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Original Research Article

Analysis of the Connectivity Index for Sea Transportation in Archipelagic Regions (Case Study of South Halmahera Regency)

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Abstract: Regional connectivity plays a crucial role in supporting economic growth, especially for areas that are geographically remote or separated by bodies of water. As an archipelagic country, Indonesia heavily relies on sea transportation as the main axis of its maritime logistics routes, which connect various regions and support the distribution of goods as well as the mobility of people. Therefore, planning and developing transportation networks require accurate measurements, such as the connectivity index, to understand the extent to which a region is connected to others. This study aims to analyze the regional connectivity index of the islands in South Halmahera Regency, North Maluku, using a graph method approach. This method is employed to evaluate how well the districts in the regency are interconnected through sea routes. The results show that overall, maritime connectivity between regions in South Halmahera Regency is fairly good. From the analysis, 13 districts have a connectivity index of > 1, indicating good connectivity, while 17 districts have an index of < 1, indicating limited connectivity. These findings suggest a disparity in connectivity between regions in South Halmahera, highlighting the need for efforts to improve infrastructure and sea transportation networks to enhance inter-district connections, especially in areas with low connectivity indices.

Keywords: Connectivity Index, Archipelago Region, South Halmahera.

I. INTRODUCTION

Transportation and regional development are closely interconnected. An efficient transportation system plays a crucial role in driving economic growth and societal progress. As an archipelagic country, Indonesia faces significant challenges in connecting regions spread across numerous islands. Maritime transportation plays a vital role in supporting the development of island clusters rich in natural resources, enabling the acceleration and expansion of economic development to improve the well-being of the population [1, 2].

Transportation and connectivity are crucial in driving economic growth and regional integration. Improved connectivity can increase trade volumes, enhance the competitiveness of major cities and countries, and reduce transportation costs, thereby promoting economic growth, social integration, and development [3]. Specifically, several studies on connectivity in economic development have been conducted. Wang *et al.*, (2019) [4], found that transportation networks play a significant role in stimulating demand and economic growth in China. Netirith and Ji (2022) [5], in their study of countries within The Regional Comprehensive Economic Partnership (RCEP), emphasized the importance of infrastructure connectivity in improving trade efficiency among member countries. This shows that the connectivity of networks and nodes established within a transportation system can act as a catalyst for economic development, evolving into a form of sharing economy that has the potential to advance the economic ecosystem as a result of more efficient distribution [6].

Land-based transportation systems have generally attracted significant attention in transportation and accessibility studies, whereas maritime transportation has received less focus in this field of research [7, 8], particularly in Eastern

Indonesia [9]. Sea and island transportation systems present a unique case in terms of transportation networks and accessibility. This is due to the substantial investment required for infrastructure and modes of transport, as well as the dispersed nature of the islands, making accessibility in these regions dependent on ferry services [10, 11].

The measurement of a region's connectivity can be expressed through the Connectivity Index. This index is a metric used to evaluate how well a region or country is connected to global transportation or communication networks. It helps assess the efficiency and effectiveness of transportation infrastructure, which is crucial for economic growth planning and regional development [12]. Uneven connectivity development has the potential to obstruct distribution channels [13]. Studies on connectivity indexes are essential as a foundation for developing efficient transportation systems, especially in island-based regions.

The North Maluku Province consists of 1,474 islands, with a total area of 140,255.36 km². The majority of this area is composed of sea, covering 106,977.32 km² or 76.27%, while the remaining 33,278 km² or 23.73% is land. This geographical condition highlights the vital role of maritime transportation in development planning to ensure economic equity across its islands. This study is therefore focused on analyzing the maritime transportation connectivity index as the lifeblood of economic development in North Maluku, particularly in South Halmahera, which serves as the study area.

Through this analysis, it is hoped that appropriate policy recommendations and strategies can be identified to improve maritime transportation connectivity in South Halmahera, thereby supporting sustainable regional development. This research will provide insights into the current state of maritime transportation and outline the necessary steps to maximize the economic and social potential of this island region.

II. RESEARCH METHODOLOGY

Research Site

The South Halmahera Regency, which is the study location, is administratively situated in the North Maluku Province. Its astronomical coordinates range from 126°45’ to 129°30’ East longitude and from 0°30’ North latitude to 2°00’ South latitude. These four longitude and latitude coordinates define the area of South Halmahera Regency, which covers 40,263.72 km², with a land area of 8,779.32 km² and a sea area of 31,484.40 km². This land area is divided into six main islands, which include Obi Island, Bacan Island, Makian Island, Kayoa Island, Kasiruta Island, and Mandioli Island, while the remainder is located in the southern part of the Halmahera Peninsula (Figure 1).

Characteristics of South Halmahera Sea Transportation

Maritime transportation infrastructure plays a vital role in South Halmahera Regency, as it is an archipelagic area. This regency consists of various islands scattered across the Maluku Sea, making sea routes the primary access to the government center from the surrounding regions. Babang Port in Bacan District serves as the main gateway to the capital of South Halmahera Regency, alongside Kupal Port.

a) Sea Transportation Mode

The maritime transportation facilities commonly used by the community consist of various types and sizes of vessels, including machine vessels (abbreviated as MV), motorized wooden boats, motorboats, sailboats, and canoes. All of these are utilized to transport goods and people according to different needs (inter-island trade, coastal transportation, or local sailing). The types of vessels operating in South Halmahera Regency include passenger ferries, speedboats, motorized wooden boats, and ferries, as shown in Figure 2.

b) Sea Transportation Infrastructure Network

The maritime transportation infrastructure network consists of nodes in the form of sea ports and traffic spaces represented by shipping lanes. A port is an area comprising land and/or water with specific boundaries designated for governmental activities and business operations, used as a docking location for ships, boarding and disembarking of passengers, and/or loading and unloading of goods. This includes terminals and berthing areas equipped with safety and security facilities for navigation, as well as support activities for the port, serving as a hub for intra- and inter-modal transportation transfers.

The hierarchy of sea ports is distinguished based on their roles and service functions. South Halmahera Regency, as an archipelagic area, has numerous ports, as shown in Figure 3. According to data from the South Halmahera Regency Transportation Agency, there are 2 collecting ports, 10 feeder ports, 47 public ports, and 5 ferry ports.

