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Analysis Of International Shipping Path Determination In Indonesian Archipelagic Sea Lanes Iii (Iasl Iii) Using Dynamic Programming

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Abstract— When a country has made part of its territorial waters open for international shipping, so the country has carried out its obligations as an archipelagic state accompanied by the granting of navigational rights to foreign ships and aircraft. The right of navigation is the right of foreign countries to freely sail along international waters and receive security protection along IASL I, IASL II, and IASL III from archipelagic countries. The determination of Indonesian Archipelagic Crossings creates benefits as well as a challenge to the sovereignty of the archipelagic state. With the change from a closed area to an open area for international shipping, issues related to the safety and security of shipping along archipelagic sea lanes arise. IASL is a guide or reference so that foreign ships do not violate the territorial waters of Indonesia. This study aims to analyze the determination of international shipping lanes at IASL III to obtain the optimal route with minimum mileage. This study was limited to IASL III, namely the IASL III-A route from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait, and Sawu Sea. IASL Branch III B: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea and Leti Strait to the Indian Ocean. IASL Branch III C: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea to the Arafura Sea. IASL Branch III D: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait and Sawu Sea to the Indian Ocean. IASL Branch III E: from the Indian Ocean across the Sawu Sea, Ombai Strait, Banda Sea, Seram Sea and Maluku Sea combined into 1 (one) route from the Pacific Ocean to the Indian Ocean resulting in the optimal route with the minimum distance obtained from the smallest value at every stage. The selected route is (1. Pacific Ocean-5. Ombai Strait-8. Sawu Sea-9. Indian Ocean) with a distance from the Pacific Ocean to the Ombai Strait is 10,596.55. The Ombai Strait to the Sawu Sea is 211.28. Sawu Sea to the Indian Ocean is 2,978.61. So that the total voyage distance is 13,786.44 Nautical miles (Nm). This study uses quantitative methods and Multistage Graph problem-solving techniques with backward or bottom-up Dynamic Programming methods, as well as secondary data collection such as: documents/journals/books.

Keywords— International Shipping Path, Indonesian Archipelagic Sea Lanes III (IASL III), Dynamic Programming.

I. INTRODUCTION

In carrying out its position as an archipelagic state, Indonesia must pay attention to the interests of the international community in the field of foreign shipping and flights for foreign ships crossing archipelagic waters such as the right of innocent passage, the right of archipelagic sea lanes passage, the right of transit passage and the right of communication access passage. These rights are guaranteed by Law No. 6 of 1996 as the implementation of the 1982 International Law of the Sea which means that archipelagic states must respect the rights of other countries and the rights of user countries must also receive attention. UU no. 6 of 1996 recognizes several rights, for example, the recognition of traditional fishing rights and shipping rights in archipelagic waters to create harmonization between archipelagic states and user countries. Other obligations and responsibilities set out in the 1983 International Law of the Sea Convention granted to archipelagic states, relate to the rights and freedoms of navigation, the sovereignty of waters, and the islands and geographical features connected to them. Maritime user countries have the right of passage for ships and aircraft through and over the archipelagic waters and territorial sea before them, as points of entry and/or exit which are called “rights of innocent passage” or “rights of archipelagic passage”.

The right of archipelagic channel passage is the same as transit passage through straits in international shipping. Article 53 paragraph 3 of the Convention on the Law of the Sea III 1982 determines the right of archipelagic sea lanes passage, namely "the right of shipping and flight in normal mode which is only used for continuous, direct and unobstructed passage from one part of the EEZ and the high seas to another part of the EEZ and free sea." From the provisions of article 53 paragraph 3, according to Kresna Buntoro, Indonesian Archipelagic Sea Lanes contains five things, namely: first, the right of the archipelagic state to determine whether archipelagic sea lanes exist. Second, there is no air route without a sea route underneath. Third, sea lanes must be suitable for passage. Fourth, must-continuous and direct cross. Fifth, passage for foreign ships and aircraft (Buntoro 2012, 92). When a country has made part of its territorial waters open for international shipping, that country has carried out its obligations as an archipelagic state accompanied by the granting of navigational rights to foreign ships and foreign aircraft. The right of navigation is the right of foreign countries to freely sail along international waters and receive security protection along Indonesian Archipelagic Sea Lanes I, Indonesian Archipelagic Sea Lanes II, and Indonesian Archipelagic Sea Lanes III from archipelagic countries. Each archipelagic country has the right to innocent passage, the right to archipelagic passage, and the right to transit passage using a separation scheme.

