized stakeholder needs into operational tourism development strategies.

This study aims to provide significant benefits to the people of Siau Tagulandang Biaro Islands Regency, including the following aspects: generating employment opportunities for the local communities, thereby supporting economic growth and reducing unemployment; strengthening the local economy through tourism-related expenditures that support local businesses and services; preserving and revitalizing cultural practices, arts, crafts, and heritage traditions; empowering local residents through entrepreneurship and community-based economic activities; improving infrastructures such as roads, utilities, and communication networks to enhance accessibility and tourism connectivity of local residents in environmentally responsible initiatives such as beach clean-ups, wildlife conservation programs, and sustainable tourism practices.

The novelty of this study lies in its integrated and participatory approach to developing a tourism strategy for the Islands Regency of Siau Tagulandang Biaro. This research leverages multiple methods including FGD, SWOT analysis, AHP, and QFD, to systematically identify stakeholder priorities and translate them into operational development strategies. A key distinguishing feature of this research is the active involvement of stakeholders and tourism actors in the decision-making process, ensuring that the resulting strategies are both contextually informed and practically applicable. Furthermore, the combined use of the AHP for priority determination and QFD for translating priorities into technical development strategies represents an innovative methodological integration within the context of island tourism planning.

Moreover, the research identifies eight operational strategies, with the top three - citizens' awareness, performance, and institutional development - accounting for more than 50% of the overall strategy priority. The prominence of the citizens' awareness strategy highlights the crucial role of community engagement and local participation in achieving sustainable tourism development.

While Indonesia's archipelagic context offers vast tourism potential, empirical studies and practical planning models for sustainable tourism development, particularly in volcanic island environments, remain limited. Existing studies often lack integration between participatory

approaches and systematic, multi-criteria decision-making frameworks. This study addresses the gap by asking the following question: How can participatory and evidence-based strategies be designed for sustainable volcanic tourism development in Sitaro Regency? By integrating FGD, SWOT analysis, the AHP, and QFD, this research ensures that both community perspectives and expert assessments are systematically translated into actionable tourism development strategies. This framework is intended to be replicable for other island destinations facing similar environmental and development challenges.

## **2. Literature review**

### **2.1. Island tourism planning**

Island tourism offers unique opportunities for economic development and cultural exchange; however, it also presents distinct challenges that require a carefully balanced planning and management approach. Recent literature emphasizes that island tourism development must balance economic opportunities against environmental and social vulnerabilities (Giampiccoli et al., 2021). Nevertheless, many existing studies remain largely descriptive and do not provide integrated frameworks that can be operationalized for participatory tourism planning. Giampiccoli et al. (2021) highlight the dual-edged nature of island tourism, where the economic benefits may be accompanied by environmental degradation and socio-cultural pressures. The unique geographical and ecological characteristics of islands, therefore, require tourism strategies that emphasize sustainability, resilience, and community participation.

One of the critical aspects of island tourism planning is the integration of community-based approaches. Involving local communities in the planning process not only fosters a sense of ownership but also ensures that tourism benefits are equitably distributed. This aligns with the broader principles of sustainable tourism, which aim to balance economic, environmental, and social considerations (Giampiccoli et al., 2021).

Environmental sustainability is a cornerstone of effective island tourism planning. Mendoza-González et al. (2018) emphasize the importance of preserving natural ecosystems, which are often the primary attractions for tourists. Over-tourism and inadequate waste management are significant threats to island environments, leading to the degradation of natural habitats and biodiversity loss. Planning strategies must therefore include measures for waste reduction, resource conservation, and the promotion of eco-friendly tourism practices.

Infrastructure development is another critical area in island tourism planning. Torsney and Buckley (2023) note that inadequate infrastructure can limit the accessibility and appeal of island destinations. However, infrastructure projects must be carefully designed to avoid adverse environmental impacts. Innovative solutions, such as renewable energy systems and sustainable transportation options, can enhance the infrastructure while preserving the natural environment.

Cultural preservation plays a vital role in island tourism planning. Islands often possess unique cultural heritages that are integral to their identity and attractiveness as tourism destinations. Vu et al. (2024) emphasize that tourism strategies should include initiatives to protect and promote local

traditions, languages, and crafts. Such initiatives not only enhance the authenticity of tourism experiences but also strengthen community pride, identity, and participation in tourism development.

## **2.2 Island tourism planning in Indonesia**

Indonesia, as one of the largest archipelagic nations in the world, exemplifies both the opportunities and challenges of island tourism planning. With over 17,000 islands, the country possesses exceptional natural and cultural diversity, making it a major destination for nature-based and cultural tourism. However, this diversity also requires carefully designed, region-specific tourism planning approaches that consider the environmental, social, and economic characteristics of each island region.

Kusubandio (2020) outlines Indonesia's ambitious tourism development targets, which include generating significant foreign exchange revenues, contributing to GDP growth, and creating millions of jobs. The government's focus on nature-based tourism aligns with global trends favoring eco-tourism and sustainable travel. Nevertheless, achieving these targets requires addressing structural challenges such as limited infrastructure, environmental degradation, and socio-economic disparities across island regions.

Indonesia's regulatory framework for tourism development is guided by laws and policies aimed at balancing economic growth with environmental preservation. Law No. 10/2009 on Tourism provides a legal foundation for sustainable tourism practices, emphasizing community participation, cultural preservation, and environmental protection. In addition, the National Medium-Term Development Plan (RPJMN) prioritizes tourism as a key economic sector, with a focus on promoting high-value destinations and diversifying tourism offerings.

One of Indonesia's key strategies is the development of "super-priority tourism destinations," which aims to position selected locations as world-class tourist attractions. Darma Putra et al. (2021) highlight the potential of destinations like Bali, which successfully combines natural beauty with cultural richness. However, the concentration of tourism activities in a limited number of destinations has contributed to over-tourism, emphasizing the need to diversify tourism development toward lesser-known island destinations.

Community involvement is a critical component of Indonesia's tourism planning. Prayitno et al. (2023) prioritize the role of social capital in sustainable tourism development. Programs that engage local communities in tourism activities not only enhance the authenticity of the tourist experience but also empower residents economically and socially. For example, initiatives that promote local crafts and culinary traditions can provide sustainable livelihoods while preserving cultural heritage. Disaster preparedness is another crucial aspect of tourism planning in Indonesia, given the country's high exposure to natural hazards such as earthquakes, volcanic eruptions, and tsunamis. Raco (2024a) provides detailed insights into planning for volcanic tourism, emphasizing the importance of hazard assessment, community preparedness, and resilient infrastructure. Integrating disaster risk management into tourism planning is therefore essential to ensure visitor safety while maintaining the long-term sustainability of tourism destinations.

Environmental conservation is at the forefront of Indonesia's tourism policies. Vu et al. (2024) show that preserving natural resources is essential for maintaining the country's competitive advantage as a tourist destination. Protected areas and marine conservation zones have been established to safeguard biodiversity, while initiatives like coral reef restoration and mangrove planting contribute to ecosystem resilience.

### **2.3 Utilization of AHP for tourism planning**

The AHP has emerged as a widely used decision-making support tool in tourism planning, particularly in contexts that involve multiple evaluation criteria and diverse stakeholder interests. Developed by Thomas Saaty in the 1970s, the AHP provides a structured framework for prioritizing factors based on their relative importance, making it suitable for complex planning scenarios, such as island tourism (Ohoitmur et al., 2019).

A key advantage of the AHP is its ability to integrate both quantitative and qualitative data. Raco et al. (2021) highlight the versatility of the AHP in handling diverse criteria, such as environmental sustainability, economic benefits, and community preferences. By organizing these criteria into a hierarchical structure, the AHP simplifies the decision-making process and ensures transparency.

In the context of island tourism, the AHP has been effectively used to prioritize strategies that address specific challenges. For example, Ohoitmur et al. (2019) utilized the AHP to evaluate the strengths, weaknesses, opportunities, and threats (SWOT) associated with tourism development in small islands. Their findings provided actionable insights for policymakers, such as prioritizing infrastructure development and community engagement.

The AHP also facilitates stakeholder participation, which is critical for the success of tourism planning. By involving government officials, tourism operators, and local residents in the decision-making process, the AHP ensures that diverse perspectives are considered. This participatory approach aligns with best practices in sustainable tourism, as noted by Prayitno et al. (2023). Moreover, the AHP has been instrumental in disaster risk management for tourism planning. Kausar et al. (2023) applied the AHP to assess the vulnerability of tourism destinations to natural disasters and identify mitigation strategies. Their study highlighted the importance of resilient infrastructure, emergency preparedness, and community training in minimizing disaster impacts. Another notable application of the AHP is in evaluating customer preferences and expectations. By analyzing survey data, the AHP can identify the most valued aspects of a tourist experience, such as environmental quality, cultural authenticity, and accessibility. These insights inform the design of tourism products and services that align with customer expectations (Raco et al., 2021).

Finally, the combination of the AHP with other methodologies, such as Quality Function Deployment (QFD), enhances its effectiveness. For instance, Raco et al. (2024b) demonstrated how the AHP and QFD could be used together to align technical requirements with customer expectations. This integrated approach ensures that tourism strategies are both data-driven and customer-centric. Despite the proven utility of the AHP and QFD in tourism planning, empirical studies that systematically integrate these methods with participatory stakeholder engagement remain limited, particularly in volcanic island contexts. This research addresses this gap by integrating FGD, SWOT analysis, AHP prioritization, and QFD-based strategy formulation. This

ensures that both qualitative stakeholder perspectives and quantitative prioritization results are incorporated into a transparent and replicable tourism planning framework.