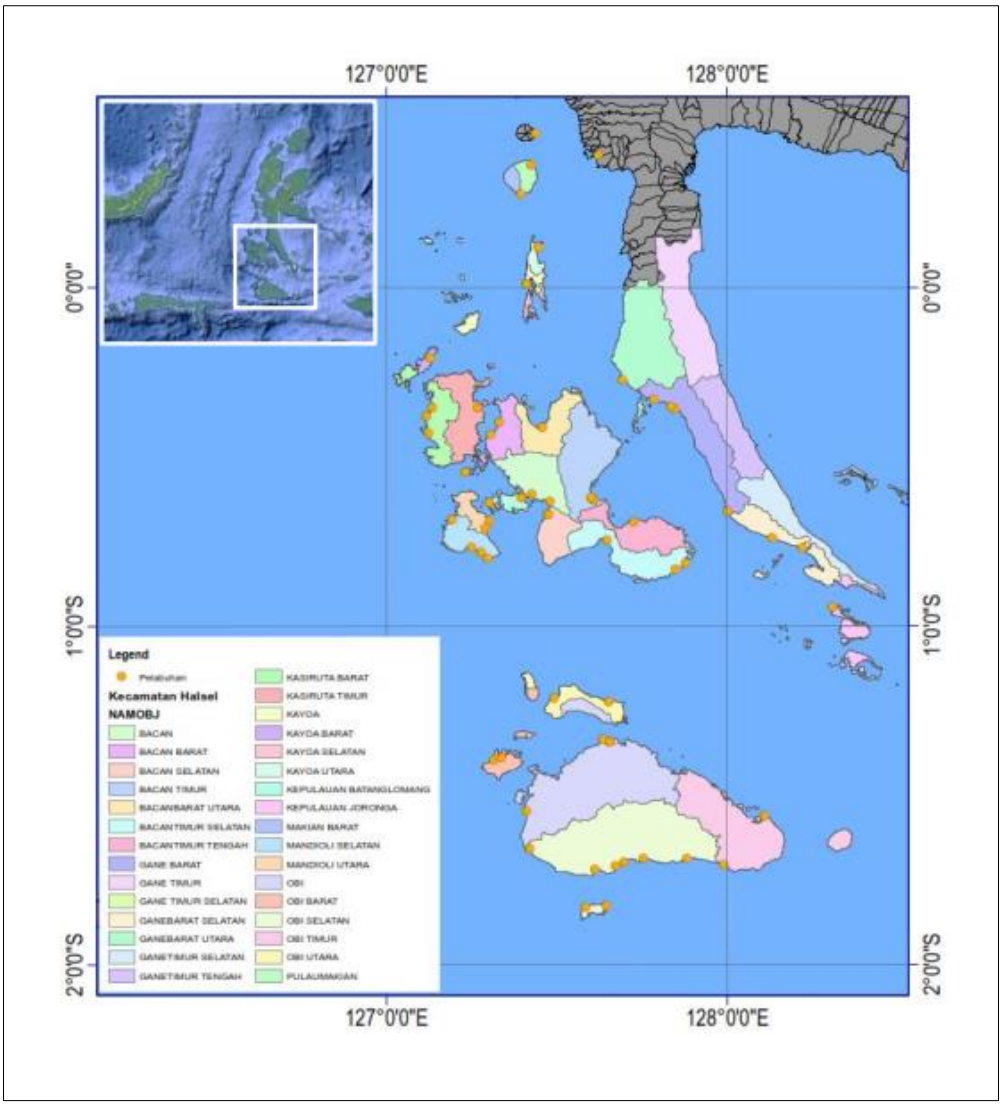


Figure 1: Research Location

Figure 2: Maritime Transportation Modes in South Halmahera

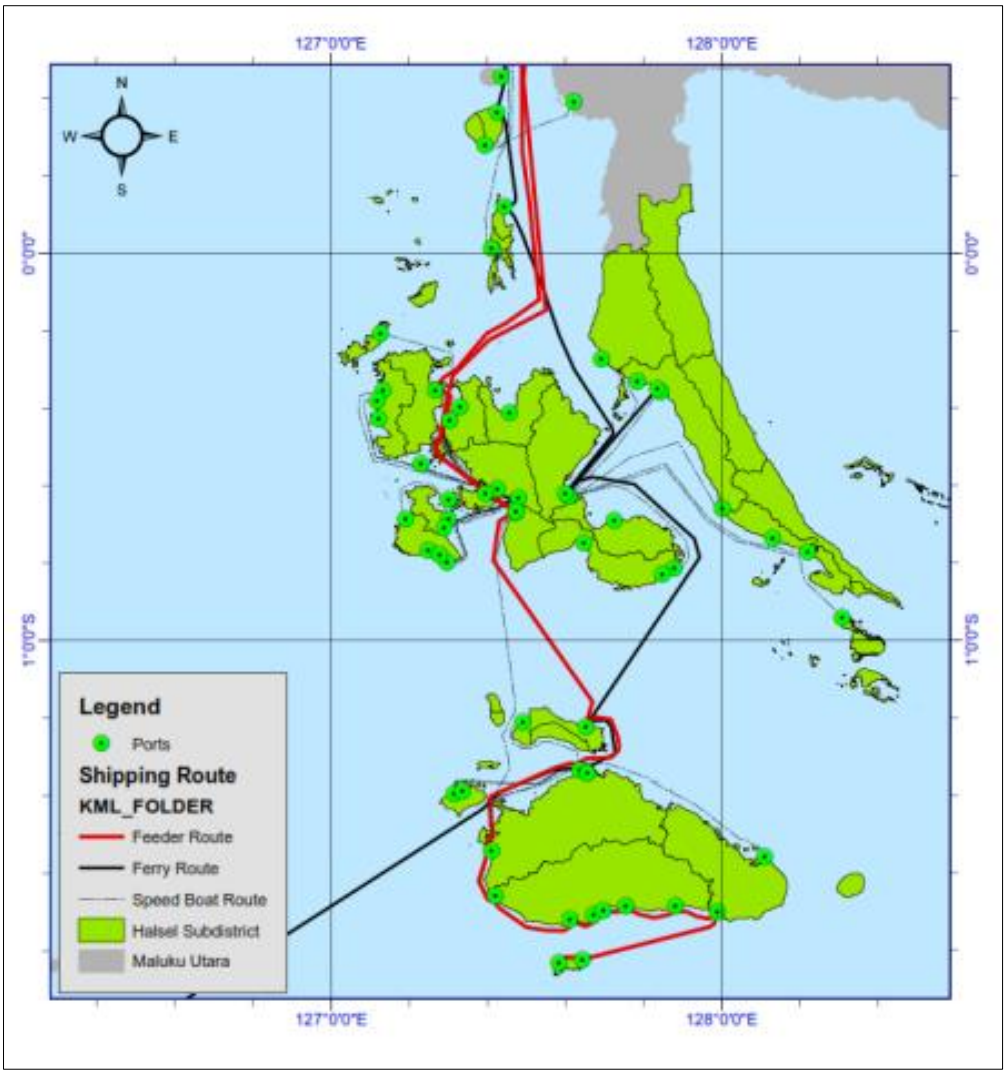


Figure 3: Shipping Routes in Maluku Utara

c) Connectivity Indices

Connectivity, according to the book The Geography of Transportation (2013) [14], is the relationship between nodes (vertices) connected by links (edges). Figure 4 shows a representation of a real network. In this study, connectivity is calculated using a graph theory approach. Theoretically, a graph is defined as a set of connecting arcs (edges), directed or undirected, between two points (vertices) within a set of points. Thus, arcs (edges) and points (vertices/nodes) are components of a graph [15]. In the maritime transportation industry, nodes can be considered as ports, and links can be considered as routes.

