



Tourism Connectivity among Small Islands in the Formulation of a Sustainable Island Tourism Hub Concept in North Gorontalo

Dewi Sartika T. Zees^{1*}, Muh. Fakhri Jamaluddin¹, Moh Fadlun Lamusu¹, Abdul Talib Modaa¹

¹Program Studi Perencanaan Wilayah, Universitas Bina Taruna Gorontalo, Gorontalo, Indonesia.

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Corresponding Author:

Dewi Sartika T. Zees

dewi.zees90@gmail.com

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Abstract: North Gorontalo Regency, characterized by its cluster of small islands, possesses significant potential for the development of marine and cultural tourism. However, limited accessibility, particularly in maritime transport, remains a major constraint. This study employs a qualitative descriptive approach, integrating spatial, environmental, tourism, and supply and demand analyses. Data were obtained through literature reviews, field surveys, and focus group discussions (FGDs) involving stakeholders. The analysis identifies Dudepo Island as having strategic advantages to serve as a sustainable tourism hub, supported by its geographical position, land carrying capacity, existing infrastructure, and potential for sustainable development. The application of the hub-and-spoke model is considered effective in enhancing inter-island connectivity, improving travel efficiency, and supporting the diversification of tourism products. The implementation of the Sustainable Island Tourism Hub concept is expected to strengthen local economic opportunities, promote environmental sustainability, and enhance community welfare.

Keywords: Archipelagic destination; Island connectivity; Sustainable tourism; Tourism hub; Tourism planning

Introduction

North Gorontalo Regency, the youngest district in Gorontalo Province located at the northern tip of Sulawesi Island, offers remarkable marine tourism potential through its cluster of small islands in northern Gorontalo. These islands feature stunning natural beauty, with white sandy beaches, crystal-clear waters, and vibrant coral reefs (Hwang & Kim, 2020; Chen et al., 2022). Each island presents unique natural attractions and characteristics (Ren et al., 2024; Bhaduri & Pandey, 2019). In addition, several inhabited islands provide rich cultural experiences through friendly fishing villages and well-preserved local traditions.

Small islands function as interconnected entities that interact ecologically, economically, socially, and culturally. Individually and collectively, they can create

synergistic effects that enhance the economic scale of resource management. From a tourism perspective, the connectivity among small islands significantly impacts regional growth, while sustainable planning and implementation create meaningful economic and social opportunities for local communities and contribute to broader regional economic development (Kasim et al., 2021; Giampiccoli et al., 2021).

Inter-island connectivity forms the foundation for determining which island can serve as the tourism hub within an archipelagic destination. This process begins with establishing transport connectivity, which plays a vital role in developing the infrastructure necessary to support destination accessibility (Patamani & Harold, 2023; Hampton & Jeyacheya, 2020). Adequate transport infrastructure is a prerequisite for destinations to accommodate, manage, and facilitate tourist activities

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across various attractions (Hamzah et al., 2022; Brumbaugh & Patil, 2017). Connectivity among islands through maritime transportation directly supports other factors that can stimulate new productivity within archipelagic destinations. A well-connected sea transport network with effective travel routes enhances accessibility, integrates tourism destinations, and promotes the development of the regional tourism sector (Hampton et al., 2018; Katili, 1978).

North Gorontalo Regency, located in northern Sulawesi, comprises a cluster of small islands with significant potential for both marine and cultural tourism (Connell, 2018). These islands possess rich natural resources, traditional fishing communities, and unique local traditions that could serve as valuable tourism assets. However, despite their high potential, the region faces persistent challenges in accessibility, particularly in terms of maritime transportation and supporting infrastructure (Connell, 2018; Giampiccoli et al., 2020). This limitation has become a major obstacle to the development of integrated tourism activities and regional economic growth (Hampton & Jeyacheya, 2015).

Beyond maritime transport connectivity, tourism development encompasses diverse concepts that must align with the unique characteristics of each destination. In island tourism contexts, every island has distinct natural and socio-cultural attributes that require context-specific planning for sustainable management and utilization (Lau & McKercher, 2006; Chi & Liu, 2023). Ensuring smooth mobility and efficient tourism operations among small islands requires identifying one island that can act as a central tourism hub—a nucleus that links surrounding islands and supports balanced regional development.

The concept of a tourism hub is relatively new and remains less explored than conventional transport hubs. According to Bai et al. (2023) and Sayuti (2023), a tourism hub refers to a destination visited multiple times within a multi-destination travel plan, serving as a central point that connects various attractions. This perspective allows destinations to be analyzed within broader spatial travel patterns, forming a framework that integrates tourism infrastructure, accessibility, and visitor mobility (Walker & Lee, 2022). In line with this concept, the hub-and-spoke model, Prideaux (2000) and Le-Klähn et al. (2015) offers a relevant theoretical foundation for understanding how transportation networks and tourism systems can be spatially organized to optimize efficiency and visitor flow (Loi et al., 2017).