### **3. Methodology**

This study adopts a mixed-methods approach to support participatory and evidence-based tourism planning in the Siau Tagulandang Biaro Islands Regency. The research process consisted of several sequential stages. First, FGDs were conducted with 15 stakeholders representing local government, tourism operators, community leaders, and tourism practitioners to identify key tourism development issues and opportunities. Second, discussion results were organized using SWOT analysis to classify internal and external factors influencing tourism development. Third, the AHP was applied to prioritize the identified criteria and sub-criteria through pairwise comparison questionnaires completed by experts, with consistency ratio checks ( $CR < 0.10$ ). Finally, the study utilized QFD to translate the prioritized stakeholder needs into operational tourism development strategies through the House of Quality (HoQ) matrix, which was validated by five tourism experts. All participants provided informed consent, and data confidentiality was maintained throughout the research. The integration of the AHP-QFD ensures that subjective stakeholder preferences are objectively prioritized and translated into actionable strategies, addressing the limitations of previous studies that relied solely on qualitative or quantitative methods.

#### **3.1. Factors identification through FGD to SWOT analysis**

This study employed an integrated multi-criteria decision-making framework to analyze volcanic tourism development in Siau Tagulandang Biaro Regency. The research began with a FGD involving 15 participants consisting of local government officials, tourism practitioners, community leaders, and academic experts. The session lasted approximately three hours and was moderated by the research team using a semi-structured discussion guide. Conducted at the Sitaro Regent's Office in Siau, the FGD aimed to identify key factors affecting volcanic tourism, including existing tourism resources, growth potentials, and aspects requiring improvement. During the discussion, participants shared their experiences and knowledge regarding tourism infrastructure, community readiness, environmental management, and institutional support. The qualitative information generated from the FGD was recorded, compiled, and analyzed. The identified factors were then categorized using the SWOT framework to identify internal and external influences on volcanic tourism development in Sitaro.

#### **3.2. Priority determination using the Analytical Hierarchy Process**

The SWOT analysis was operationalized as the basis for structuring the AHP model. The factors identified through the FGD were first categorized into four strategic dimensions: strengths, weaknesses, opportunities, and threats. These four SWOT components were then defined as the main criteria within the AHP hierarchy which consists of three levels: (1) the research objective, (2) tourism development criteria derived from SWOT analysis, and (3) sub-criteria representing specific tourism development factors in Siau Tagulandang Biaro Regency.

Furthermore, the specific factors identified under each dimension were defined as sub-criteria in the AHP model. The AHP method was subsequently applied to conduct pairwise comparisons

among these criteria and sub-criteria, enabling the calculation of priority weights and determining the relative ranking of factors influencing volcanic tourism development in Siau Tagulandang Biaro Regency.

Respondents indicated their preferences using a scale established by Saaty, ranging from one (indicating equal importance) to nine (indicating extreme importance). Local weights were then multiplied by their respective criteria weights to obtain global priority values for all sub-criteria. A sensitivity analysis was conducted to examine the stability of the priority rankings under different weighting scenarios, ensuring the robustness of the decision results.

### **3.3. Identification of tourists' expectations and design destination in QFD**

The results obtained from the AHP were further operationalized in the QFD stage. The prioritized factors generated by the AHP analysis were interpreted by tourism experts as the WHATs, representing the key expectations and needs of tourists visiting the Siau Tagulandang Biaro volcanic tourism destination. These WHATs reflect the most critical aspects that influence visitor satisfaction and destination attractiveness. Subsequently, the experts translated these expectations into technical requirements or development strategies, known as the HOWs, which describe the operational design and management actions required for developing the volcanic tourism destination. This translation was structured using the House of Quality framework (HoQ).

Five tourism experts participated in the evaluation process to determine the relationships between stakeholder needs and technical development strategies. The relationship matrix was constructed by assigning weights (9 = strong, 3 = moderate, 1 = weak) to represent the strength of the relationship between each WHAT and HOW. The final technical priorities were calculated by multiplying the AHP-derived importance weights with the relationship scores in the HoQ matrix to determine the most important operational tourism development strategies.

Service quality dimensions frequently differ from the technical aspects controlled by service providers. To link stakeholder expectations with operational tourism development strategies, a matrix known as the HoQ was constructed to connect service quality dimensions with technical development actions. In this study, the HoQ matrix was used to identify which tourism development strategies should be prioritized based on the importance weights derived from the AHP analysis.

The HoQ plays a crucial role in the process. Figure 2 illustrates the structure of the HoQ matrix applied in this study. The left side of the matrix contains the Customer Expectations (WHAT) derived from the global priority weights calculated using the AHP. The top section presents the Technical Requirements (HOWs) representing tourism development strategies identified through expert consultation. The central section contains the strength of relationships between WHATs and HOWs, while the bottom section shows the calculated technical priorities,

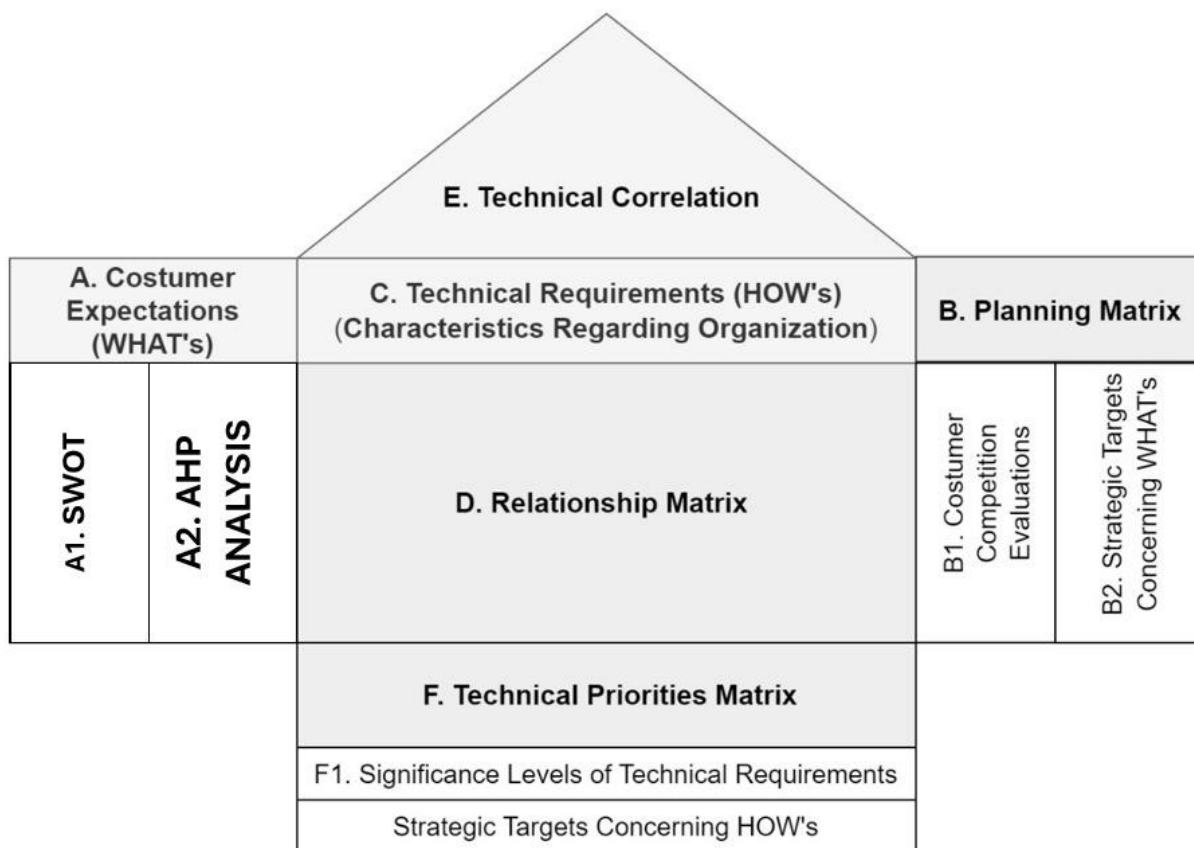


Figure 2 House of Quality Matrix applied in the tourism development analysis (Source: Raco, 2024b)

After defining the WHATs and HOWs, the next step involved constructing the relationship matrix to evaluate the strength of the relationship between stakeholder expectations and tourism development strategies. The weighting system presented in Table 2 was applied, where 9 indicates a strong relationship, 3 indicates a moderate relationship, and 1 indicates a weak relationship. If no relationship exists between a WHAT and a HOW, the corresponding cell in the matrix remains empty.

Table 2  
Symbols and numbers used in HOQ

|   |                       |   |
|---|-----------------------|---|
| △ | Low relationship      | 1 |
| ○ | Moderate relationship | 3 |
| ◎ | Strong relationship   | 9 |

Source: Raco, 2024b

Once all the relationships between WHATs and HOWs were established, the priority score of each technical requirement was calculated by multiplying the relationship weights with the AHP-derived importance values of stakeholder expectations. The resulting scores were then used to rank the tourism development strategies. In this study, QFD provided a systematic framework for translating prioritized stakeholder needs into operational tourism development strategies, ensuring that planning decisions were aligned with stakeholder expectations.