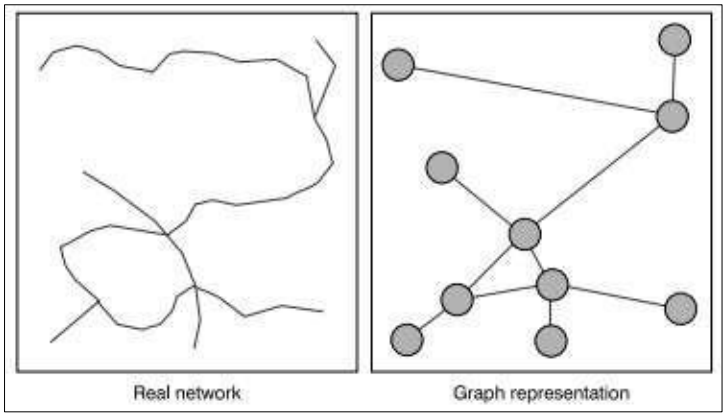
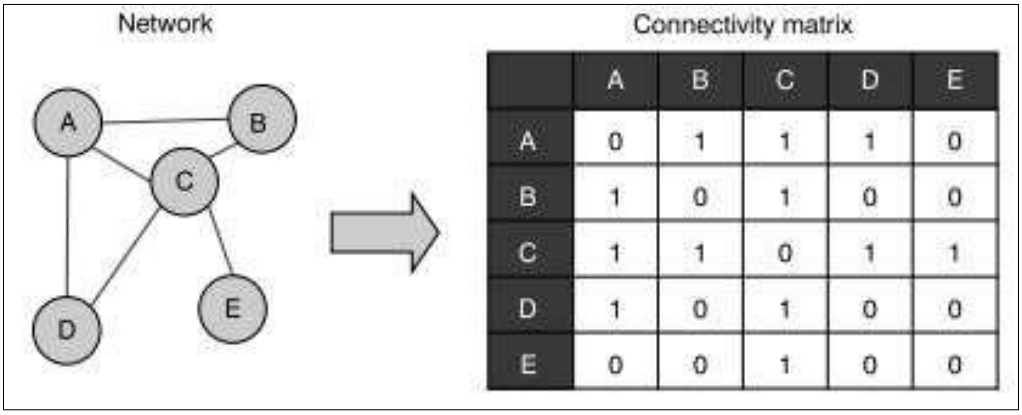


Figure 4: Grafik representasi jaringan nyata [14]

This graph illustrates the shipping network and its connectivity. In other words, the graph represents the actual state of the transportation network, which can be simplified as a collection of connected nodes. The network representation is depicted in a network model graph as a collection of nodes (vertices) and links (edges). Several assumptions and processes are necessary to convert a real network into a graph, including: Each point or port functions as a node or vertex, and each node is connected by a straight segment (link) based on routes. The connectivity index is a complex method for representing the structural properties of the graph because it involves comparing one measure to another. Therefore, the calculation of this index is based on the number of nodes and links obtained from the network model graph and the adjacency matrix, as shown in Figure 5. The Adjacency Matrix is one representation of a graph used to show connectivity between nodes in a graph [16]. This matrix is square-shaped, where its rows and columns represent the nodes in the graph.



	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	0
E	0	0	1	0	0

Figure 5: Connectivity Matrix [14]

III. RESULTS AND DISCUSSIONS

South Halmahera Regency, where the majority of the area consists of seas, relies on maritime fleets to operate and access the ports located in each district, supporting smooth economic activities and serving as a means of passenger transportation. According to data from the South Halmahera Regency Transportation Agency, there are 2 collecting ports, 10 feeder ports, 47 public ports, and 5 ferry ports. In general, all districts have ports, but not all ports have scheduled ship services. Districts with ports that do not have scheduled sailings can be accessed by chartered boats or speedboats. The sailing routes for Collecting Ports, Feeder Ports, Ferry Ports, and Public Ports are shown in Tables 1 to 4.

Based on Tables 1 to 4, it can generally be observed that East Bacan and South Bacan are the busiest districts in terms of port activity in South Halmahera. This is, of course, due to the availability of various port infrastructure, including passenger ships, ferries, wooden boats, and speedboats. Babang Port connects the East Bacan district with areas around Halmahera Island and the Jorongan Islands. Meanwhile, Kupal Port serves as a feeder port for routes to the western part of Bacan Island, Obi Island, and the islands to the north of Bacan Island.

Table 1: Truly Ports and Routes

No	Truly Port	Number of routes	Route
1	Babang	7	Babang-Ternate-Bitung-Banggai-Bau Bau-Makassar-Surabaya; Babang-Sorong-Manokwari-Biak-Jayapura; Babang-Sanana-Namlea-Ambon-Banda-Geser-Fak Fak; Babang-Ternate-Bitung; Babang-Ternate; Babang-Bibinoi-Tomara-Pigaraja-Pasipalele-Dowora-Gane Dalam-Sekely/Kurunga-Gane Luar-Ranga-Ranga-Bisui-Wosi-Mafa-Weda; Babang-Saketa/Koititi-Dolik-Tokaka-Samo-Batulak-Lifofo-Maidi-Makian-Moti-Gita-Ternate
2	Laiwui	9	Laiwui-Sanana-Dofa-Tikong-Bobong; Laiwui-Madapolo-Pigaraja-Ternate-Jailolo-Mayau-Bitung; Laiwui-Sanana-Banggai-Pola-Bau Bau-Banabungi-Langara-Kendari; Laiwui-Jojame-Kupal-Ternate; Laiwui-Kawasi; Laiwui-Kawasi-Soligi-Wayaloar-Ocimaloleo-Gambaru-Fluk-Bobo-Wooi-Gamumu; Laiwui-Jojame-Kupal-Ternate; Laiwui–Jojame–Kupal–Bajo-Indari–Loleo Jaya-Ternate; Tanjung Perak-Wanci-Namrole-Obi-Tanjung Perak

Table 2: Feeder Ports and Routes

No	Feeder Port	Number of routes	Route
1	Kupal	9	Kupal-Ternate-Jailolo-Manado; Kupal-Ternate-Kupal-Jojame-Laiwui-Kawasi; Kupal-Jojame-Laiwui-Kawasi; Kupal-Ternate; Kupal-Jojame-Laiwui-Kawasi-Soligi-Wayaloar-Ocimaloleo-Gambaru-Fluk-Bobo-Wooi-Gamumu; Kupal-Jojame-Laiwui; Kupal-Bajo-Indari-Loleo Jaya-Ternate; Kupal-Mandioli; Kupal-Kasiruta-Busua
2	Saketa	4	Babang-Saketa/Koititi-Dolik-Tokaka-Samo-Batulak-Lifofo-Maidi-Makian-Moti-Gita-Ternate; Tanjung Perak-Wayaloar-Malbufa-Babang-Saketa-Gimea-Tg. Perak; Saketa-Balitata-Oha-Papaceda-Tabamasa-Lemo Lemo-Tawa-Pasipalele-Gane Dalam; Saketa-Koititi-Fulai-Dolik-Suka Damai-Tokaka-Nurjihat-Moloku-Samo-Samat-Posi Posi-Batulak-Lipopa-Maidi-Ternate
3	Mafa	2	Mafa-Weda; Mafa-Wosi-Bisui-Ranga Ranga-Gane Luar-Sekely/Kurunga-Gane Dalam-Dowora-Pasipalele-Pigaraja-Tomara-Bibinoi-Babang
4	Pigaraja	3	Pigaraja-Pasipalele-Dowora-Gane Dalam-Sekely/Kurunga- Gane Luar-Ranga-Ranga-Bisui-Wosi-Mafa-Weda; Pigaraja-Tomara-Bibinoi-Babang; Pigaraja-Ternate-Jailolo-Mayau-Bitung; Pigaraja-Madapolo-Laiwui-Sanana-Dofa-Tikong-Bobong
5	Pelita	1	Bobo (Mandioli) – Kupal;
6	Loleo Jaya	5	Pelabuhan Loleo Jaya; Loleo Jaya (Kasiruta) – Busua; Loleo Jaya (Kasiruta) – Kupal; Loleo Jaya-Ternate; Loleo Jaya- Indari-Bajo-Kupal-Laiwui-Kawasi-Soligi-Wayaloar-Ocimaloleo-Gambaru-Fluk-Bobo-Wooi-Gamumu.
7	Indari	2	Indari - Loleo Jaya-Ternate; Indari-Bajo-Kupal-Laiwui-Kawasi-Soligi-Wayaloar-Ocimaloleo-Gambaru-Fluk-Bobo-Wooi-Gamumu
8	Busua	1	Busua - Loleo Jaya (Kasiruta) - Kupal
9	Makian	2	Makian-Moti-Gita-Ternate; Makian-Maidi-Lifofo-Batulak-Samo-Tokaka-Dolik-Saketa-Babang
10	Wayaloar	4	Tanjung Perak-Wayaloar-Malbufa-Babang-Saketa-Gimea-Tg. Perak; Wayaloar-Gamumu-Buano-Ambon; Wayaloar-Wooi-Sum-Sekely-Gane Dalam-Dowora-Moti-Soasiu-Ternate; Wayaloar-Soligi-Kawasi-Laiwui-Jojame-Kupal-Bajo Indari-Loleo Jaya- Ternate; Wayaloar-Ocimaloleo-Gambaru-Fluk-Bobo-Wooi-Gamumu