In North Gorontalo, the absence of a structured inter-island tourism network limits the region's capacity to attract and retain tourists. Developing a sustainable island tourism hub is therefore essential to overcome

these challenges. It is expected to create a focal point for tourism activities, encourage equitable development across small islands, and strengthen the local economy through community-based tourism initiatives.

Accordingly, this study addresses the key research problem: How can the concept of a Sustainable Island Tourism Hub be implemented through inter-island tourism connectivity in North Gorontalo? By exploring this question, the study aims to formulate a strategic framework that supports sustainable tourism planning and integrated regional development, while maintaining the ecological and cultural integrity of the island environments.

Method

The method employed in this study is a qualitative descriptive data analysis method, utilizing several analytical approaches considered suitable to meet the research objectives, as outlined below:

Spatial Study

The spatial study approach emphasizes the analysis of space as a container or medium for accommodating human activities (Dewi, 2021). Spatial planning must be able to reflect the aspirations of all community members and development actors. Therefore, all stakeholders should feel assured that, in due course, the spatial plan will serve as an effective instrument for creating and enhancing public welfare, safety, comfort, and overall community well-being.



Figure 1. Research area boundary

Environmental Approach Study

The environmental approach analyzes the interrelationship between specific geospheric phenomena and existing environmental variables. The main focus of the ecological approach lies in understanding the interactions between humans and the natural environment (Praptiwi et al., 2021; Tezar &

Setiadi, 2023; Styawan, 2024). The term “ecological” refers to the study of interactions between living organisms and their environments (Dewi, 2021; Yu & Yang, 2024). In spatial planning, the ecological approach concerns the regulation of relationships or interactions between human life and the physical environment. One of the key theories in ecological analysis is the theory of environmental interdependence.

This approach also explores existing environmental conditions and potential ecological challenges, including coral reef degradation due to unmanaged tourism activities, pollution from the growth of the tourism industry especially organic waste (Dewi, 2021; Mokodongan et al., 2025) habitat destruction caused by tourism infrastructure development, land-use changes threatening biodiversity, additional pressure on water resources, and the impacts of climate change such as rising sea temperatures.

Tourism Approach Study

According to Law No. 10 of 2009 on Tourism, tourism is defined as a variety of travel activities supported by various facilities and services provided by the community, entrepreneurs, and both central and local governments (Robinson et al., 2020; Paulino et al., 2019). The framework adopted in this study follows the 6A theory (Attraction, Accessibility, Amenities, Available packages, Activities, and Ancillary services), which is then linked to the application of sustainable tourism principles (Rosalina et al., 2021; Bai & Fan, 2023). This connection is crucial, as the sustainability of a destination depends on maintaining a spatial balance among the various aspects of tourism implementation (Jasman et al., 2023; Gading et al., 2024).

Supply-Demand Approach Study

In this approach, it is essential first to identify the characteristics of tourism demand in addition to the availability of supply, both internally within the study area and in its relation to the wider region. The characteristics of supply and demand are identified based on several related conditions. By comparing these characteristics, any gaps or discrepancies between supply and demand can be identified. These “gaps” essentially represent problems that must be addressed through a well-formulated development plan (Sun et al., 2023; Lu et al., 2022).

The main focus of this research is to provide a comprehensive understanding of the sustainable development concept for island destinations, in which one of the key factors of sustainability is the interconnectivity of small islands through tourist movement. Research on inter-island tourism connectivity in formulating the Sustainable Island Tourism Hub concept requires a comprehensive

approach that includes carrying capacity analysis, spatial mapping analysis, and destination development analysis (Ginting et al., 2006; Ginting, 2013; Bartuska et al., 2023).

Carrying capacity analysis is crucial for understanding the maximum capacity of small islands to withstand the impacts of tourism activities, including infrastructure strain, environmental degradation, and socio-economic sustainability. This analysis enables researchers to identify existing limitations and determine potential areas for sustainable development.

Result and Discussion

Spatial mapping analysis plays a crucial role in designing an effective transportation system and tourism route network. Mapping the study area allows researchers to visualize the spatial relationships among small islands, transportation infrastructure, and existing tourist attractions. This process enables the formulation of optimal travel routes that take into account accessibility, natural beauty, and the efficient distribution of tourism destinations.

Meanwhile, destination development analysis is essential for planning sustainable and competitive tourism growth. This includes identifying each destination’s unique potentials, determining development priorities, and managing land use and natural resources wisely. By integrating carrying capacity analysis, spatial mapping analysis, and destination development analysis, this study establishes a strong foundation for formulating a sustainable and successful Sustainable Island Tourism Hub concept that promotes inter-island tourism development.

To obtain data and validate the research outcomes, the study employs a Focus Group Discussion (FGD) process to expand insights and test the ideas and strategic concepts developed in relation to the study’s objectives. The research also involves one university student to assist with field surveys and data collection, providing direct research experience and practical exposure. The collected data will then be processed and analyzed to produce comprehensive and conclusive research findings.