The determination of Indonesian Archipelagic Crossings creates benefits as well as a challenge to the sovereignty of the archipelagic state. With the change from a closed area to an open area for international shipping, issues related to the safety and security of shipping along archipelagic sea lanes arise. Indonesian Archipelagic Sea Lanes is a guideline or reference so that foreign ships do not violate the territorial waters of Indonesia.[3] In determining archipelagic sea lanes there are factors that must be considered, namely: First, the provisions of the 1982 International Law of the Sea and other provisions of international law. Second, maritime engineering includes hydrography, protection of the marine environment, mining areas, pipelines, underwater pipelines, dumping, and mine disposal areas, and fishery areas. Third, the location of the archipelagic sea lanes. Fourth, how many archipelagic sea lanes and archipelagic sea lanes have been determined by Indonesia, namely: Lanes in Indonesian Archipelagic Sea Lanes I which function for shipping from the South China Sea across the Natuna Sea, Karimata Strait, Java Sea, and Sunda Strait to the Indian Ocean, and vice versa, and for shipping from the Singapore Strait through the Natuna Sea and vice versa (Ocean Lanes Branch IA).

The route on Indonesian Archipelagic Sea Lanes II functions for shipping from the Sulawesi Sea across the Makassar Strait, Flores Sea, and Lombok Strait to the Indian Ocean and vice versa. The route on Indonesian Archipelagic Sea Lanes III-A is used for shipping from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait, and Sawu Sea. Indonesian Archipelagic Sea Lane III A itself has 4 branches, namely Indonesian Archipelagic Sea Lanes Branch III B: for shipping from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, and Leti Strait to the Indian Ocean and vice versa. Indonesian Archipelagic Sea Lanes Branch III C: for shipping from the Pacific Ocean across the Maluku Sea, Seram Sea, and Banda Sea to the Arafura Sea and vice versa. Indonesian Archipelagic Sea Lanes Branch III D: for shipping from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait, and Sawu Sea to the Indian Ocean and vice versa. Indonesian Archipelagic Sea Lanes Branch III E: for shipping from the Indian Ocean across the Sawu Sea, Ombai Strait, Banda Sea, Seram Sea, and Maluku Sea.[1] The safety and security of international shipping must be a priority for archipelagic states in accordance with the mandate of Article 53 paragraph 10 of the 1982 International Law of the Sea Convention, that archipelagic states must clearly indicate the axes of sea lanes and traffic separation schemes determined or stipulated on maps that must be announced as it should.

In addition to establishing sea axes and separation schemes, Indonesia is required to establish sea traffic separation schemes (Traffic Separation Scheme/TSS) in shipping lanes, especially in canals/straits, for example, shipping lanes in the Singapore Strait and the Malacca Strait. The determination of the TSS is aimed at shipping safety, protection at sea, and avoiding accidents at sea. In determining the TSS, Indonesia submits it to IMO for approval. The International Maritime Organization (IMO) defines a "traffic separation scheme" as a plan that organizes traffic proceedings in opposite or nearly opposite directions by means of a separation zone or line, traffic lane, etc. The Traffic Separation Scheme (TSS) is regulated by the International Convention on Preventing Collision at Sea (COLREG) 1972 rule 10 (Lloyd's Register Rulefinder, 2005). The rule states that ships crossing traffic lanes are required to do so "as nearly as practicable at right angles to the general direction of traffic flow." This reduces confusion to other ships as to the crossing vessel's intentions and of course and at the same time enables the vessel to cross the lane as quickly as possible. If a vessel is obliged to cross traffic lanes it should do so as nearly as practicable at right angles to the general direction of the traffic flow. From the TSS rules crossing vessels that sail between two crossing ports will intersect with the TSS and have the potential for collision with the vessels sailing on the TSS.[9] Approval was issued after going through a trial process from the Maritime Safety Committee (MSC) and being examined by Sub-Navigation. Indonesia is a country that has many straits. This TSS was then installed in Indonesian-owned straits such as the Sunda Strait, Makassar Strait, Lombok Strait, and others.