Table 3: Ferry Ports and Routes

No	Ferry Station	Number of routes	Trayek
1	Babang	3	Babang – Saketa; Babang – Kayoa – Makian – Moti – Bastiong; Babang – Jojame – Obi – Sanana – Mangoli – Bobong
2	Saketa	1	Saketa - Babang
3	Kayoa	2	Kayoa – Makian – Moti – Bastiong ; Kayoa – Babang
4	Makian	2	Makian – Moti – Bastiong ; Makian – Kayoa – Babang
5	Obi	2	Obi – Jojame – Babang ; Obi – Sanana – Mangole – Bobong

Table 4: Speed Boat Station and Routes

No	Speedboat Station	Number of routes	Route
1	Kupal	2	Kupal – Doko, Kupal - Kawasi
2	Labuha (Habibi)	13	Labuha – Kususbibi, Labuha – Jojame, Labuha – Galala, Labuha – Bisori, Labuha – Palamea, Labuha – Loleo Jaya, Labuha – Loid, Labuha – Indari, Labuha - Kampung Baru, Labuha – Indong, Labuha – Yoyok, Labuha – Waya, Labuha – Bajo, Labuha – Jiko, Labuha - Bahu
3	Pasar Baru Babang	5	Babang – Yamli/Gane Dalam, Babang – Kepulauan Joronga, Babang – Gane Barat Utara, Babang - Lemo Lemo, Babang - Pigaraja - Wayakuba
4	Laiwui	7	Laiwui – Soligi, Laiwui – Cap, Laiwui – Manatahan, Laiwui – Jikohay, Laiwui – Kawasi, Laiwui – Kawasi – Mala Mala – Hol Sagu, Laiwui – Sum
5	Guruapin	2	Guruapin – Ternate, Guruapin – Labuha
6	Gorup-Makian	2	Makian – Ternate, Makian – Gita

South Halmahera Regency, consisting of 30 districts, is generally connected through a maritime transportation network, with only 2 districts—South Kayoa and West Makian—remaining unconnected due to the absence of fixed and scheduled routes. The connectivity between districts within South Halmahera Regency using sea transportation is shown in the connectivity matrix between districts in Table 5.

The origin-destination matrix serves as the basis for calculation, analysis, and discussion to determine the connectivity index of the maritime transportation network in each district of South Halmahera Regency. The calculation process involves iterating the origin-destination matrix, with the process being stopped once all the cells in the matrix are filled (none with a zero value).

The calculation of the connectivity level of sea and ferry transportation between districts in South Halmahera Regency stopped at the fifth iteration, as shown in Table 6. This indicates that the network of maritime and ferry transportation services between districts in South Halmahera Regency remains low.

Table 5: Origin-Destination Matrix of Sea Transport in Halmahera Selatan

Pelabuhan	Bacan	Bacan Barat	Bacan Barat Utara	Mandioli Utara	Mandioli Selatan	Botang Lomang	Obi	Obi Selatan	Obi Utara	Pulau Makian	Makian Barat	Kayoa	Kayoa Barat	Kayoa Selatan	Kayoa Utara	Bacan Selatan	Kasiruta Barat	Kasiruta Timur	Obi Barat	Obi Timur	Bacan Timur	Gane Barat	Gane Barat	Kepulauan	Gane Barat Utara	Bacan Timur	Bacan Timur	Gane Timur	Gane Timur	Gane Timur	Ternate (Moti dan	Oba (Tidore)	Oba selatan	Sanana Utara	Sanana	Mangoli	Bobong	Jailolo (Halbar)	Patani Utara	Weda (Halteng)	Manado	Surabaya	Ambon
Bacan	0	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacan Barat	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacan Barat Utara	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mandioli Utara	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mandioli Selatan	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Botang Lomang	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Obi	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Obi Selatan	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
Obi Utara	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pulau Makian	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Makian Barat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayoa	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Kayoa Barat	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayoa Selatan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayoa Utara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacan Selatan	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Kasiruta Barat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kasiruta Timur	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Obi Barat	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Obi Timur	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacan Timur	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Gane Barat	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Gane Barat Selatan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Kepulauan Joronga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gane Barat Utara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Bacan Timur Selatan	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bacan Timur Tengah	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gane Timur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Gane Timur Selatan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gane Timur Tengah	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ternate (Moti dan	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0
Oba (Tidore)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Oba selatan (Tidore)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sanana Utara	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sanana	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mangoli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bobong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jailolo (Halbar)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Patani Utara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Weda (Halteng)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manado	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Surabaya	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ambon	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6: 5th iteration of Origin-Destination Matrix