Geology

The coastal area of North Gorontalo Regency, which directly faces the Sulawesi Sea, is composed of various rock formations of different ages and characteristics. This lithological diversity is the result of a series of geological processes such as tectonism, volcanism, and sedimentation that have occurred from the Miocene to the Quaternary period. These processes are closely related to the dynamic interactions among three major tectonic plates surrounding Sulawesi: the

Indo-Australian Plate, the Eurasian Plate, and the Pacific Plate. The collision and movement of these plates have triggered the formation of volcanic arcs, intense magmatic activity, and shallow marine sedimentation along the coastal region (Amir et al., 2023; Giampiccoli et al., 2020; Ibrahim et al., 2018).

Therefore, the coastal geology of North Gorontalo Regency reflects highly active tectonic dynamics. This not only shapes the region’s geomorphological diversity but also influences the availability of natural resources and the potential geological hazards present in the area (Rahmawati et al., 2019; Saleh et al., 2018).

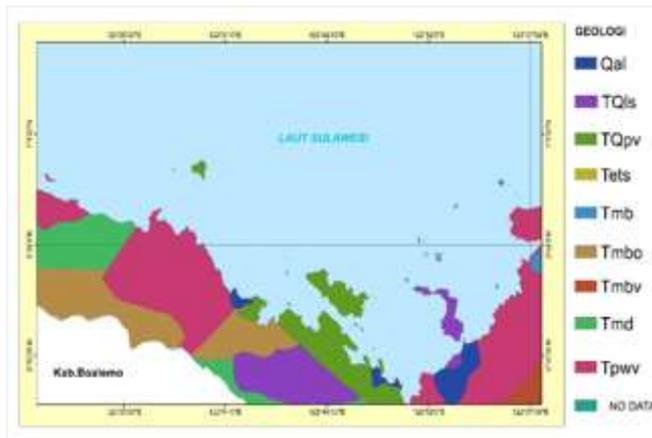


Figure 2. Geological map of North Gorontalo region (Source: Spatial Planning Document of North Gorontalo Regency)

Hydrology

In general, the hydrological system of North Gorontalo Regency is shaped by its natural landscape, which is dominated by mountainous areas extending toward the coastal plains, resulting in numerous rivers that flow directly into the Sulawesi Sea. Based on the hydrological map, a relatively dense river network can be observed throughout the mainland area, both in the lowlands and the hilly regions. Most rivers in this region are perennial, meaning they flow year-round, although their discharge tends to decrease during the dry season. The river distribution in North Gorontalo Regency generally follows a northward flow pattern toward the Sulawesi Sea (Hariyanti et al., 2024).

The longer rivers typically originate from the southern and central highlands, flowing through settlements and agricultural lands before reaching the coast. This condition makes rivers an essential element in supporting the community’s clean water needs, agricultural irrigation, and inland fisheries potential. In addition, several rivers also function as natural boundaries between sub-districts. The map indicates that the river network follows the natural contours of the landscape, forming a relatively dense drainage system (Hariyanti et al., 2024; Hamzah et al., 2022).

Given these characteristics, the hydrology of North Gorontalo Regency plays a vital role not only in sustaining coastal and marine ecosystems but also in supporting the social and economic activities of surrounding communities.



Figure 3. Hydrological map of North Gorontalo Region (Source: North Gorontalo Regency Spatial Planning Document)

Land Use

North Gorontalo Regency exhibits a diverse range of land uses influenced by its topography, soil types, and the socio-economic activities of local communities. Based on the land use map, several categories of land cover can be identified, extending from the coastal zones to the mountainous interior. The composition of land use reflects a strong interconnection between the region’s natural resource potential and the utilization patterns adopted by local residents.



Figure 4. Land use map of North Gorontalo Region

Most of the mainland area in North Gorontalo Regency remains covered by primary and secondary dryland forests, particularly in the southern and central parts of the region. These forests play an essential role as water catchment areas, ecological buffers, and habitats for biodiversity (Hamzah et al., 2022). In addition,

mangrove forests, both primary and secondary, are found along the coastal zones and river estuaries, with significant concentrations in the bay areas and surrounding small islands. The mangrove ecosystems serve as natural protection against coastal abrasion and provide crucial support for the fisheries activities of coastal communities.

Inter-Island Connectivity Existing Connectivity

Inter-island connectivity in North Gorontalo Regency currently remains heavily dependent on traditional wooden boats known locally as katinting. These boats, which have been modified by local communities to provide greater comfort and protection from changing weather conditions, serve as the primary means of transportation between islands. This dependency is particularly evident in Ponelo Island and Dudepo Island, the two inhabited islands in North Gorontalo.

According to Wolok (2025), the so-called *Taksi Perahu* (Boat Taxi) has become a vital mode of transport supporting the daily activities of residents, from commuting to work and school, conducting trade, to ferrying tourists to nearby small islands (Hamzah et al., 2022). Operated using one or two small engines, these boats remain relatively slow for tourism purposes, though they function as the main accessibility mode connecting the islands.