The essential aspect of constructing an HoQ revolves around prioritizing customer needs and ensuring that the design and development process aligns with customer preferences while accommodating technological advancements and innovation (Rahman et al., 2020). QFD can be a valuable tool in improvement initiatives, mainly when quality is a primary focus (Erdil & Arani, 2019). In the context of this research, QFD was applied to formulate strategic tourism development priorities for the Siau Tagulandang Biaro Islands Regency by integrating the AHP-derived stakeholder priorities with expert-based technical development strategies.

The final score for each technical descriptor is calculated using Equation (1):

$$A_j = \sum_{i=1}^m R_{ij}C_i \quad (1)$$

- $A_j$  = Column vector of final scores for  $j^{\text{th}}$  technical descriptor ( $j= 1,2,\dots,n$ )
- $R_{ij}$  = Weights assigned to the relationship matrix ( $i= 1,2,\dots,m, j- 1,2,\dots,n$ )
- $C_i$  = Row vector of importance assigned to the  $i^{\text{th}}$  customer requirement ( $i= 1,2,\dots,m$ )

The novelty of this research lies in its integrated multi-method framework for tourism development planning in volcanic island destinations, especially when applied to Siau Tagulandang Biaro Regency in Indonesia. By combining FGDs, SWOT analysis, AHP prioritization, and QFD-based strategy translation, this study incorporates both stakeholder perspectives and expert evaluations in a systematic and participatory decision-making process. What distinguishes this study is the integrated use of the AHP and QFD within a participatory tourism planning framework, which is rarely applied in a volcanic island tourism context. The AHP enables the prioritization of development factors based on stakeholder evaluations, while QFD translates these prioritized needs into implementable tourism development strategies through the HoQ matrix.

Moreover, the emphasis on community engagement and institutional strengthening, particularly through the prioritization of citizens' awareness, performance, and institutional development, highlights the importance of local participation in sustainable tourism governance. The integration of disaster risk management and environmental sustainability further strengthens the model for tourism development in volcanic island environment.

In summary, this research contributes to the island tourism literature by proposing a replicable decision-support framework that integrates participatory stakeholder engagement with multi-criteria decision-making tools such as AHP and QFD, providing practical guidance for sustainable tourism strategy development in volcanic island destinations.

## **4. Results**

### **4.1. SWOT analysis results**

During the FGD, stakeholders and researchers collaboratively identified the internal factors (strengths and weaknesses) and external factors (opportunities and threats) related to tourism in the Siau Tagulandang Biaro Islands. The factors were then organized as the AHP criteria and sub-criteria for subsequent prioritization analysis. The four main criteria consisted of strengths, weaknesses, opportunities, and threats, each represented by several sub-criteria. The strengths included natural attractions, economic potential, tourist friendliness, and government support. The weaknesses included limited facilities, lack of community of tourism, limited promotion, and lack of coordination among stakeholders. The opportunities comprised high tourism demand, international reputation, potential income growth, and cultural preservation. The threats included intense competition, high investment costs, volcanic eruption risk, and environmental degradation. The findings are presented in Table 3.

Table 3  
SWOT criteria and sub-criteria

| SWOT factors<br>(Criteria) | SWOT sub factors<br>(Sub Criteria)  |
|----------------------------|---|
| Strengths (S)              | S1 Natural tourism attraction<br>S2 Economic potential<br>S3 Tourist friendliness<br>S4 Government support                              |
| Weakness (W)               | W1 Limited facilities<br>W2 Lack of understanding of tourism among local communities<br>W3 Limited promotion<br>W4 Lack of coordination |
| Opportunities (O)          | O1 High tourism demand<br>O2 International reputation<br>O3 Potential for increased income<br>O4 Cultural preservation                  |
| Threats (T)                | T1 Tight competition<br>T2 High investment cost<br>T3 Volcanic eruption risk<br>T4 Environmental degradation                            |

#### 4.2. Criteria calculation results

The results of the AHP-based calculation of the main criteria weights are presented in Table 4.

Table 4  
Weights of the criteria

|   | S    | W    | O    | T    | Weight |
|---|------|------|------|------|--------|
| <b>S</b>  | 1.00 | 2.34 | 1.29 | 1.68 | 0.34   |
| <b>W</b>  | 0.43 | 1.00 | 0.70 | 0.90 | 0.16   |
| <b>O</b>  | 0.78 | 1.43 | 1.00 | 5.05 | 0.36   |
| <b>T</b>  | 0.59 | 1.11 | 0.20 | 1.00 | 0.14   |
| $\lambda_{\max} = 4.25, CI = 0.083, CR = 0.092$ |      |      |      |      |        |

The results of the criteria calculation indicate that the Consistency Ratio (CR) is 0.092, which is below the acceptable threshold of 0.10. This suggests that the expert judgments are consistent and acceptable. The analysis reveals that Opportunities (0.36) received the highest priority weight, followed by Strengths (0.34), Weaknesses (0.16), and finally, Threats (0.14). This finding indicates that respondents considered external development opportunities and existing destination's existing strengths as more important than weaknesses and threats when shaping tourism strategy.

#### 4.3. Sub-criteria weight calculation results

The results of the AHP calculations for the strength sub-criteria are presented in Table 5.

Table 5  
Strength sub-criteria calculation

|   | S1   | S2   | S3   | S4   | Weight |
|---|------|------|------|------|--------|
| S1  | 1.00 | 1.20 | 0.63 | 0.38 | 0.17   |
| S2  | 0.83 | 1.00 | 0.51 | 0.38 | 0.14   |
| S3  | 1.60 | 1.98 | 1.00 | 2.71 | 0.39   |
| S4  | 2.64 | 2.64 | 0.37 | 1.00 | 0.30   |
| $\lambda \max = 4.25, CI = 0.085, CR = 0.094$ |      |      |      |      |        |

Note: S1-natural tourism attraction; S2- economics potential; S3- tourist friendliness; S4- government support

The calculation results for the strength sub-criteria indicate a CR of 0.094, signifying that the results are consistent and acceptable. The sub-criterion with the highest weight is tourist friendliness (0.39), followed by government support (0.30), natural tourism attractions (0.17), and economic potential (0.14). This result suggests that respondents perceived the social atmosphere and residents' attitudes towards visitors as the most important internal strength for tourism development in Sitaro. The AHP calculation for the weakness sub-criteria yielded the following results.

Table 6  
Weight of the weakness sub-criteria

|   | W1   | W2   | W3   | W4   | Weight |
|---|------|------|------|------|--------|
| W1  | 1.00 | 2.99 | 0.70 | 1.54 | 0.32   |
| W2  | 0.33 | 1.00 | 0.70 | 0.42 | 0.13   |
| W3  | 1.43 | 1.43 | 1.00 | 0.46 | 0.24   |
| W4  | 0.65 | 2.38 | 2.19 | 1.00 | 0.32   |
| $\lambda \max = 4.25, CI = 0.082, CR = 0.091$ |      |      |      |      |        |

Note: W1- limited facilities; W2- lack of understanding of tourism; W3- limited promotion; W4- lack of coordination

The obtained CR is 0.091, which is below the threshold of 0.10, indicating that the results are acceptable. The highest weight is assigned to the lack of coordination (0.32), followed closely by limited facilities (0.32), limited promotion (0.24), and lack of understanding of tourism (0.13). These findings indicate that institutional and managerial weaknesses were perceived as more critical barriers than knowledge-related limitations. The weights of the opportunity sub-criteria were calculated as follows.

Table 7  
Weight of the opportunity sub-criteria

|   | <b>O1</b> | <b>O2</b> | <b>O3</b> | <b>O4</b> | <b>Weight</b> |
|---|-----------|-----------|-----------|-----------|---------------|
| <b>O1</b>                                     | 1.00      | 2.86      | 0.46      | 1.15      | 0.26          |
| <b>O2</b>                                     | 0.35      | 1.00      | 0.36      | 0.44      | 0.11          |
| <b>O3</b>                                     | 2.19      | 2.75      | 1.00      | 0.55      | 0.31          |
| <b>O4</b>                                     | 0.87      | 2.28      | 1.83      | 1.00      | 0.32          |
| $\lambda \max = 4.24, CI = 0.079, CR = 0.087$ |           |           |           |           |               |

Note: O1- high tourism demand; O2- international reputation; O3- potentials of income increase; O4- cultural preservation

The calculated CR result is 0.087, indicating that the findings are consistent and acceptable. Table 7 shows the weights of the opportunity sub-criteria. It reveals that cultural preservation (O4) has the highest weight (0.32), followed by potential income increase (0.31), high tourism demand (0.26), and international reputation (0.11). This indicates that respondents viewed cultural sustainability and local economic gain as the most significant external opportunities for tourism development. The weights of the threat sub-criteria are summarized below

Table 8  
Weights of the threats sub-criteria

|  | <b>T1</b> | <b>T2</b> | <b>T3</b> | <b>T4</b> | <b>Weight</b> |
|--|-----------|-----------|-----------|-----------|---------------|
| <b>T1</b>                                    | 1.00      | 0.58      | 0.27      | 0.44      | 0.12          |
| <b>T2</b>                                    | 1.72      | 1.00      | 0.60      | 0.49      | 0.18          |
| <b>T3</b>                                    | 3.64      | 1.66      | 1.00      | 0.42      | 0.29          |
| <b>T4</b>                                    | 2.27      | 2.05      | 2.36      | 1.00      | 0.41          |
| $\lambda \max = 4.16 CI = 0.052, CR = 0.058$ |           |           |           |           |               |

Note: T1- tight competition; T2- high-cost investment; T3- eruption disaster; T4- environmental damage

The CR is 0.058, suggesting that the calculation is consistent and acceptable. The highest weight is assigned to environmental damage (0.41), followed by volcanic eruption risk (0.29), high-cost investment (0.18), and tight competition in tourism (0.12). This finding suggests that environmental and hazard-related concerns were perceived as more serious external threats than market competition.