Bacan	**4,E+09**	2,E+09	2,E+09	2,E+09	8,E+08	2,E+09	1,E+09	2,E+09	8,E+08	2,E+09	0,E+00	3,E+09	2,E+09	0,E+00	0,E+00	4,E+09	1,E+09	3,E+09	3,E+08	3,E+08	3,E+09	2,E+09	2,E+09	7,E+08	8,E+08	2,E+09	1,E+09	2,E+07	5,E+08	1,E+08	4,E+09	2,E+09	6,E+08	1,E+09	3,E+08	7,E+07	1,E+07	1,E+09	5,E+08	5,E+06	1,E+09	6,E+08	5,E+08
Bacan barat	2,E+09	**1,E+09**	1,E+09	9,E+08	4,E+08	1,E+09	7,E+08	1,E+09	4,E+08	1,E+09	0,E+00	2,E+09	8,E+08	0,E+00	0,E+00	2,E+09	5,E+08	2,E+09	1,E+08	1,E+08	2,E+09	9,E+08	1,E+09	4,E+08	5,E+08	1,E+09	6,E+08	1,E+07	3,E+08	6,E+07	2,E+09	1,E+09	3,E+08	6,E+08	2,E+08	4,E+07	7,E+06	6,E+08	3,E+08	3,E+06	6,E+08	3,E+08	2,E+08
Bacan barat utara	3,E+09	2,E+09	**2,E+09**	1,E+09	6,E+08	2,E+09	9,E+08	2,E+09	6,E+08	2,E+09	0,E+00	2,E+09	1,E+09	0,E+00	0,E+00	3,E+09	7,E+08	3,E+09	2,E+08	2,E+08	2,E+09	1,E+09	2,E+09	5,E+08	7,E+08	2,E+09	9,E+08	2,E+07	4,E+08	8,E+07	3,E+09	1,E+09	5,E+08	9,E+08	2,E+08	5,E+07	1,E+07	9,E+08	4,E+08	4,E+06	9,E+08	4,E+08	3,E+08
Mandioli utara	2,E+09	9,E+08	9,E+08	**8,E+08**	4,E+08	1,E+09	5,E+08	9,E+08	3,E+08	9,E+08	0,E+00	1,E+09	7,E+08	0,E+00	0,E+00	2,E+09	4,E+08	2,E+09	1,E+08	1,E+08	1,E+09	7,E+08	9,E+08	3,E+08	4,E+08	1,E+09	5,E+08	1,E+07	2,E+08	5,E+07	2,E+09	8,E+08	3,E+08	5,E+08	1,E+08	3,E+07	7,E+06	5,E+08	2,E+08	2,E+06	5,E+08	2,E+08	2,E+08
Mandioli selatan	8,E+08	5,E+08	5,E+08	4,E+08	**2,E+08**	5,E+08	3,E+08	5,E+08	2,E+08	5,E+08	0,E+00	6,E+08	3,E+08	0,E+00	0,E+00	1,E+09	2,E+08	8,E+08	6,E+07	6,E+07	7,E+08	4,E+08	5,E+08	2,E+08	2,E+08	5,E+08	3,E+08	5,E+06	1,E+08	2,E+07	9,E+08	4,E+08	1,E+08	3,E+08	6,E+07	1,E+07	3,E+06	3,E+08	1,E+08	1,E+06	3,E+08	1,E+08	1,E+08
Botang lomang	2,E+09	1,E+09	1,E+09	1,E+09	5,E+08	**1,E+09**	7,E+08	1,E+09	4,E+08	1,E+09	0,E+00	2,E+09	9,E+08	0,E+00	0,E+00	2,E+09	5,E+08	2,E+09	2,E+08	2,E+08	2,E+09	9,E+08	1,E+09	4,E+08	5,E+08	1,E+09	7,E+08	1,E+07	3,E+08	6,E+07	2,E+09	1,E+09	4,E+08	6,E+08	2,E+08	3,E+07	9,E+06	7,E+08	3,E+08	3,E+06	7,E+08	3,E+08	2,E+08
Obi	1,E+09	7,E+08	7,E+08	6,E+08	3,E+08	7,E+08	**5,E+08**	7,E+08	3,E+08	7,E+08	0,E+00	1,E+09	5,E+08	0,E+00	0,E+00	2,E+09	3,E+08	1,E+09	9,E+07	9,E+07	1,E+09	6,E+08	7,E+08	3,E+08	3,E+08	8,E+08	4,E+08	9,E+06	2,E+08	4,E+07	1,E+09	6,E+08	2,E+08	4,E+08	9,E+07	3,E+07	4,E+06	4,E+08	2,E+08	2,E+06	4,E+08	2,E+08	2,E+08
Obi selatan	2,E+09	1,E+09	1,E+09	1,E+09	4,E+08	1,E+09	6,E+08	**1,E+09**	5,E+08	1,E+09	0,E+00	2,E+09	8,E+08	0,E+00	0,E+00	2,E+09	5,E+08	2,E+09	2,E+08	2,E+08	2,E+09	9,E+08	1,E+09	4,E+08	5,E+08	1,E+09	7,E+08	1,E+07	3,E+08	6,E+07	2,E+09	1,E+09	4,E+08	6,E+08	2,E+08	3,E+07	1,E+07	6,E+08	3,E+08	3,E+06	6,E+08	3,E+08	2,E+08
Obi utara	3,E+08	2,E+08	2,E+08	1,E+08	6,E+07	2,E+08	9,E+07	2,E+08	**6,E+07**	2,E+08	0,E+00	2,E+08	1,E+08	0,E+00	0,E+00	3,E+08	8,E+07	3,E+08	2,E+07	2,E+07	3,E+08	1,E+08	2,E+08	6,E+07	7,E+07	2,E+08	1,E+08	2,E+06	4,E+07	9,E+06	3,E+08	1,E+08	5,E+07	9,E+07	3,E+07	4,E+06	1,E+06	9,E+07	4,E+07	5,E+05	9,E+07	4,E+07	3,E+07
Pulau makian	2,E+09	1,E+09	1,E+09	1,E+09	5,E+08	1,E+09	7,E+08	1,E+09	5,E+08	**1,E+09**	0,E+00	2,E+09	9,E+08	0,E+00	0,E+00	3,E+09	6,E+08	2,E+09	2,E+08	2,E+08	2,E+09	1,E+09	1,E+09	4,E+08	5,E+08	1,E+09	7,E+08	2,E+07	3,E+08	7,E+07	2,E+09	1,E+09	4,E+08	7,E+08	2,E+08	4,E+07	8,E+06	7,E+08	3,E+08	3,E+06	7,E+08	3,E+08	3,E+08
Makian barat	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	**0,E+00**	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00
Kayoa	3,E+09	2,E+09	2,E+09	1,E+09	7,E+08	2,E+09	1,E+09	2,E+09	6,E+08	2,E+09	0,E+00	**2,E+09**	1,E+09	0,E+00	0,E+00	4,E+09	8,E+08	3,E+09	2,E+08	2,E+08	3,E+09	1,E+09	2,E+09	6,E+08	7,E+08	2,E+09	1,E+09	2,E+07	4,E+08	9,E+07	4,E+09	2,E+09	5,E+08	1,E+09	2,E+08	6,E+07	1,E+07	1,E+09	4,E+08	5,E+06	1,E+09	5,E+08	4,E+08
Kayoa barat	2,E+09	9,E+08	8,E+08	7,E+08	3,E+08	9,E+08	5,E+08	9,E+08	3,E+08	9,E+08	0,E+00	1,E+09	**7,E+08**	0,E+00	0,E+00	2,E+09	4,E+08	1,E+09	1,E+08	1,E+08	1,E+09	7,E+08	9,E+08	3,E+08	4,E+08	1,E+09	5,E+08	1,E+07	2,E+08	4,E+07	2,E+09	8,E+08	3,E+08	5,E+08	1,E+08	3,E+07	6,E+06	5,E+08	2,E+08	2,E+06	5,E+08	2,E+08	2,E+08
Kayoa selatan	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	**0,E+00**	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00
Kayoa utara	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	**0,E+00**	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00	0,E+00
Bacan Selatan	4,E+09	2,E+09	2,E+09	2,E+09	8,E+08	2,E+09	1,E+09	2,E+09	8,E+08	2,E+09	0,E+00	3,E+09	2,E+09	0,E+00	0,E+00	**4,E+09**	9,E+08	3,E+09	3,E+08	3,E+08	3,E+09	2,E+09	2,E+09	7,E+08	8,E+08	2,E+09	1,E+09	3,E+07	5,E+08	1,E+08	4,E+09	2,E+09	6,E+08	1,E+09	3,E+08	7,E+07	1,E+07	1,E+09	5,E+08	5,E+06	1,E+09	6,E+08	5,E+08