The level of regional connectivity in archipelagic areas is highly influenced by the quality of the maritime transport system, which includes speed, frequency, and operational reliability. Conventional *Taksi Perahu* boats, with an average speed of 15–20 km/h, lag significantly behind modern alternatives such as speedboats, which, based on manufacturer specifications, can reach speeds of 30–60 knots (equivalent to 55–110 km/h) (Ananda et al., 2024). This limited speed directly affects travel time efficiency, a critical factor in the tourism industry.

A comparison with more advanced marine transportation technologies reveals a significant gap in operational efficiency. The Wing-in-Ground (WIG) vehicle, as a futuristic maritime transport innovation, according to the Ministry of Investment’s Project Map of Investment Opportunities for WIG Development as Tourism Accessibility in Batam, is capable of reaching cruising speeds of 180–420 km/h, drastically reducing inter-island travel time. Even more realistically, conventional speed boats have demonstrated superior efficiency in terms of travel time and operational flexibility compared to traditional wooden boats. This condition highlights the urgent need for a comprehensive evaluation of the existing marine transport system to better support tourism development in the island regions of North Gorontalo Regency.

Furthermore, the reliance on *taksi perahu* (boat taxis) for inter-island mobility in North Gorontalo, which tends to lack flexibility, has become a structural issue within the maritime accessibility system. This challenge is particularly evident due to weather constraints, sea waves, and difficult navigation points across certain water areas. According to the Meteorology, Climatology, and Geophysics Agency (BMKG) weather conditions have a significant influence on the continuity and safety of sea crossings, where rain, storms, strong winds, and high waves may occur suddenly during travel. This situation is worsened by the fact that weather changes occur rapidly and unpredictably, leading to frequent cancellations or delays in departure schedules.

The operational impact of unstable weather conditions on maritime transportation has been well-documented in various studies. Salim (2023) identified that shifting weather patterns directly affect the safety and efficiency of marine transport, as storms and large waves can delay or disrupt ship operations, posing safety risks to both crew and passengers. In the context of North Gorontalo, this issue is compounded by the geographical characteristics of its islands, which are highly vulnerable to marine environmental fluctuations, often forcing *taksi perahu* operations to halt or reroute when sea conditions are unfavorable (Salim, 2023; Bai & Fan, 2023).

The instability of maritime transport operations for inter-island connectivity in North Gorontalo affects not only technical and economic aspects but also generates psychological discomfort and safety concerns among passengers (Sayuti, 2023; Rozikin et al., 2024). Hall (2002) found that traumatic experiences during travel can cause psychological disturbances, including anxiety, trauma, and dissociative reactions among transport users. In the context of island maritime transport, uncertain departure schedules, poor weather, and fear of safety



Figure 5. Distance correlation matrix between islands

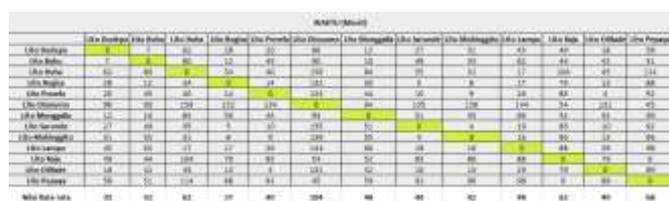


Figure 6. Travel time correlation matrix between islands

risks can impose considerable psychological burdens on tourists (Hariyanti et al., 2024).

Passenger comfort and safety in maritime transport have become central issues in many regulatory discussions. According to Praptiwi et al. (2021), common complaints among sea passengers include uncomfortable waiting areas, lack of cleanliness on vessels, schedule inaccuracy, and safety concerns during voyages. These conditions are worsened by the limited safety facilities on conventional *taksi perahu*, raising doubts about their reliability (Bai & Fan, 2023). Over time, these negative experiences can lead to decreased tourist interest in visiting small island destinations in North Gorontalo.

Research on transport-related trauma indicates that negative experiences are often retained in long-term memory, influencing future travel decisions. Ultimately, this may hinder the growth of island-based tourism potential in North Gorontalo, as accessibility remains a key factor in determining the attractiveness and competitiveness of island tourism destinations.

The development of more efficient and reliable maritime transportation alternatives has therefore become an urgent necessity to support the tourism sector. Strategies for improving marine transport connectivity among small islands require a comprehensive approach that includes upgrading facilities and infrastructure, diversifying transport modes, and enhancing passenger safety and comfort systems (Praptiwi et al., 2021). In the long term, adopting more advanced maritime technologies such as speed boats or even WIG vehicles could serve as a strategic solution to strengthen the competitiveness of North Gorontalo’s island tourism destinations.

Hub-and-Spoke Model for Island Tourism Destinations

The hub-and-spoke theory of maritime connectivity represents a fundamental concept in the development of marine transportation networks, proven effective in optimizing inter-island connectivity particularly within the context of island tourism development. Numerous academic studies have demonstrated that this model offers significant advantages in terms of economic efficiency, network reach, and infrastructure resource optimization compared to the relatively traditional point-to-point system. The implementation of this theory within Indonesia, as the world’s largest archipelagic nation, holds transformative potential to enhance the accessibility of small island tourism destinations while simultaneously fostering sustainable regional economic development.