#### 4.3. Global weights

The global weights were determined by multiplying each criterion's weight by the corresponding local weight of each sub-criterion.

Table 9  
Global weight calculation

| <b>Criteria and sub-criteria</b> | <b>Local weight</b> | <b>Overall weight</b> |
|----------------------------------|---------------------|-----------------------|
| <i>Strength</i>                  |                     | <i>0.34</i>           |
| S1                               | 0.17                | 0.06                  |
| S2                               | 0.14                | 0.05                  |
| S3                               | 0.39                | 0.13                  |
| S4                               | 0.30                | 0.10                  |
| <i>Weakness</i>                  |                     | <i>0.16</i>           |
| W1                               | 0.32                | 0.05                  |
| W2                               | 0.13                | 0.02                  |
| W3                               | 0.24                | 0.04                  |
| W4                               | 0.32                | 0.05                  |
| <i>Opportunities</i>             |                     | <i>0.36</i>           |
| O1                               | 0.26                | 0.09                  |
| O2                               | 0.11                | 0.04                  |
| O3                               | 0.31                | 0.11                  |
| O4                               | 0.32                | 0.11                  |
| <i>Threats</i>                   |                     | <i>0.14</i>           |
| T1                               | 0.12                | 0.02                  |
| T2                               | 0.18                | 0.03                  |
| T3                               | 0.29                | 0.04                  |
| T4                               | 0.41                | 0.06                  |

The global weight results indicate that S3 (Tourist Friendliness) has the highest overall weight (0.13), followed by O3 (Potential for Income Increase) and O4 (Cultural Preservation), each at 0.11, followed by S4 (Government Support) with a weight of 0.10. These results suggest that both internal social strengths and external development opportunities play a dominant role in shaping the strategic priorities for tourism development in Sitaro. For transparency, the detailed AHP pairwise comparison matrices and consistency calculations are presented in the Appendix.

#### 4.4. Sensitivity analysis

The initial AHP results indicate that the sub-criterion S3 (Friendliness to Tourists) obtained the highest global weight (0.13) among all sub-criteria.

In Scenario 1, the weights of the four main criteria were equalized at 0.25 to test the stability of the ranking results. Under this scenario, S3 (Friendliness to Tourists) and T4 (Environmental Damage) emerged with the highest weight (0.10).

In Scenario 2, the weights of the two most influential criteria (Opportunities and Strengths) were exchanged to examine whether the ranking of the sub-criteria changed significantly. The analysis shows that S3 (Friendliness to Tourists) consistently remained the highest-ranked sub-criterion across the sensitivity scenarios.

Therefore, it can be concluded that the priority structure derived from the AHP analysis is robust, indicating that small variations in criteria weights do not substantially alter the ranking of the key tourism development factors.

Table 10  
Results of the sensitivity analysis

| Criteria and sub-criteria | Local weight | Overall weight |             |             |
|---------------------------|--------------|----------------|-------------|-------------|
|                           |              | Original       | Scenario 1  | Scenario 2  |
| <i>Strengths</i>          |              | <i>0.34</i>    | <i>0.25</i> | <i>0.36</i> |
| S1                        | 0.17         | 0.06           | 0.04        | 0.06        |
| S2                        | 0.14         | 0.05           | 0.04        | 0.05        |
| S3                        | 0.39         | 0.13           | 0.10        | 0.14        |
| S4                        | 0.30         | 0.10           | 0.07        | 0.11        |
| <i>Weakness</i>           |              | <i>0.16</i>    | <i>0.25</i> | <i>0.16</i> |
| W1                        | 0.32         | 0.05           | 0.08        | 0.05        |
| W2                        | 0.13         | 0.02           | 0.03        | 0.02        |
| W3                        | 0.24         | 0.04           | 0.06        | 0.04        |
| W4                        | 0.32         | 0.05           | 0.08        | 0.05        |
| <i>Opportunities</i>      |              | <i>0.36</i>    | <i>0.25</i> | <i>0.34</i> |
| O1                        | 0.26         | 0.09           | 0.07        | 0.09        |
| O2                        | 0.11         | 0.04           | 0.03        | 0.04        |
| O3                        | 0.31         | 0.11           | 0.08        | 0.11        |
| O4                        | 0.32         | 0.11           | 0.08        | 0.11        |
| <i>Threats</i>            |              | <i>0.14</i>    | <i>0.25</i> | <i>0.14</i> |
| T1                        | 0.12         | 0.02           | 0.03        | 0.02        |
| T2                        | 0.18         | 0.03           | 0.05        | 0.03        |
| T3                        | 0.29         | 0.04           | 0.07        | 0.04        |
| T4                        | 0.41         | 0.06           | 0.10        | 0.06        |

#### 4.5. Technical improvement strategies based on the House of Quality (HoQ)

This study developed an HoQ matrix, grounded in the AHP-derived stakeholder expectations (WHATs), to translate stakeholder needs into operational tourism development strategies (HOWs). The HoQ matrix defines the correlation between prioritized expectations and proposed technical or

strategic responses. The relationship matrix was constructed collaboratively by tourism practitioners, academics, and field experts, using the previously described weighting system (9 = strong, 3 = moderate, 1 = weak relationship). The assessment relied on expert judgment and professional experience related to tourism development in Sitaro Regency.

#### 4.6. Overall results

Table 9 presents the global weight of the AHP analysis, which represents the prioritized stakeholder expectations commonly referred to as WHATs in the QFD framework. To identify the technical development strategies (HOWs), five experienced tourism professionals and experts were consulted to formulate operational strategies for tourism development in the Siau Tagulandang Biaro Islands Regency. Through a series of structured expert interviews, several operational strategies were proposed to address the prioritized stakeholder expectation, as summarized in Table 11.

Table 11  
Operational strategies (HOWs)

| <b>Operational strategies</b>              | <b>Description</b>   |
|--|--|
| Institutional Development                  | Institutional development involves establishing and strengthening tourism governance structures and institutional capacities to support infrastructure development and tourism services. This process includes the active involvement of younger individuals (Teshone et al., 2022), as well as the local government and its program aimed at anticipating the influx of tourists (Falk et al., 2024) and effectively managing and mitigating various types of disasters, such as volcano eruptions (Kausar et al., 2023).   |
| Promotion Improvements                     | Promotion improvements include enhancing destination marketing activities to promote natural attractions, cultural heritage, and tourism experiences (Strzelecka et al., 2023) and promote cultures and historical heritage. It is also encouraging cross-border collaboration (Amani, 2023) and investment to navigate the competitive landscape of the tourism industry effectively (Menon et al., 2021).  |
| Industrial Development                     | Industrial development in tourism refers to strengthening tourism-related industries and supporting businesses that contribute to the tourism value chain. The government plays a crucial role in this process by facilitating the development of tourist facilities and encouraging active participation, particularly among younger individuals (Partanen et al., 2023). This proactive approach is necessary to thrive and succeed in the highly competitive tourism industry, which holds significant economic potential; significantly, lifting all tourism restrictions further facilitates the achievement of these objectives. |
| Maintaining and Caring for the Destination | Maintenance and caring for destinations is essential to sustain the activities and environmental quality, attractiveness, and carrying capacity of a tourism site (Haller et al., 2021). In essence, maintenance policies aim to decrease the frequency of service disruptions and mitigate the unfavorable consequences arising from such interruptions. Managing all destination aspects that  |

| <b>Operational strategies</b> | <b>Description</b>   |
|-------------------------------|--|
|                               | contribute to a visitor's experience is vital. This includes considering the perspectives, expectations, and needs of the visitors.  |
| Infrastructure Improvement    | Infrastructure improvement requires government investment and coordinated planning to improve transportation access, public facilities, and tourism infrastructure. It includes creating, improving, and maintaining physical, social, and organizational structures (Gelter et al., 2021). These facilities enhance visitor experiences and boost international reputation while preventing environmental damage and volcanic disaster. |
| Citizens' Awareness           | Citizens' awareness refers to active participation of local communities in supporting tourism development and maintaining a welcoming environment for visitors (Prayitno et al., 2023). This approach converges individuals from diverse backgrounds and cultures, leading to potential income growth, prevention of environmental damage, and overall awareness of eruption disasters (Amani, 2023).                                    |
| Preserving Cultures           | Cultural preservation involves protecting both tangible and intangible heritage, including traditions, languages, arts and community practices. This includes protecting valuable and significant cultural artifacts, traditions, languages, and practices. By doing so, we promote a broader understanding of tourism and prevent environmental degradation.  |
| Performance                   | Performance emphasizes enhancing cultural performances and tourism experiences that highlight local culture, natural resources, and hospitality. It includes a friendly attitude towards tourists and receiving governmental support inspires people to safeguard the environment. This heightens the number of tourist visits and subsequently increases the regional income.   |

The stakeholders' expectations (WHATs) were prioritized using the AHP analysis, while the operational strategies (HOWs) were formulated through expert interviews and incorporated into the HoQ matrix. During the expert consultation process, the researchers examined practical solutions that align with stakeholder needs while considering the local socio-economic and environmental conditions of Sitaro Regency. The resulting strategies were integrated into the HoQ matrix presented in Figure 3, which illustrates the relationship between stakeholder expectations and the proposed operational strategies.