Kasiruta barat	8,E+08	4,E+08	5,E+08	4,E+08	2,E+08	5,E+08	3,E+08	5,E+08	2,E+08	4,E+08	0,E+00	6,E+08	3,E+08	0,E+00	0,E+00	9,E+08	**2,E+08**	8,E+08	6,E+07	6,E+07	7,E+08	4,E+08	5,E+08	2,E+08	2,E+08	5,E+08	3,E+08	5,E+06	1,E+08	2,E+07	9,E+08	4,E+08	1,E+08	2,E+08	7,E+07	1,E+07	4,E+06	3,E+08	1,E+08	1,E+06	3,E+08	1,E+08	9,E+07
Kasiruta timur	3,E+09	2,E+09	2,E+09	2,E+09	7,E+08	2,E+09	1,E+09	2,E+09	7,E+08	2,E+09	0,E+00	3,E+09	1,E+09	0,E+00	0,E+00	4,E+09	9,E+08	**3,E+09**	2,E+08	2,E+08	3,E+09	2,E+09	2,E+09	6,E+08	8,E+08	2,E+09	1,E+09	2,E+07	4,E+08	1,E+08	4,E+09	2,E+09	6,E+08	1,E+09	3,E+08	6,E+07	1,E+07	1,E+09	4,E+08	5,E+06	1,E+09	5,E+08	4,E+08
Obi barat	3,E+08	2,E+08	2,E+08	1,E+08	6,E+07	2,E+08	9,E+07	2,E+08	6,E+07	2,E+08	0,E+00	2,E+08	1,E+08	0,E+00	0,E+00	3,E+08	8,E+07	3,E+08	**2,E+07**	2,E+07	3,E+08	1,E+08	2,E+08	6,E+07	7,E+07	2,E+08	1,E+08	2,E+06	4,E+07	9,E+06	3,E+08	1,E+08	5,E+07	9,E+07	3,E+07	4,E+06	1,E+06	9,E+07	4,E+07	5,E+05	9,E+07	4,E+07	3,E+07
Obi timur	3,E+08	2,E+08	2,E+08	1,E+08	6,E+07	2,E+08	9,E+07	2,E+08	6,E+07	2,E+08	0,E+00	2,E+08	1,E+08	0,E+00	0,E+00	3,E+08	8,E+07	3,E+08	2,E+07	**2,E+07**	3,E+08	1,E+08	2,E+08	6,E+07	7,E+07	2,E+08	1,E+08	2,E+06	4,E+07	9,E+06	3,E+08	1,E+08	5,E+07	9,E+07	3,E+07	4,E+06	1,E+06	9,E+07	4,E+07	5,E+05	9,E+07	4,E+07	3,E+07
Bacan timur	4,E+09	2,E+09	2,E+09	2,E+09	9,E+08	2,E+09	1,E+09	2,E+09	9,E+08	2,E+09	0,E+00	3,E+09	2,E+09	0,E+00	0,E+00	5,E+09	1,E+09	4,E+09	3,E+08	3,E+08	**4,E+09**	2,E+09	2,E+09	8,E+08	1,E+09	3,E+09	1,E+09	3,E+07	5,E+08	1,E+08	5,E+09	2,E+09	7,E+08	1,E+09	3,E+08	7,E+07	2,E+07	1,E+09	6,E+08	7,E+06	1,E+09	6,E+08	5,E+08
Gane barat	2,E+09	1,E+09	1,E+09	9,E+08	4,E+08	1,E+09	7,E+08	1,E+09	4,E+08	1,E+09	0,E+00	2,E+09	8,E+08	0,E+00	0,E+00	2,E+09	5,E+08	2,E+09	1,E+08	1,E+08	2,E+09	**1,E+09**	1,E+09	4,E+08	5,E+08	1,E+09	7,E+08	2,E+07	3,E+08	6,E+07	2,E+09	1,E+09	3,E+08	7,E+08	1,E+08	4,E+07	7,E+06	6,E+08	3,E+08	3,E+06	6,E+08	3,E+08	3,E+08
Gane barat selatan	2,E+09	1,E+09	1,E+09	1,E+09	5,E+08	1,E+09	8,E+08	1,E+09	5,E+08	1,E+09	0,E+00	2,E+09	1,E+09	0,E+00	0,E+00	3,E+09	6,E+08	2,E+09	2,E+08	2,E+08	2,E+09	1,E+09	**1,E+09**	5,E+08	6,E+08	2,E+09	8,E+08	2,E+07	3,E+08	8,E+07	3,E+09	1,E+09	4,E+08	8,E+08	2,E+08	4,E+07	1,E+07	8,E+08	3,E+08	4,E+06	8,E+08	4,E+08	3,E+08
Kepulauan joronga	9,E+08	5,E+08	5,E+08	4,E+08	2,E+08	5,E+08	3,E+08	5,E+08	2,E+08	5,E+08	0,E+00	7,E+08	4,E+08	0,E+00	0,E+00	1,E+09	2,E+08	8,E+08	6,E+07	6,E+07	8,E+08	4,E+08	5,E+08	**2,E+08**	2,E+08	6,E+08	3,E+08	7,E+06	1,E+08	3,E+07	1,E+09	5,E+08	2,E+08	3,E+08	6,E+07	2,E+07	3,E+06	3,E+08	1,E+08	1,E+06	3,E+08	1,E+08	1,E+08
Gane barat utara	1,E+09	6,E+08	5,E+08	5,E+08	2,E+08	6,E+08	4,E+08	6,E+08	2,E+08	6,E+08	0,E+00	8,E+08	4,E+08	0,E+00	0,E+00	1,E+09	3,E+08	9,E+08	7,E+07	7,E+07	9,E+08	5,E+08	6,E+08	2,E+08	**2,E+08**	7,E+08	4,E+08	8,E+06	1,E+08	3,E+07	1,E+09	5,E+08	2,E+08	3,E+08	7,E+07	2,E+07	3,E+06	3,E+08	1,E+08	2,E+06	3,E+08	2,E+08	1,E+08
Bacan timur selatan	3,E+09	1,E+09	1,E+09	1,E+09	6,E+08	2,E+09	9,E+08	2,E+09	6,E+08	2,E+09	0,E+00	2,E+09	1,E+09	0,E+00	0,E+00	3,E+09	7,E+08	2,E+09	2,E+08	2,E+08	2,E+09	1,E+09	2,E+09	5,E+08	6,E+08	**2,E+09**	9,E+08	2,E+07	4,E+08	8,E+07	3,E+09	1,E+09	5,E+08	9,E+08	2,E+08	5,E+07	1,E+07	9,E+08	4,E+08	4,E+06	9,E+08	4,E+08	3,E+08
Bacan timur tengah	1,E+09	8,E+08	8,E+08	7,E+08	3,E+08	8,E+08	5,E+08	8,E+08	3,E+08	8,E+08	0,E+00	1,E+09	6,E+08	0,E+00	0,E+00	2,E+09	4,E+08	1,E+09	1,E+08	1,E+08	1,E+09	7,E+08	9,E+08	3,E+08	4,E+08	1,E+09	**5,E+08**	1,E+07	2,E+08	5,E+07	2,E+09	7,E+08	3,E+08	5,E+08	1,E+08	3,E+07	5,E+06	5,E+08	2,E+08	2,E+06	5,E+08	2,E+08	2,E+08
Gane timur	3,E+07	2,E+07	2,E+07	1,E+07	6,E+06	2,E+07	1,E+07	2,E+07	7,E+06	2,E+07	0,E+00	2,E+07	1,E+07	0,E+00	0,E+00	3,E+07	7,E+06	3,E+07	2,E+06	2,E+06	3,E+07	2,E+07	2,E+07	6,E+06	7,E+06	2,E+07	1,E+07	**3,E+05**	4,E+06	1,E+06	3,E+07	2,E+07	5,E+06	1,E+07	2,E+06	6,E+05	1,E+05	1,E+07	4,E+06	5,E+04	1,E+07	5,E+06	4,E+06
Gane timur selatan	5,E+08	3,E+08	3,E+08	3,E+08	1,E+08	3,E+08	2,E+08	3,E+08	1,E+08	3,E+08	0,E+00	4,E+08	2,E+08	0,E+00	0,E+00	7,E+08	1,E+08	5,E+08	4,E+07	4,E+07	5,E+08	3,E+08	3,E+08	1,E+08	1,E+08	4,E+08	2,E+08	4,E+06	**8,E+07**	2,E+07	6,E+08	3,E+08	1,E+08	2,E+08	4,E+07	1,E+07	2,E+06	2,E+08	8,E+07	1,E+06	2,E+08	9,E+07	7,E+07