The hub-and-spoke connectivity theory in the maritime context has strong roots in network theory and graph theory, in which transportation systems are conceptualized as graph networks consisting of nodes

that represent ports or islands and edges that depict maritime transport routes (Ginting, 2013). Within this structure, hubs serve as central nodes with high degrees of connectivity, while spokes function as satellite nodes connected primarily through the main hub. Recent studies in maritime network science indicate that the hub-and-spoke structure achieves an optimal trade-off between high transport efficiency and relatively low infrastructure costs (Aldrian & Susanto, 2003). This concept is grounded in the principle of modular gateway-ness connectivity, which enables the optimization of passenger and goods flow through the concentration of services at strategic points (Bai & Fan, 2023; Farmakis et al., 2023).

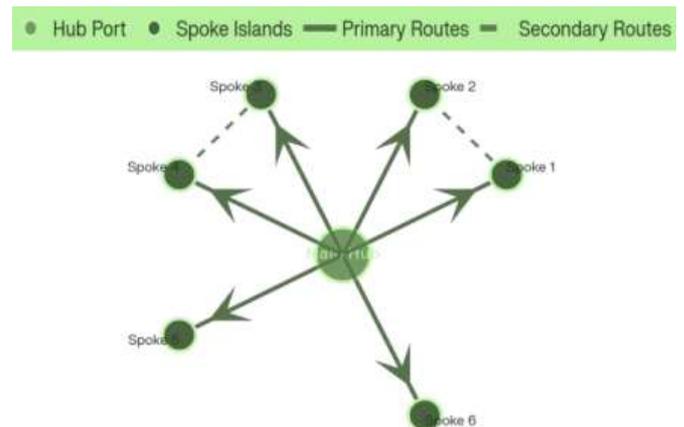


Figure 7. Hub-and-spoke connectivity model for archipelagic maritime networks

From a theoretical framework perspective, the maritime hub-and-spoke model adopts the central place theory developed by Walter Christaller, yet adapts it to the unique characteristics of archipelagic environments. The theory emphasizes spatial hierarchies in service provision, where larger service centers (hubs) cater to wider areas and offer more diversified services compared to smaller centers (spokes) (Bai & Fan, 2023; Zhao et al., 2024).

The fundamental advantage of the hub-and-spoke model lies in its ability to harness economies of scale and scope in maritime operations. Economies of scale are achieved through the concentration of traffic volumes along primary routes between hubs and spokes, enabling the use of larger-capacity vessels with lower per-unit operating costs. Empirical research suggests that the hub-and-spoke system can reduce operational costs by approximately 30-40% compared to the point-to-point system in networks with a large number of island destinations.

Meanwhile, economies of scope are realized through service diversification and optimized infrastructure utilization at hub locations (Kasim et al., 2021; Pratama et al., 2025). A well-designed hub can

integrate multiple types of transportation services, ranging from regular passenger transport and cargo to specialized tourism operations. This diversification not only enhances operational efficiency but also provides better financial stability for both operators and surrounding communities. The concept of density economies also plays a critical role in this model, as increasing service frequency on high-volume routes leads to efficiency gains that are disproportionate to the increase in cost (Kasim et al., 2021; Humang et al., 2025). This is particularly relevant in the context of island tourism, where high service frequency is a determining factor for the accessibility and attractiveness of tourism destinations.

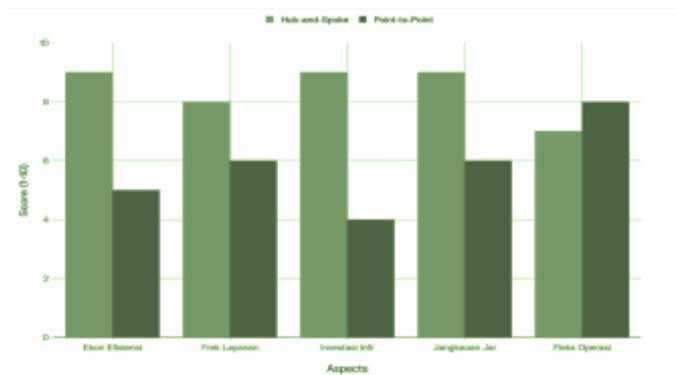


Figure 8. Comparison of the advantages of hub-and-spoke and point-to-point models in island connectivity

North Gorontalo Regency possesses geographical characteristics that are highly suitable for implementing the maritime hub-and-spoke model, given its archipelagic configuration consisting of a mainland and several small islands scattered across the Ponelo Archipelago District. Studies indicate that this region has diverse marine tourism potential that remains underutilized due to limited inter-island connectivity (Patamani & Harold, 2023).