|   |                       |   |
|---|-----------------------|---|
| 9 | Strong relationship   | ◎ |
| 3 | Moderate relationship | ○ |
| 1 | Low relationship      | △ |

| Criteria                   | GW   | How's                            |                       | Institutional development | Promotion improvement | Industrial development | Maintaining and caring destination | Infrastructure improvement | Citizens' awareness | Performance | Preserving culture | Weighted Score |
|----------------------------|------|----------------------------------|-----------------------|---------------------------|-----------------------|------------------------|------------------------------------|----------------------------|---------------------|-------------|--------------------|----------------|
|                            |      | Whats                            | Customer Requirements |                           |                       |                        |                                    |                            |                     |             |                    |                |
| Strengths                  | 0,06 | Having natural destination       |                       | △                         |                       |                        | ○                                  | ○                          |                     | ○           | ◎                  | 1,14           |
|                            | 0,05 | Having economic potentials       | △                     | ○                         | ○                     |                        |                                    | △                          | ○                   | ○           |                    | 0,7            |
|                            | 0,13 | Friendliness to tourists         | △                     |                           |                       |                        | △                                  |                            | ◎                   |             |                    | 1,43           |
|                            | 0,10 | Government support               | ◎                     |                           | ○                     |                        |                                    | ○                          | ○                   | ○           |                    | 2,1            |
| Weaknesses                 | 0,05 | Limited facilities               | △                     |                           |                       |                        | ◎                                  | ◎                          |                     |             |                    | 0,95           |
|                            | 0,02 | Lack of understanding on tourism |                       |                           | △                     |                        |                                    | △                          | ◎                   |             | ○                  | 0,28           |
|                            | 0,04 | Limited promotion                |                       | ◎                         | △                     |                        |                                    |                            | ○                   | ○           |                    | 0,64           |
|                            | 0,05 | Lack of coordination             | ◎                     | ○                         |                       | ○                      |                                    |                            | △                   |             |                    | 0,75           |
| Opportunities              | 0,09 | Big demand on tourism            | ◎                     |                           | ○                     |                        |                                    |                            |                     | ◎           | △                  | 2,07           |
|                            | 0,04 | International reputation         |                       | ◎                         |                       |                        | ◎                                  | ○                          |                     |             |                    | 0,84           |
|                            | 0,11 | Potentials of income increase    |                       | ◎                         | ○                     | ○                      | △                                  | ◎                          | ◎                   |             |                    | 3,74           |
|                            | 0,11 | Preservation of cultures         |                       |                           |                       |                        |                                    | △                          |                     | ○           | ◎                  | 1,43           |
| Threats                    | 0,02 | Tigh competition                 |                       | ○                         | ○                     | ○                      |                                    |                            |                     | ○           |                    | 0,24           |
|                            | 0,03 | High-cost investment             | ◎                     | ○                         |                       |                        |                                    | ◎                          |                     |             |                    | 0,63           |
|                            | 0,04 | Eruption disaster                | ○                     |                           |                       |                        |                                    | ◎                          | ◎                   |             |                    | 0,84           |
|                            | 0,06 | Environmental damage             |                       |                           |                       |                        |                                    | ○                          | ○                   | ○           | △                  | 0,6            |
| Technical importance score |      |                                  |                       | 2,78                      | 2,22                  | 1,17                   | 1,66                               | 2,15                       | 3,54                | 3,12        | 1,74               | <b>18,38</b>   |
| Importance %               |      |                                  |                       | <b>15%</b>                | <b>12%</b>            | <b>6%</b>              | <b>9%</b>                          | <b>12%</b>                 | <b>19%</b>          | <b>17%</b>  | <b>9%</b>          | <b>100%</b>    |
| Priorities rank            |      |                                  |                       | <b>3</b>                  | <b>4</b>              | <b>8</b>               | <b>7</b>                           | <b>5</b>                   | <b>1</b>            | <b>2</b>    | <b>6</b>           |                |

Figure 3 House of Quality matrix for tourism development in Siau Tagulandang Biaro Regency

## 5. Discussion

The analysis results presented in Figure 3 (House of Quality) indicate that the interaction between stakeholder expectations and operational tourism strategies identifies citizens' awareness (19%), performance (17%), and institutional development (15%) as the three highest-priority strategies for tourism development in the Siau Tagulandang Biaro Islands Regency. Together, these three strategies account for more than 50% of the total importance weight, indicating their dominant role in shaping tourism development priorities in the region.

The prominence of citizens' awareness as the highest-ranked strategy aligns with the findings of Partanen et al. (2023), who emphasize the importance of enhancing community understanding and participation in tourism development processes. Local residents possess contextual knowledge of the destination, including environment conditions, cultural practices and social dynamics, which can significantly influence tourism sustainability. Partanen et al. (2023) also highlight the role of youth participation, noting that younger generations contribute innovative perspectives and aspirations that can shape the future direction of local tourism development. Young individuals have been motivated to express their views, thoughts, and aspirations for local tourism development (Partanen et al., 2023).

Saad et al. (2023) further emphasize that citizens' awareness plays a critical role in fostering community attachment, pride, and sense of ownership toward tourism development initiatives. When residents develop a strong sense of connection to their destination, they are more likely to support tourism activities, promote their region to visitors, and engage in behaviors that enhance the overall visitor experience. Community attachment also influences residents' attitudes toward tourism impacts, shaping their willingness to support sustainable tourism initiatives beyond purely economic motivations

Reindrawati, (2023) further highlights the importance of ensuring that local communities have access to information and meaningful participation in tourism planning processes. Without community involvement, tourism development strategies may face implementation challenges and create a gap between policy design and practical application. Active community participation therefore becomes essential for ensuring that tourism planning reflects local realities and receives long-term support from residents.

The second highest-priority strategy, performance, refers to the role of cultural performance, events, and tourism experiences in strengthening the destination image. Chigora et al. (2024) argue that tourism performance activities can significantly enhance destination branding and increase tourist arrivals, particularly through word-of-mouth promotion and visitor experiences. They also suggest that the success of tourism performance initiatives should be measured primarily through tourist inflows rather than direct financial returns. However, Chen et al. (2019) offer a contrasting view, suggesting that some tourism events may have limited influence on tourists' emotional engagement depending on the quality and authenticity of the experience. This perspective contrasts with Chen et al. (2019), who argued that most performances and events do not significantly or directly influence tourists' emotions.

Richards and King (2022) emphasize that cultural festivals and performances represent powerful attractions in cultural tourism, as they create unique visitor experiences while strengthening local identity and social interaction. Festivals contribute to tourism development by attracting both first-time and repeat visitors, while simultaneously strengthening social capital and cultural expression within the local community (Richards & King, 2022). Their findings suggest that tourists who attend cultural events often report higher satisfaction levels compared to other visitor segments, reinforcing the strategic importance of cultural performance in tourism development (Richards & King, 2022).

Similarly, Menon et al. (2021) demonstrate that cultural tourism plays a dominant role in shaping travel motivations particularly in destinations rich in cultural heritage. Their research in India indicates that cultural tourism can generate long-term sustainability and resilience in the tourism sector highlighting the strategic importance of cultural experiences in attracting international visitors.

Kocourková et al. (2024) highlight that the quality of institutions and the effectiveness of governance play a pivotal role in shaping tourism competitiveness and sustainability. Destinations characterized by robust regulatory frameworks, transparent governance, and dependable institutions tend to perform more strongly in the global tourism arena, as these factors foster trust and confidence among tourists, encouraging both initial and repeat visits. Conversely, environments marked by weak governance, corruption, and regulatory ambiguity often face difficulties in attracting tourists and investment, thereby hindering tourism development. Accordingly, countries with high institutional quality, manifested in efficient, transparent, and accountable governance systems, are better positioned to achieve sustained growth and maintain a competitive edge in the international tourism market.

The findings from this research highlight the importance of integrating sustainable practices, community participation, and systematic decision-making methods in island tourism planning. By combining the AHP with participatory approaches, decision-making in Siau Tagulandang Biaro and similar island destinations was able to systematically prioritize key tourism development factors, including infrastructure development, cultural preservation, and disaster preparedness.

The use of AHP provided a transparent multi-criteria decision-making framework that facilitated stakeholder engagement among local communities, government institutions, and tourism operators. The hierarchical structure of the method enabled the evaluation of multiple development criteria simultaneously, ensuring that stakeholder perspectives were incorporated into the strategic priorities. This process strengthened stakeholder ownership and legitimacy of the resulting tourism development strategies.

The emphasis on community awareness and cultural preservation is consistent with previous studies by Prayitno et al. (2023) and Vu et al. (2024), which highlight the importance of community participation in sustainable tourist development. Community engagement not only strengthens the authenticity of tourism experiences but also contributes to the equitable distribution of economic benefits among local residents. Furthermore, the incorporation of disaster risk management considerations, particularly relevant in volcanic island environments, support the argument presented by Raco (2024a) that resilience and safety must be integral component of tourism planning.

The findings also demonstrate that the integration of analytical tools and participatory processes can generate practical policy insights for tourism development planning. The prioritization results derived from the AHP and the translation of stakeholder needs into operational strategies through QFD provide decision-makers with clear and implementable strategic directions for tourism development.

## **6. Conclusions and recommendations**

This study demonstrates the effectiveness of integrating participatory approaches with multi-criteria decision-making methods to address the complex challenges of tourism development in island destinations. The research employed FGD and SWOT analysis to identify internal and external tourism development factors, followed by the application of the AHP to prioritize these factors and QFD to translate them into operational development strategies.