Gane timur tengah	1,E+08	7,E+07	7,E+07	6,E+07	3,E+07	7,E+07	4,E+07	8,E+07	3,E+07	7,E+07	0,E+00	1,E+08	5,E+07	0,E+00	0,E+00	2,E+08	3,E+07	1,E+08	1,E+07	1,E+07	1,E+08	6,E+07	8,E+07	3,E+07	3,E+07	9,E+07	5,E+07	1,E+06	2,E+07	**4,E+06**	1,E+08	7,E+07	2,E+07	4,E+07	1,E+07	2,E+06	5,E+05	4,E+07	2,E+07	2,E+05	4,E+07	2,E+07	2,E+07
Ternate (moti dan	4,E+09	2,E+09	2,E+09	2,E+09	9,E+08	2,E+09	1,E+09	2,E+09	9,E+08	2,E+09	0,E+00	3,E+09	2,E+09	0,E+00	0,E+00	5,E+09	1,E+09	4,E+09	3,E+08	3,E+08	4,E+09	2,E+09	2,E+09	8,E+08	1,E+09	3,E+09	1,E+09	3,E+07	5,E+08	1,E+08	**5,E+09**	2,E+09	7,E+08	1,E+09	3,E+08	7,E+07	2,E+07	1,E+09	6,E+08	7,E+06	1,E+09	6,E+08	5,E+08
Oba (tidore)	2,E+09	1,E+09	1,E+09	9,E+08	4,E+08	1,E+09	7,E+08	1,E+09	4,E+08	1,E+09	0,E+00	2,E+09	8,E+08	0,E+00	0,E+00	2,E+09	5,E+08	2,E+09	1,E+08	1,E+08	2,E+09	9,E+08	1,E+09	4,E+08	5,E+08	1,E+09	7,E+08	1,E+07	3,E+08	6,E+07	2,E+09	**1,E+09**	3,E+08	6,E+08	1,E+08	3,E+07	7,E+06	6,E+08	3,E+08	3,E+06	6,E+08	3,E+08	2,E+08
Oba selatan	7,E+08	4,E+08	4,E+08	3,E+08	1,E+08	4,E+08	2,E+08	4,E+08	2,E+08	4,E+08	0,E+00	5,E+08	3,E+08	0,E+00	0,E+00	8,E+08	2,E+08	6,E+08	5,E+07	5,E+07	6,E+08	3,E+08	4,E+08	1,E+08	2,E+08	5,E+08	2,E+08	5,E+06	9,E+07	2,E+07	8,E+08	3,E+08	**1,E+08**	2,E+08	6,E+07	1,E+07	3,E+06	2,E+08	1,E+08	1,E+06	2,E+08	1,E+08	8,E+07
sanana utara	1,E+09	7,E+08	7,E+08	6,E+08	3,E+08	7,E+08	5,E+08	7,E+08	3,E+08	8,E+08	0,E+00	1,E+09	5,E+08	0,E+00	0,E+00	2,E+09	3,E+08	1,E+09	9,E+07	9,E+07	1,E+09	7,E+08	8,E+08	3,E+08	3,E+08	9,E+08	5,E+08	1,E+07	2,E+08	4,E+07	1,E+09	7,E+08	2,E+08	**4,E+08**	9,E+07	3,E+07	4,E+06	4,E+08	2,E+08	2,E+06	4,E+08	2,E+08	2,E+08
Sanana	3,E+08	2,E+08	2,E+08	1,E+08	7,E+07	2,E+08	9,E+07	2,E+08	7,E+07	2,E+08	0,E+00	2,E+08	1,E+08	0,E+00	0,E+00	3,E+08	8,E+07	3,E+08	3,E+07	3,E+07	3,E+08	1,E+08	2,E+08	6,E+07	7,E+07	2,E+08	1,E+08	2,E+06	4,E+07	1,E+07	3,E+08	1,E+08	5,E+07	9,E+07	**3,E+07**	5,E+06	2,E+06	9,E+07	4,E+07	5,E+05	9,E+07	4,E+07	3,E+07
Mangoli	7,E+07	4,E+07	3,E+07	3,E+07	1,E+07	4,E+07	3,E+07	4,E+07	1,E+07	4,E+07	0,E+00	5,E+07	3,E+07	0,E+00	0,E+00	8,E+07	2,E+07	6,E+07	4,E+06	4,E+06	6,E+07	3,E+07	4,E+07	1,E+07	2,E+07	4,E+07	2,E+07	5,E+05	9,E+06	2,E+06	8,E+07	3,E+07	1,E+07	2,E+07	5,E+06	**2,E+06**	2,E+05	2,E+07	9,E+06	9,E+04	2,E+07	1,E+07	1,E+07
Bobong	1,E+07	8,E+06	9,E+06	8,E+06	3,E+06	9,E+06	4,E+06	1,E+07	4,E+06	8,E+06	0,E+00	1,E+07	6,E+06	0,E+00	0,E+00	2,E+07	4,E+06	1,E+07	1,E+06	1,E+06	1,E+07	7,E+06	9,E+06	3,E+06	4,E+06	1,E+07	5,E+06	9,E+04	2,E+06	5,E+05	2,E+07	7,E+06	3,E+06	5,E+06	2,E+06	2,E+05	**1,E+05**	5,E+06	2,E+06	3,E+04	5,E+06	2,E+06	2,E+06
Jailolo (halmahera	1,E+09	6,E+08	6,E+08	5,E+08	2,E+08	7,E+08	4,E+08	6,E+08	2,E+08	7,E+08	0,E+00	9,E+08	5,E+08	0,E+00	0,E+00	1,E+09	3,E+08	1,E+09	8,E+07	8,E+07	1,E+09	6,E+08	7,E+08	2,E+08	3,E+08	8,E+08	4,E+08	8,E+06	2,E+08	4,E+07	1,E+09	6,E+08	2,E+08	4,E+08	9,E+07	2,E+07	4,E+06	**4,E+08**	2,E+08	2,E+06	4,E+08	2,E+08	1,E+08
Patani Utara	5,E+08	3,E+08	3,E+08	3,E+08	1,E+08	3,E+08	2,E+08	3,E+08	1,E+08	3,E+08	0,E+00	4,E+08	2,E+08	0,E+00	0,E+00	6,E+08	1,E+08	5,E+08	5,E+07	5,E+07	5,E+08	3,E+08	3,E+08	1,E+08	1,E+08	4,E+08	2,E+08	4,E+06	8,E+07	2,E+07	6,E+08	3,E+08	1,E+08	2,E+08	5,E+07	8,E+06	3,E+06	2,E+08	**9,E+07**	1,E+06	2,E+08	8,E+07	6,E+07
Weda	6,E+06	3,E+06	3,E+06	3,E+06	1,E+06	4,E+06	2,E+06	4,E+06	2,E+06	4,E+06	0,E+00	5,E+06	2,E+06	0,E+00	0,E+00	7,E+06	2,E+06	6,E+06	5,E+05	5,E+05	6,E+06	3,E+06	4,E+06	1,E+06	2,E+06	4,E+06	2,E+06	5,E+04	1,E+06	2,E+05	7,E+06	3,E+06	1,E+06	2,E+06	5,E+05	1,E+05	3,E+04	2,E+06	1,E+06	**2,E+04**	2,E+06	1,E+06	8,E+05
Manado	1,E+09	6,E+08	6,E+08	5,E+08	2,E+08	7,E+08	4,E+08	6,E+08	2,E+08	7,E+08	0,E+00	9,E+08	5,E+08	0,E+00	0,E+00	1,E+09	3,E+08	1,E+09	8,E+07	8,E+07	1,E+09	6,E+08	7,E+08	2,E+08	3,E+08	8,E+08	4,E+08	8,E+06	2,E+08	4,E+07	1,E+09	6,E+08	2,E+08	4,E+08	9,E+07	2,E+07	4,E+06	4,E+08	2,E+08	2,E+06	**4,E+08**	2,E+08	1,E+08
Surabaya	6,E+08	3,E+08	3,E+08	2,E+08	1,E+08	3,E+08	2,E+08	3,E+08	1,E+08	3,E+08	0,E+00	4,E+08	2,E+08	0,E+00	0,E+00	7,E+08	1,E+08	5,E+08	4,E+07	4,E+07	5,E+08	3,E+08	3,E+08	1,E+08	1,E+08	4,E+08	2,E+08	4,E+06	8,E+07	2,E+07	6,E+08	3,E+08	1,E+08	2,E+08	4,E+07	1,E+07	2,E+06	2,E+08	7,E+07	8,E+05	2,E+08	**1,E+08**	8,E+07
Ambon	4,E+08	2,E+08	2,E+08	2,E+08	9,E+07	2,E+08	2,E+08	2,E+08	9,E+07	3,E+08	0,E+00	3,E+08	2,E+08	0,E+00	0,E+00	5,E+08	1,E+08	4,E+08	3,E+07	3,E+07	4,E+08	2,E+08	3,E+08	9,E+07	1,E+08	3,E+08	1,E+08	3,E+06	6,E+07	1,E+07	5,E+08	2,E+08	8,E+07	1,E+08	3,E+07	1,E+07	1,E+06	1,E+08	6,E+07	6,E+05	1,E+08	8,E+07	**6,E+07**