Based on the identification of existing potentials, Saronde Island has been recognized for its sandy beach tourism attraction (DTW) with physical characteristics that support beach recreation activities. It is currently managed by a foreign investor as a private island resort (Patamani & Harold, 2023). Dyonumo Island also shows significant potential as a natural tourism destination, although it has not yet been optimally developed. Raja and Popaya Islands, located in Dunu Tourism Village, are designated as conservation islands under the supervision of the Natural Resources Conservation Agency (BKSDA), but they can still be utilized for conservation-based tourism such as education and research purposes. Meanwhile, the Ponelo area features a mangrove ecosystem covering more than 47.79 hectares along the village coastline and supports

seaweed cultivation, which serves as the primary livelihood for local communities.

The application of the hub-and-spoke theory in the context of North Gorontalo can adopt a three-tier hierarchical structure aligned with the region's geographical and infrastructural conditions. The first tier functions as the main gateway located in Gorontalo Regency and Gorontalo City, which has air accessibility through Djalaluddin Airport and serves as the primary entry point for domestic and international tourists via the Gorontalo Seaport.

The second tier represents the primary hubs located in Anggrek and Kwandang, which serve as centers of governance and mobility within North Gorontalo Regency. These hubs possess better port infrastructure capable of accommodating medium to large vessels. Kwandang serves as the central distribution point, consolidating passengers and goods from the main gateway for further distribution to smaller islands.

The third tier functions as a secondary hub located on Dudepo Island, serving as a regional hub for the island cluster and as the central Island Tourism Hub for the small-island tourism ecosystem. Given that Dudepo is the largest island in the cluster, with relatively developed infrastructure and a smaller population compared to Ponelo, it holds strategic potential as a distribution center for the surrounding support islands in the next 10 to 15 years (Ardhanariswari & Pratiwi, 2021).

The implementation of the hub-and-spoke model within the framework of a sustainable island tourism hub around North Gorontalo, positioning Dudepo Island as the tourism hub requires an approach that integrates the principles of community-based tourism with a creative economy based on local resources. Studies reveal that the communities of Dudepo and the Ponelo Archipelago already have an established seaweed-based economy with active local participation in coastal resource management. The Blue Economy Hub concept can also be applied, allowing each small island to develop specialization based on its sustainable development potential (Bai & Fan, 2023).

The hub in Dudepo would not only function as a transportation node but also as a living laboratory for sustainable marine practices, supported by two conservation islands located to its west. This aligns with the concept proposed by Sharpley et al. (2014) in the context of Small Island Developing States (SIDS), where the hub integrates education, conservation, and tourism functions into a single mutually supportive system.

*Sustainable Island Hub Development
Island Hub*

Based on the multi-criteria analysis conducted, Dudepo Island demonstrates significant advantages as

the potential tourism hub of the North Gorontalo archipelago compared to Ponelo Island. These advantages are derived from four main factors considered essential in determining a sustainable island hub:

The first factor is strategic connectivity. Dudepo Island possesses a geographical position that allows optimal access to the small islands on both the eastern and western sides of North Gorontalo, with relatively balanced average travel time and distance. This differs from Ponelo Island, which is only close to the islands on the eastern side, making it less optimal as a regional tourism distribution center.

Accessibility analysis shows that from Dudepo Island, the average travel time to the farthest tourist destination is approximately 45 minutes by local motorboat, while from Ponelo Island it takes about 1 hour and 15 minutes for the same distance. This connectivity efficiency aligns with the central place theory, which emphasizes the importance of a central position in the spatial hierarchy.

Dudepo Island holds a comparative advantage in terms of land availability for tourism infrastructure development. With a land area of around 2.3 km² and relatively flat topography in the central part of the island, Dudepo provides sufficient space for the construction of tourism-supporting facilities without disturbing the sensitive coastal ecosystem.

The basic infrastructure on Dudepo Island is currently under development, including an ongoing PLN electricity network project and a connecting road between the pier and the island's center. This infrastructure development follows the principles of sustainable infrastructure development, which aim to minimize environmental impacts while maximizing socio-economic benefits for the local community.

The potential freshwater resources on Dudepo Island are also superior to those of Ponelo Island, with the presence of natural springs and opportunities for water harvesting system development. Studies on carrying capacity, particularly concerning freshwater availability in small islands, indicate that access to clean water is a major limiting factor in developing island tourism (Rozikin et al., 2024).

The connectivity among tourism attractions (Destinasi Tujuan Wisata/DTW) within the North Gorontalo island hub is designed using a hub-and-spoke system approach to optimize travel efficiency for tourists. This system places Dudepo Island as the main hub connected to spokes in the form of small surrounding islands serving as tourist attractions. Transportation network analysis indicates that with Dudepo as the hub, tourists can access up to eight small island destinations within a 30-kilometer radius, with a maximum travel time of 45 minutes. Island-hopping

tour packages can be designed with various route combinations, allowing tourists to visit two to three islands in a single day trip.