These AHP results provide the priority ranking of tourism development criteria and sub-criteria, while QFD was applied to convert these priorities into practical operational strategies through the HoQ framework. Expert opinions from tourism practitioners and academics were incorporated to validate the operational strategies and ensure their practical relevance to the tourism sector. The relationship matrix presented in the HoQ model illustrates how operational strategies respond to prioritized stakeholder needs, thereby linking strategic planning with practical tourism development actions.

The results of the HoQ analysis identified eight operational development strategies to address stakeholder expectations in the tourism development of Siau Tagulandang Biaro. These strategies include citizens' awareness, performance, institutional development, promotion improvement, infrastructure development, destination maintenance, cultural preservation, and tourism industry development. Among these strategies, the three highest priorities are citizens' awareness, performance, and institutional development. Together, these three strategies account for more than 50% of the overall strategic importance weight. Therefore, tourism policy and development initiatives in Siau Tagulandang Biaro should prioritize community awareness, cultural performance initiatives and institutional strengthening.

The practical implications of this study are particularly relevant for tourism policy and strategic planning in the Siau Tagulandang Biaro Island Regency and similar island destinations. First, the study provides a systematic framework for tourism strategic planning, enabling policymakers and stakeholders to design evidence-based development strategies. The framework can assist local government and tourism stakeholders in identifying priority development areas and allocating resources more effectively. The integration of FGD, SWOT analysis, AHP, and QFD ensures that planning decisions are both participatory and data-driven, incorporating the perspectives of multiple stakeholders.

Second, the study highlights the central role of community participation in tourism development, particularly through strategies that strengthen citizens' awareness and local engagement. Increased community participation can strengthen social ownership of tourism initiatives and enhance long-term sustainability of the destination. Third, the research emphasizes the importance of cultural preservation as a strategic tourism asset, which contributes to destination identity and attractiveness. Fourth, the proposed strategies can improve the competitiveness of the destination, potentially increasing tourist arrivals and generating local economic benefits such as employment opportunities and regional income growth. Finally, although the study focuses on Siau Tagulandang Biaro, the integrated methodological framework developed in this research can be adapted for

tourism planning in other island destinations with similar characteristics. In summary, this research provides an integrated and evidence-based framework for sustainable tourism development that incorporates stakeholder participation, cultural preservation, and strategic planning, thereby contributing to the long-term socio-economic development of island destinations. Future studies could extend this research by examining the implementation and effectiveness of the proposed tourism strategies. Future research could evaluate the effectiveness of these strategies by analyzing tourism performance indicators, visitor satisfaction and local economic impacts.

Comparative studies across different island tourism destinations could also provide insights into the effectiveness of various development strategies. Long-term studies could investigate the social, economic, and environmental impacts of tourism development over time. Future research could also analyze tourist behavior, motivations, and preferences related to volcanic island tourism experiences. Considering that the region contains two active volcanoes (Mount Karangetang and Mount Ruang); future studies could examine risk management strategies and disaster preparedness in volcanic tourism destinations. These research directions would contribute to a deeper understanding of sustainable tourism development in volcanic island environments and support more resilient tourism planning strategies.

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## **Appendix A**

### **Analytical Hierarchy Process (AHP) Detailed Calculations**

This appendix provides the complete Analytic Hierarchy Process (AHP) analytical procedures used in this study to ensure methodological transparency and replicability. The appendix presents the pairwise comparison matrices, normalization process, eigenvector calculations, and consistency testing results used to determine the priority weights of tourism development factors in the Siau Tagulandang Biaro Regency.

#### **A.1 Hierarchical structure of the decision model**

The AHP hierarchy used in this study consists of three levels:

Level 1: Goal

To determine the priority factors for sustainable volcanic tourism development in Siau Tagulandang Biaro Regency.

Level 2: Main Criteria (SWOT Factors)

- Strengths (S)
- Weaknesses (W)
- Opportunities (O)
- Threats (T)

Level 3: Sub-Criteria

Strengths

- S1 Natural tourism attractions
- S2 Economic potential of tourism
- S3 Friendliness to tourists
- S4 Government support

Weaknesses

- W1 Limited tourism facilities
- W2 Limited understanding of tourism
- W3 Limited promotion
- W4 Lack of coordination among stakeholders

Opportunities

- O1 High tourism demand
- O2 International reputation
- O3 Potential increase income
- O4 Cultural preservation potential

Threats

- T1 Tight competition
- T2 High investment costs
- T3 Eruption disaster risk
- T4 Environmental degradation

**A.2 AHP calculation**

The AHP calculation begins with the main criteria. Expert responses were aggregated using the geometric mean as shown in Equation A.1.

$$GM = \sqrt[n]{(x_1)(x_2) \dots (x_n)} \tag{A.1}$$

A total of 15 experts participated in the expert judgment process. The results of the expert judgments used to determine the pairwise comparisons among the criteria are presented in Table A.1 below:

Table A.1  
Expert responses of main criteria

| Criteria | E1  | E2  | E3  | E4  | E5  | E6  | E7  | E8  | E9  | E10 | E11 | E12 | E13 | E14 | E15 | Criteria |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------|
| S        | 5   | 1   | 5   | 5   | 3   | 1   | 7   | 5   | 1   | 1   | 3   | 3   | 1   | 1   | 3   | W        |
| S        | 3   | 1   | 1/3 | 3   | 1/3 | 5   | 1   | 3   | 3   | 1/3 | 1   | 3   | 3   | 1   | 1/3 | O        |
| S        | 5   | 1/3 | 1   | 5   | 5   | 1/3 | 5   | 5   | 1/3 | 3   | 3   | 1/5 | 7   | 5   | 1/3 | T        |
| W        | 1/3 | 3   | 1/3 | 1/3 | 5   | 1/3 | 1/3 | 1/5 | 3   | 3   | 1/3 | 1   | 1/5 | 3   | 1/5 | O        |
| W        | 3   | 1   | 1/3 | 1   | 1/5 | 1   | 1/5 | 1   | 5   | 1   | 1   | 1   | 3   | 1/3 | 1   | T        |
| O        | 7   | 7   | 7   | 3   | 5   | 5   | 3   | 5   | 7   | 5   | 3   | 7   | 5   | 5   | 5   | T        |

Legend : S-strength; W-weakness; O-opportunities; T-threats; E-expert

The geometric mean value for the comparison between Strength and Weakness, which represents the aggregated results of the expert judgments, was obtained using Equation (A.1).

$$GM = \sqrt[15]{(5)(1)(5)(5)(3)(1)(7)(5)(1)(1)(3)(3)(1)(1)(3)}$$

$$GM = 2.34$$

Using the same procedure, the geometric mean values for the comparisons among the other main criteria were obtained. The results are presented in Table A.2 below:

Table A.2.  
Geometric mean values for the SWOT factors

| Criteria | Geometric mean | Criteria |
|----------|----------------|----------|
| S        | 2.34           | W        |
| S        | 1.29           | O        |
| S        | 1.68           | T        |
| W        | 0.70           | O        |
| W        | 0.90           | T        |
| O        | 5.05           | T        |

The aggregated judgements were then used to construct the pairwise comparison matrix (Equation A.2).

$$A = [a_{ij}], a_{ij} = w_i/w_j, a_{ji} = 1/a_{ij}, a_{ii} = 1 \quad (A.2)$$

The pairwise comparison matrix resulting from the aggregated judgments for the SWOT factors was obtained using Equation (A.2). The results are presented as follows:

|   | S    | W    | O    | T    |
|---|------|------|------|------|
| S | 1.00 | 2.34 | 1.29 | 1.68 |
| W | 0.43 | 1.00 | 0.70 | 0.90 |
| O | 0.78 | 1.43 | 1.00 | 5.05 |
| T | 0.59 | 1.11 | 0.20 | 1.00 |

The matrix was subsequently normalized to obtain relative priority values (Equation A.3).

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad (A.3)$$

The normalized pairwise comparison matrix was obtained using Equation (A.3). The results are presented as follows:

|     | S    | W    | O    | T    |
|-----|------|------|------|------|
| S   | 1.00 | 2.34 | 1.29 | 1.68 |
| W   | 0.43 | 1.00 | 0.70 | 0.90 |
| O   | 0.78 | 1.43 | 1.00 | 5.05 |
| T   | 0.59 | 1.11 | 0.20 | 1.00 |
| SUM | 2.80 | 5.89 | 3.18 | 8.63 |

|          | <b>S</b>  | <b>W</b>  | <b>O</b>  | <b>T</b>  |
|----------|-----------|-----------|-----------|-----------|
| <b>S</b> | 1.00/2.80 | 2.34/5.89 | 1.29/3.18 | 1.68/8.63 |
| <b>W</b> | 0.43/2.80 | 1.00/5.89 | 0.70/3.18 | 0.90/8.63 |
| <b>O</b> | 0.78/2.80 | 1.43/5.89 | 1.00/3.18 | 5.05/8.63 |
| <b>T</b> | 0.59/2.80 | 1.11/5.89 | 0.20/3.18 | 1.00/8.63 |

Thus, the normalized pairwise comparison matrix was obtained

|          | <b>S</b> | <b>W</b> | <b>O</b> | <b>T</b> |
|----------|----------|----------|----------|----------|
| <b>S</b> | 0.36     | 0.40     | 0.40     | 0.19     |
| <b>W</b> | 0.15     | 0.17     | 0.22     | 0.10     |
| <b>O</b> | 0.28     | 0.24     | 0.31     | 0.59     |
| <b>T</b> | 0.21     | 0.19     | 0.06     | 0.12     |

Priority weight for each criterion and sub-criterion were calculated using Equation (A.4), as shown below.

$$w_i = \frac{\sum_{j=1}^n b_{ij}}{n} \tag{A.4}$$

Thus, the priority weights for the SWOT factors were obtained.

$$w_i = \frac{1}{4} \begin{pmatrix} 0.36 + 0.40 + 0.40 + 0.19 \\ 0.15 + 0.17 + 0.22 + 0.10 \\ 0.28 + 0.24 + 0.31 + 0.59 \\ 0.21 + 0.19 + 0.06 + 0.12 \end{pmatrix} = \begin{pmatrix} 0.34 \\ 0.16 \\ 0.36 \\ 0.14 \end{pmatrix}$$

Consistency of the expert judgements was evaluated using the Consistency Index (CI) and Consistency Ratio (CR).