Table 7: The Results of Connectivity Indices for Sub-district

Sub-district	Value of Iteration 5th	Connectivity Indices	Remarks
Bacan	3.749.292.606	4,170	High
Bacan barat	1.105.095.960	1,229	High
Bacan barat utara	1.528.755.255	1,700	High
Mandioli utara	782.202.334	0,870	Low
Mandioli selatan	182.165.363	0,203	Low
Botang lomang	1.240.767.426	1,380	High
Obi	474.069.303	0,527	Low
Obi selatan	1.214.280.066	1,351	High
Obi utara	64.267.788	0,071	Low
Pulau makian	1.226.530.576	1,364	High
Makian barat	0	-	Low
Kayoa	2.421.350.538	2,693	High
Kayoa barat	653.488.989	0,727	Low
Kayoa selatan	0	-	Low
Kayoa utara	0	-	Low
Bacan Selatan	4.362.816.607	4,853	High
Kasiruta barat	210.640.858	0,234	Low
Kasiruta timur	3.099.063.805	3,447	High
Obi barat	24.195.464	0,027	Low
Obi timur	24.195.464	0,027	Low
Bacan timur	3.684.904.771	4,099	High
Gane barat	990.247.784	1,101	High
Gane barat selatan	1.458.309.852	1,622	High

Sub-district	Value of Iteration 5th	Connectivity Indices	Remarks
Kepulauan joronga	177.784.574	0,198	Low
Gane barat utara	248.659.727	0,277	Low
Bacan timur selatan	1.786.099.200	1,987	Tinggi
Bacan timur tengah	508.694.334	0,566	Low
Gane timur	265.436	0,000	Low
Gane timur selatan	79.228.529	0,088	Low
Gane timur tengah	4.439.186	0,005	Low

Table 7 shows that the majority of districts in the island areas of South Halmahera Regency are connected, although some regions still have low connectivity. This is based on the obtained connectivity index, where an index value > 1 indicates high connectivity in 13 districts, while an index value < 1 indicates low connectivity in 17 districts.

Sub-districts with high connectivity indexes are likely located near major shipping routes, such as feeder or ferry routes. These routes provide better access to other regions. For example, Bacan and South Bacan, which have very high connectivity indexes (4.170 and 4.853), appear to be on major shipping routes that connect several large islands in the North Maluku region. The presence of ports and shipping routes around these areas supports their high connectivity. East Kasiruta and East Bacan also have high connectivity, likely due to their location along major shipping routes or direct connections to ports, enhancing their access.

Areas with low connectivity indexes tend to be located farther from major shipping routes or are not directly connected to ports. Low connectivity can be caused by greater geographical distance from port points or limited shipping routes. For instance, South Mandioli (index 0.203) and North Obi (index 0.071) are likely not on the main shipping routes, making access to these areas more difficult or time-consuming. Similarly, West Obi and East Obi, which also have very low connectivity indexes (0.027), seem to be far from the main shipping routes, resulting in poor accessibility to these areas. Meanwhile, West Makian, South Kayoa, and North Kayoa possibly do not yet have port access.

Therefore, the transportation development strategy in South Halmahera Regency is directed towards a triadic model, which involves building direct connectivity between districts to form triads (groups of three nodes) within the network [17]. This approach has the potential to strengthen inter-district relationships. For example, a route could be opened from South Kayoa to East Kasiruta via Loleo Jaya Port. Additionally, a route could be established from West Makian to North Kayoa via Laromabati Port.

Connecting districts that are not yet linked must be accompanied by the development of supporting infrastructure, such as ports, land transportation connecting ports to district economic centers, the use of information technology to optimize transportation schedules and routes, and encouraging private sector investment to open new routes to target districts.

Overall, the transportation development strategy in South Halmahera should involve enhancing port infrastructure, increasing the frequency and regularity of sea transportation, integrating multimodal transportation, utilizing technology, and developing the maritime economy. Furthermore, collaboration between regions, private sector involvement, and local community skill development are key to ensuring better and more sustainable connectivity. By implementing these strategies, it is hoped that areas with low connectivity can be better linked to economic centers, accelerating economic growth and improving the overall welfare of the population.

IV. CONCLUSIONS

Based on the findings of this study, several conclusions can be drawn:

1. Areas with high connectivity indexes tend to have well-developed transportation infrastructure, which allows transportation modes to access these regions. Additionally, proximity to main shipping routes is a key factor that promotes connectivity with surrounding areas. In contrast, areas farther from these routes, especially those in southern or remote locations, tend to have lower connectivity indexes due to limited access to ports or regular shipping routes.
2. The data also highlights the need for improved transportation infrastructure, particularly ports, in districts with low connectivity indexes. A possible scenario for connecting South Kayoa District is by opening a route from South Kayoa to East Kasiruta via Loleo Jaya Port. Furthermore, for West Makian District, a route could be opened to North Kayoa via Laromabati Port, or the regional government could collaborate with the private sector to open a new route passing through West Makian to Ternate City.

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