This connectivity must be supported by a well-planned maritime transport fleet, consisting of speedboats with a capacity of 12–15 passengers for regular routes and traditional boats for cultural tourism. Integration with the AGIT port as a cargo port provides additional value in supporting tourism logistics. However, further studies are required to assess the potential impacts of port activities and the role of basic infrastructure on environmental quality from the mainland to the islands. Therefore, infrastructure development on Dudepo Island should adhere to sustainable island development principles that consider resource limitations and ecosystem sensitivity. Planning should include renewable energy systems, clean water and waste management, and telecommunication facilities to support tourism activities.

The energy system is designed as a hybrid model, combining the PT. PLN electricity grid with small-scale solar panel and wind turbine systems to ensure energy reliability. This approach aligns with the smart island concept, which integrates environmentally friendly technologies into small island development (Agustine et al., 2017). For the hub in particular, telecommunication and internet facilities are prioritized to support digital tourism and destination promotion. The planned installation of a fiber optic submarine cable to Dudepo Island will enhance digital connectivity, which is crucial for online booking services, virtual tours, and digital marketing of island tourism destinations. This strategy aims to diversify the tourist experience, allowing visitors to enjoy both the attractions and natural beauty of the smaller islands that may not yet have internet access.

Sustainable Tourism Strategy

Every tourism destination development requires a well-formulated strategy to ensure that its ecosystem operates sustainably. Sustainable tourism emphasizes a balance among environmental, socio-cultural, and economic aspects so that the benefits generated are not only enjoyed by the current generation but can also be passed on to future generations. According to the World Tourism Organization (UNWTO), sustainable tourism is a form of management that fully considers the economic, social, and environmental impacts of tourism activities, both present and future, while addressing the needs of tourists, the industry, the environment, and host communities. Therefore, the development strategy for Dudepo Island as a hub and its surrounding islands should not merely aim to increase visitor numbers but must also ensure environmental preservation, local community empowerment, and the continuity of cultural values in the area.

Environmental Sustainability

Sustainable tourism development in Dudepo as the island hub of North Gorontalo must prioritize environmental aspects, given the vulnerability of island ecosystems to anthropogenic pressures, or human-induced stresses resulting from intensive activity in limited spaces. Marine and terrestrial ecosystem conservation serves as the foundation of all development stages. Marine ecosystem conservation includes the establishment of Marine Protected Areas (MPA) around island tourist destinations, applying a zoning system to regulate tourism intensity. The zoning system consists of: (1) a core zone with strict protection for marine biota reproduction, (2) a limited-use zone for diving and snorkeling, and (3) a buffer zone for maritime transportation activities (Humang et al., 2025). The implementation of MPAs must involve local communities as primary stewards who hold traditional knowledge of local marine ecosystems.

Environmental carrying capacity management can be conducted through an adaptive management approach, which allows policy adjustments based on periodic ecosystem monitoring (Fachrusyiah, 2018). Monitoring parameters include seawater quality, coral cover, fish population, air quality, and noise levels. Furthermore, an early warning system should be developed not only for disaster prevention but also to provide alerts when environmental indicators approach critical thresholds. Waste management should adopt a circular economy approach with the principles of reduce, reuse, and recycle—adapted to island conditions. This can be integrated with small-scale waste-to-energy facilities for converting organic waste into biogas, greywater and blackwater treatment using constructed wetland technology, and plastic waste reduction programs through tourist education and the use of eco-friendly packaging.

Socio-Cultural Sustainability

Empowering local communities is key to achieving socio-cultural sustainability in island tourism development. The community-based tourism (CBT) approach should be implemented through the establishment of kelompok sadar wisata (tourism awareness groups or Pokdarwis) on every inhabited island involved in destination development, particularly Dudepo and Ponelo Islands.

Community assistance and capacity-building programs should include hospitality skills training, local guide certification, traditional food processing, handicrafts, and homestay management. Basic English language training is also essential to improve communication with international tourists. Cultural and local wisdom preservation in each village should be integrated into the creation of authentic cultural tourism

destinations. The inventory and documentation of traditions, rituals, arts, cuisine, and traditional knowledge of Dudepo and Ponelo communities form the foundation for developing cultural tourism products. Annual cultural festivals, traditional craft workshops, and cultural immersion programs add economic value for locals while preserving cultural heritage.

As a reciprocal mechanism for community empowerment and cultural tourism development, a fair and transparent benefit-sharing system must be established to ensure that tourism’s economic benefits are distributed equitably among local residents.

Economic Sustainability

Economic sustainability in the development of the island hub should focus on generating optimal multiplier effects for the local economy while minimizing economic leakages (Kasim et al., 2021). The strategy involves diversifying tourism products, strengthening local value chains, and empowering local tourism MSMEs (micro, small, and medium enterprises).

Tourism product diversification helps reduce dependence on a single attraction type and extends tourists’ length of stay. For instance, combining marine-based tourism (diving, snorkeling, and island-hopping) with cultural and community-based tourism can attract a broader market segment. Strengthening local value chains ensures that most tourism expenditures, such as food supply, souvenirs, accommodation, and transportation, benefit local producers and service providers. Support for MSMEs can be realized through access to microcredit, business incubation programs, and digital marketing training to enhance competitiveness.