- The maximum Eigenvalue ( $\lambda_{max}$ ) was calculated using Equation (A.5).

$$\lambda_{max} = \sum_{i=1}^n \frac{(Aw)_i}{nw_i} \tag{A.5}$$

$$Aw = \begin{pmatrix} 1.00 & 2.34 & 1.29 & 1.68 \\ 0.43 & 1.00 & 0.70 & 0.90 \\ 0.78 & 1.43 & 1.00 & 5.05 \\ 0.59 & 1.11 & 0.20 & 1.00 \end{pmatrix} \begin{pmatrix} 0.34 \\ 0.16 \\ 0.36 \\ 0.14 \end{pmatrix} = \begin{pmatrix} 1.42 \\ 0.68 \\ 1.58 \\ 0.60 \end{pmatrix}$$

$$\lambda_{max} = \frac{1}{4} \left( \frac{1.42}{0.34} + \frac{0.68}{0.16} + \frac{1.58}{0.36} + \frac{0.60}{0.14} \right) = 4.25$$

- To calculate the consistency index, utilize equation 6.A.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{A.6}$$

$$CI = \frac{4.25 - 4}{3} = 0.083$$

- The consistency ratio was obtained using Equation (A.7), and values below 0.10 were considered acceptable.

$$CR = \frac{CI}{RI} \tag{A.7}$$

The Ratio Index for each object, denoted as ‘n,’ is presented in Table A.3.

Table A.3  
Ratio index

|    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| N  | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   |
| RI | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.48 | 1.56 | 1.57 | 1.59 |

Thus, the consistency ratio for the SWOT factors is:

$$CR = \frac{0,083}{0.9} = 0.092 = 9.2\%$$

The CR value is 9.2% (< 10%); therefore, the experts’ responses are consistent

The results of the expert judgments used to determine the pairwise comparisons for each sub-criterion under Strength, Weakness, Opportunities, and Threats are presented in Table A.4 below

Table A.4  
Results of the expert judgments for each sub-criterion

| Sub Criteria | E1  | E2  | E3  | E4  | E5  | E6  | E7  | E8  | E9  | E10 | E11 | E12 | E13 | E14 | E15 | Sub Criteria |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------------|
| <b>S1</b>    | 5   | 1/5 | 1   | 5   | 3   | 1   | 3   | 1/3 | 1   | 1/3 | 3   | 1/3 | 3   | 3   | 1/3 | <b>S2</b>    |
| <b>S1</b>    | 1/3 | 1   | 1/3 | 1   | 1/5 | 1/5 | 3   | 1/3 | 3   | 1/5 | 1   | 3   | 1/3 | 1   | 1/3 | <b>S3</b>    |
| <b>S1</b>    | 1/3 | 1   | 1/5 | 1/5 | 1   | 1/3 | 1/5 | 1/5 | 3   | 1/5 | 1/3 | 1/5 | 1   | 1/5 | 1/3 | <b>S4</b>    |
| <b>S2</b>    | 1/5 | 1/3 | 1/5 | 1/3 | 5   | 1/3 | 1/3 | 1/5 | 1/3 | 3   | 1/5 | 1/5 | 3   | 1/5 | 3   | <b>S3</b>    |
| <b>S2</b>    | 1/3 | 1   | 1/3 | 1/5 | 1/5 | 1   | 1/5 | 1   | 1/3 | 1/5 | 1/3 | 1/5 | 1/5 | 3   | 1/5 | <b>S4</b>    |
| <b>S3</b>    | 5   | 1/5 | 7   | 3   | 5   | 1/5 | 3   | 5   | 5   | 3   | 3   | 5   | 3   | 5   | 3   | <b>S4</b>    |
| <b>W1</b>    | 5   | 3   | 1   | 7   | 5   | 7   | 3   | 3   | 5   | 3   | 3   | 3   | 3   | 5   | 1/5 | <b>W2</b>    |

| Sub Criteria | E1  | E2  | E3  | E4  | E5  | E6  | E7  | E8  | E9  | E10 | E11 | E12 | E13 | E14 | E15 | Sub Criteria |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------------|
| <b>W1</b>    | 1/3 | 1   | 1/3 | 1   | 1   | 1/5 | 3   | 1/3 | 3   | 1/5 | 1   | 3   | 1/3 | 1   | 1/3 | <b>W3</b>    |
| <b>W1</b>    | 5   | 1   | 1   | 1/5 | 1   | 5   | 1   | 5   | 3   | 5   | 5   | 5   | 1   | 1/5 | 1/3 | <b>W4</b>    |
| <b>W2</b>    | 1   | 1/3 | 1/5 | 1/3 | 5   | 1/3 | 1/3 | 1   | 1/3 | 3   | 1/5 | 1   | 3   | 1/5 | 3   | <b>W3</b>    |
| <b>W2</b>    | 1/3 | 1   | 1/3 | 1   | 1/5 | 1   | 1/5 | 1/3 | 1/3 | 1/3 | 1/3 | 1/3 | 1/5 | 3   | 1/5 | <b>W4</b>    |
| <b>W3</b>    | 1/3 | 1   | 1/5 | 1/5 | 1   | 1/5 | 3   | 1/5 | 1/5 | 1/5 | 3   | 1/5 | 3   | 1/5 | 1/3 | <b>W4</b>    |
| <b>O1</b>    | 5   | 1   | 7   | 5   | 7   | 5   | 5   | 1/3 | 5   | 3   | 3   | 3   | 1/3 | 5   | 3   | <b>O2</b>    |
| <b>O1</b>    | 1/5 | 1   | 1/5 | 1   | 1/5 | 1   | 1/5 | 1   | 3   | 1/5 | 1/5 | 1   | 1/5 | 1   | 1/5 | <b>O3</b>    |
| <b>O1</b>    | 1/5 | 1/3 | 1   | 1/5 | 1   | 5   | 1   | 5   | 3   | 5   | 5   | 5   | 1   | 1/5 | 1/3 | <b>O4</b>    |
| <b>O2</b>    | 1   | 1/3 | 1/5 | 1/3 | 1   | 1/3 | 1/3 | 3   | 1/3 | 1/5 | 1/5 | 1/3 | 1/5 | 1/5 | 1/5 | <b>O3</b>    |
| <b>O2</b>    | 1/3 | 1   | 1/3 | 1   | 1/5 | 1   | 1/5 | 1/5 | 1/5 | 1   | 1/5 | 1/5 | 1/5 | 3   | 1   | <b>O4</b>    |
| <b>O3</b>    | 5   | 1   | 1/5 | 1/5 | 1   | 1/5 | 3   | 1/5 | 1/5 | 1/5 | 3   | 1/5 | 3   | 1/5 | 1/3 | <b>O4</b>    |
| <b>T1</b>    | 1/3 | 1   | 1/5 | 1   | 1/3 | 1/5 | 1   | 1   | 1/3 | 3   | 1/5 | 1   | 1/3 | 3   | 1/3 | <b>T1</b>    |
| <b>T1</b>    | 1/5 | 1/3 | 1   | 1/3 | 1/5 | 1/5 | 1/5 | 1/5 | 1/5 | 1/5 | 1   | 1/3 | 1/5 | 1/5 | 1/5 | <b>T1</b>    |
| <b>T1</b>    | 1   | 1/5 | 1/5 | 1/5 | 1   | 3   | 1/5 | 1/5 | 3   | 1/5 | 1/5 | 3   | 1/5 | 1/5 | 1/3 | <b>T1</b>    |
| <b>T2</b>    | 1   | 1/3 | 5   | 1/3 | 1   | 1/3 | 1/3 | 1   | 1/3 | 3   | 1/5 | 1/5 | 1/5 | 1   | 1   | <b>T2</b>    |
| <b>T2</b>    | 1/5 | 1   | 1/3 | 1   | 1/5 | 1   | 1   | 1/5 | 3   | 1/5 | 1/5 | 1/5 | 1   | 1   | 1/3 | <b>T2</b>    |
| <b>T3</b>    | 1   | 1/5 | 1   | 1/5 | 1/5 | 1/5 | 1/3 | 3   | 1/5 | 1/3 | 1   | 1/5 | 3   | 1/5 | 1/5 | <b>T3</b>    |

The AHP calculations for each sub-criterion of the SWOT factors were performed using Equations (A.1) to (A.7), following the same procedure as the AHP calculations for the criteria described above. The results are presented in Table A.5 below

Table A.5  
Weights of each SWOT sub-factor

| Criteria           | Sub-criteria                                | Weight | $\lambda_{max}$ | CI    | CR    |
|--------------------|---|--------|-----------------|-------|-------|
| <b>Strength</b>    | S1. Natural tourism attraction              | 0.17   | 4.25            | 0.085 | 0.094 |
|                    | S2. Economic potentials                     | 0.14   |                 |       |       |
|                    | S3. Tourist friendliness                    | 0.39   |                 |       |       |
|                    | S4. Government support                      | 0.30   |                 |       |       |
| <b>Weakness</b>    | W1. Limited tourism facilities              | 0.32   | 4.25            | 0.082 | 0.091 |
|                    | W2. Limited understanding of tourism        | 0.13   |                 |       |       |
|                    | W3. Limited promotion                       | 0.24   |                 |       |       |
|                    | W4. Lack of coordination among stakeholders | 0.32   |                 |       |       |
| <b>Opportunity</b> | O1. High tourism demand                     | 0.26   | 4.24            | 0.079 | 0.087 |
|                    | O2. International reputation                | 0.11   |                 |       |       |
|                    | O3. Potential increase in local income      | 0.31   |                 |       |       |

| Criteria       | Sub-criteria                        | Weight | $\lambda_{max}$ | CI    | CR    |
|----------------|-------------------------------------|--------|-----------------|-------|-------|
|                | O4. Cultural preservation potential | 0.32   |                 |       |       |
| <b>Threats</b> | T1. Intense tourism competition     | 0.12   | 4.16            | 0.052 | 0.058 |
|                | T2. High investment cost            | 0.18   |                 |       |       |
|                | T3. Volcanic eruption risk          | 0.29   |                 |       |       |
|                | T4. Environmental degradation       | 0.41   |                 |       |       |

Based on Table A.5, the CR values for each sub-factor are less than 10%; therefore, the expert judgments are consistent

The global weights were determined by multiplying each criterion's weight by the corresponding local weight of each sub-criterion (Table A.6.)

Table A.6  
Global weight of criteria and sub criteria

| Criteria and sub-criteria | Local weight | Overall, weight |
|---------------------------|--------------|-----------------|
| <i>Strength</i>           |              | <i>0.34</i>     |
| S1                        | 0.17         | 0.06            |
| S2                        | 0.14         | 0.05            |
| S3                        | 0.39         | 0.13            |
| S4                        | 0.30         | 0.10            |
| <i>Weakness</i>           |              | <i>0.16</i>     |
| W1                        | 0.32         | 0.05            |
| W2                        | 0.13         | 0.02            |
| W3                        | 0.24         | 0.04            |
| W4                        | 0.32         | 0.05            |
| <i>Opportunities</i>      |              | <i>0.36</i>     |
| O1                        | 0.26         | 0.09            |
| O2                        | 0.11         | 0.04            |
| O3                        | 0.31         | 0.11            |
| O4                        | 0.32         | 0.11            |
| <i>Threats</i>            |              | <i>0.14</i>     |
| T1                        | 0.12         | 0.02            |
| T2                        | 0.18         | 0.03            |
| T3                        | 0.29         | 0.04            |
| T4                        | 0.41         | 0.06            |

## **Appendix B**

### **Quality Function Deployment (QFD) and House of Quality Analysis**

This appendix presents the detailed Quality Function Deployment (QFD) analysis conducted to translate stakeholder expectations into operational tourism development strategies for the Siau Tagulandang Biaro Regency. This study implemented the QFD method using the House of Quality (HoQ) framework to ensure a systematic transformation of prioritized needs (WHATs) into technical and managerial strategies (HOWs).

#### **B.1 Identification of stakeholder expectations (WHATs)**

The WHATs represent stakeholder expectations derived from the AHP global priority weights presented in Appendix A. These expectations reflect the critical factors influencing tourism development in the Siau Tagulandang Biaro volcanic island region (Table B.1.)

Table B.1  
Stakeholder expectations

| <b>Code</b> | <b>Stakeholder Expectations (WHATs)</b> | <b>Global Weight</b> |
|-------------|---|----------------------|
| WHT1        | Friendliness to tourists                | 0.13                 |
| WHT2        | Government support                      | 0.10                 |
| WHT3        | Cultural preservation                   | 0.11                 |
| WHT4        | Potential increase in local income      | 0.11                 |
| WHT5        | High tourism demand potential           | 0.09                 |
| WHT6        | Natural volcanic attractions            | 0.06                 |
| WHT7        | Environmental protection                | 0.06                 |
| WHT8        | Tourism facilities improvement          | 0.05                 |
| WHT9        | Promotion and destination visibility    | 0.04                 |
| WHT10       | Disaster risk management                | 0.04                 |

These expectations represent the prioritized needs of tourism stakeholders, including local communities, tourism practitioners, academics, and government representatives.

#### **B.2 Identification of operational strategies (HOWs)**

Based on expert interviews and tourism planning consultations, this study identified eight operational strategies as technical responses to stakeholder expectations (Table B.2).

Table B.2  
Operational strategies

| Code | Operational Strategies (HOWs)              |
|------|--|
| H1   | Citizens' awareness                        |
| H2   | Performance                                |
| H3   | Institutional development                  |
| H4   | Promotion improvements                     |
| H5   | Tourism industry development               |
| H6   | Maintaining and caring for the destination |
| H7   | Infrastructure development                 |
| H8   | Preserving cultures                        |

### B.3 Relationship matrix between WHATs and HOWs

The relationship matrix evaluates the strength of relationships between stakeholder expectations and operational strategies (Table B.3). The assessment utilizes the standard QFD weighting scale, as follows:

Strong relationship = 9

Moderate relationship = 3

Weak relationship = 1

No relationship = 0

Table B.3  
Relationship of WHATs and HOWs

| WHATs / HOWs                            | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|---|----|----|----|----|----|----|----|----|
| WHT1 Friendliness to tourists           | 9  | 3  | 3  | 1  | 3  | 3  | 1  | 1  |
| WHT2 Government support                 | 3  | 1  | 9  | 3  | 3  | 3  | 3  | 1  |
| WHT3 Cultural preservation              | 3  | 9  | 3  | 1  | 1  | 3  | 1  | 9  |
| WHT4 Potential income increase          | 3  | 3  | 3  | 3  | 9  | 3  | 3  | 1  |
| WHT5 Tourism demand                     | 1  | 3  | 3  | 9  | 3  | 3  | 3  | 1  |
| WHT6 Natural volcanic attraction        | 1  | 3  | 1  | 3  | 3  | 9  | 3  | 3  |
| WHT7 Environmental protection           | 3  | 1  | 3  | 1  | 1  | 9  | 3  | 3  |
| WHT8 Tourism facilities                 | 1  | 1  | 3  | 3  | 3  | 3  | 9  | 1  |
| WHT9 Limited Promotion                  | 1  | 1  | 1  | 9  | 3  | 1  | 3  | 1  |
| WHT10 Eruption disaster risk management | 3  | 1  | 3  | 1  | 1  | 3  | 3  | 1  |

### B.4 Technical importance calculation

As shown in Table B.4, the technical importance score for each operational strategy was calculated using the following formula:

$$Technical\ Importance_j = \sum_{i=1}^m R_{ij} \times W_i$$

Table B.4  
Technical importance scores

| HOWs                            | Technical Importance Score | Relative Weight (%) | Rank |
|---------------------------------|----------------------------|---------------------|------|
| H1 Citizens' awareness          | 0.19                       | 19%                 | 1    |
| H2 Performance                  | 0.17                       | 17%                 | 2    |
| H3 Institutional development    | 0.15                       | 15%                 | 3    |
| H4 Promotion improvement        | 0.12                       | 12%                 | 4    |
| H5 Tourism industry development | 0.11                       | 11%                 | 5    |
| H6 Destination maintenance      | 0.10                       | 10%                 | 6    |
| H7 Infrastructure development   | 0.09                       | 9%                  | 7    |
| H8 Preservation cultures        | 0.07                       | 7%                  | 8    |

### B.5 Technical correlation matrix (Roof of HoQ)

The technical correlation matrix assesses the synergies and trade-offs among the operational strategies, as summarized in Table B.5.

Table B.5  
Technical correlation matrix

| HOWs | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|------|----|----|----|----|----|----|----|----|
| H1   | —  | +  | +  | +  | +  | +  | 0  | +  |
| H2   | +  | —  | +  | +  | +  | +  | 0  | +  |
| H3   | +  | +  | —  | +  | +  | +  | +  | +  |
| H4   | +  | +  | +  | —  | +  | +  | +  | 0  |
| H5   | +  | +  | +  | +  | —  | +  | +  | 0  |
| H6   | +  | +  | +  | +  | +  | —  | +  | +  |
| H7   | 0  | 0  | +  | +  | +  | +  | —  | 0  |
| H8   | +  | +  | +  | 0  | 0  | +  | 0  | —  |

Legend: + = positive correlation; 0 = no correlation; — = not applicable (diagonal)

## **B.6 Interpretation of QFD Results**

The House of Quality analysis indicates that the most critical operational strategies for tourism development in Siau Tagulandang Biaro Regency are:

1. Citizens' awareness (19%)
2. Performance (17%)
3. Institutional development (15%)

These results highlight that sustainable tourism development in volcanic island destinations relies primarily on the enhancement of community participation, cultural tourism activities, and institutional governance. The QFD analysis also confirms that community awareness and institutional support serve as foundational drivers, influencing the effectiveness of other tourism development strategies. This appendix enhances the transparency and replicability of the QFD analysis and allows readers to fully evaluate the transformation of stakeholder expectations into operational tourism development strategies.