Through these integrated environmental, socio-cultural, and economic strategies, Dudepo Island’s role as a sustainable tourism hub in North Gorontalo can become a model of resilient and inclusive island tourism development that harmonizes ecological preservation, cultural vitality, and local economic growth.

Table 1. Diversification Options for Tourism Products and Supporting Attractions of the Island Hub Destination

Tourism Products/Concepts	Tourist Attractions
Marine Tourism	Diving Snorkeling Fishing Tourism
Cultural Tourism	Village Tour Traditional Ceremony Handicraft Workshop
Adventure Tourism	Island Hopping Bird/Bat Watching Mangrove Tracking
Agro-Mina-Tourism	Organic Farming

Tourism Products/Concepts	Tourist Attractions
	Coconut Processing
	Seagrass Plantation

The development of tourism attractions and potential destinations must involve multiple stakeholders to provide year-round, diverse visitor experiences in a sustainable manner. Strengthening local value chains prioritizes the use of locally produced goods and services in tourism operations, such as:

- a) Local regulations and policies (at the village or destination level) requiring accommodation and restaurant managers to use local agricultural and fishery products;
- b) Local handicrafts from the island communities of Dudepo and Ponelo as distinctive souvenirs;
- c) Tourism accessibility services and inter-island transportation managed by local residents;
- d) Partnership systems between large-scale enterprises and local MSMEs to ensure clear, mutually beneficial relationships;
- e) The development of supporting infrastructure for local economic sustainability centered on the island hub, including: (a) a tourism market, (b) a craft center, (c) a local product gallery, and (d) a tourism information center managed by local institutions. These facilities serve as a one-stop tourism marketplace and a showcase for regional flagship products.

Development Zoning

The growth center of island-based tourism adapts Perroux’s Growth Pole Theory (1950) to an archipelagic context. Dudepo Island is designated as the primary growth center driving tourism-based economic expansion across the smaller surrounding islands through linkage effects and spillover benefits.

The tourism growth center on Dudepo Island is designed as an integrated hub including a marina, a visitor center, a craft workshop, a culinary and gastronomy area, and an eco-lodge. These facilities are expected to incorporate vernacular architecture reflecting local cultural identity and utilize environmentally friendly technologies. The development of a marina as a tourism port on Dudepo Island is justified by the proximity of the mainland ports in Anggrek and Kwandang, which already operate for different (non-tourism) purposes. The Dudepo location avoids congestion by aligning with existing sea transportation circulation patterns while enhancing maritime tourism mobility.

The development of this growth center follows compact development principles to minimize ecological footprints and optimize infrastructure efficiency. The mixed-use development concept integrates commercial,

residential, and recreational functions within a walkable and bicycle-friendly zone. Benchmark examples such as Gili Trawangan (Lombok, NTB Province) demonstrate how pedestrian and bicycle-based circulation can dominate coastal tourist areas, minimizing vehicle emissions and preserving environmental quality.

Connectivity with smaller island destinations (DTWs) is supported through a network of speedboats, regular boats, and nautical tour programs. Each small island is designed to host specialized tourism products, reinforcing the diversity of attractions available to tourists from the central hub and generating cross-benefits across the regional tourism network.

Conclusion

Inter-island marine transport connectivity in North Gorontalo Regency still faces significant challenges in supporting tourism development. The current system relies heavily on conventional water taxis with limited capacity and speed, reducing travel efficiency and the quality of tourist transport services. These limitations are compounded by external factors such as weather and sea conditions, which affect operational stability and tourist confidence. The hub-and-spoke model analysis demonstrates high effectiveness when applied to the island network of North Gorontalo. By designating one island as the hub, the flow of tourists and logistics can be organized more efficiently toward the surrounding islands (spokes). This system reduces operational costs, shortens travel times, and enhances the overall connectivity of marine tourism destinations. The approach also enables better integration between transport, tourism, and local economic systems in a sustainable framework. Based on multi-criteria analysis, Dudepo Island was identified as the most suitable tourism hub in North Gorontalo. It holds strategic advantages in its central geographic position, availability of land for infrastructure, freshwater resources, and shorter travel times to surrounding destinations. Moreover, Dudepo experiences lower socio-economic pressures than Ponelo, making it more feasible for sustainable development without disturbing local ecosystems or community welfare. Thus, Dudepo can serve as both a regional tourism distribution center and a living laboratory for sustainable tourism practices. Tourism development zoning integrates conservation and utilization principles: (a) The core zone focuses on protecting marine and terrestrial ecosystems; (b) The limited-use zone supports snorkeling, diving, and eco-education activities; (c) The buffer zone accommodates transport and tourism with higher intensity levels. The sustainable tourism strategy emphasizes environmental conservation, community empowerment through community-based tourism (CBT), and product

diversification (marine tourism, cultural tourism, and agro-marine tourism). This integrated approach ensures equitable distribution of tourism benefits, ecosystem preservation, and long-term economic resilience for local communities.

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Author Contributions

All authors contributed to writing this article.

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Conflicts of Interest

No conflict interest.

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