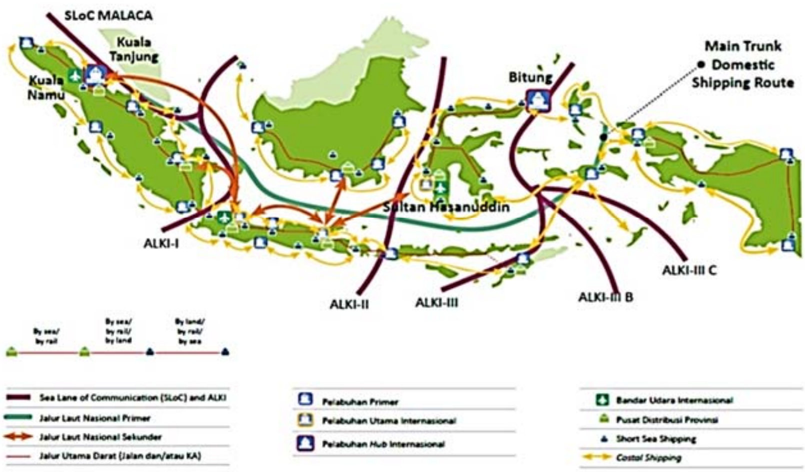

Figure 1. Indonesian Archipelagic Sea Lanes (IASL)

The waters of Sulawesi and Maluku are strategic areas in Eastern Indonesia which are geographically located in two sea shipping lanes Indonesian Archipelagic Sea Lanes II and Indonesian Archipelagic Sea Lanes III and most of the world's main shipping (global shipping) passes through and utilizes these channels as shipping lanes so that these waters become one of the waters which is quite busy traversed by international ships.[6] Indonesian Archipelagic Sea Lanes III which crosses the Pacific Ocean, Maluku Sea, Seram Sea, and Banda Sea, has a potential threat that is almost the same as Indonesian Archipelagic Sea Lanes I and Indonesian Archipelagic Sea Lanes II, namely the influence of the release of East Timor to become a sovereign country (Timor Leste) related to the oil and gas block in the south of the island. Timor. The Indonesian Archipelagic Sea Lanes III A area is also a means of escape from crimes against humanity or other activities that endanger security. There are also threats to borders, law enforcement, sovereignty over fishing seas, marine tourism, offshore exploration, sea transportation, territorial claims, and management of natural resources. The role of sea transportation in the two water areas is quite large, but it still faces obstacles in terms of the availability and quality of facilities and infrastructure. Therefore, the mode of sea transportation is very important as a tool to unite all regions of Indonesia. The purpose of this research is to analyze the determination of international shipping lanes at Indonesian Archipelagic Sea Lanes III to get the optimal route with the minimum distance traveled.

II. RESEARCH METHODS

This study uses quantitative methods and Multistage Graph problem solving techniques with Dynamic Programming and secondary data collection such as: documents/journals/books. In this study the authors used the backward or bottom-up Dynamic Programming method. There are several important things in the backward method, namely:

1. Principle: analysis is performed by calculating the path from a source to a node.
2. Formula: $\boldsymbol{bcost\,(i,j) = min\{cost(i-1,l) + c(l,j)\}}$
3. The calculation starts from the nodes in stage 3.
4. ***bcost*** (***i,j***) means the length of the backward path from source (s) to node ***j*** in stage ***i***.
5. ***c*** (***l,j***) means the path length from node ***l*** to node ***j***.

Dynamic programming calculations or dynamic programming backward method, namely calculating the distance backwards (from the source).

For example X_1, X_2, X_3 is the node visited in the stage *k* (*k* = 1, 2, 3). So the route taken is:

$1 \rightarrow X_1 \rightarrow X_2 \rightarrow X_3$ in this case X_3 = 9. Indian Ocean.

Step (k) in this problem is the procedure for selecting the next node destination (there are 3 stages). Graph nodes represent the state (s) connected to each step. Shortest route from status (s) to X_3 on step k represented by the recurrence relationship shown below:

$f_3\ (s) = C_{sx3}$ (Base)

$f_k\ (s) = \min_{xk} \{C_{sxk} + f_{k+1}\ (x_k)\}$, k = 1, 2 (rekurens)

Explanation:

x_k = decision variables at stage *k* (*k* = 1, 2)

C_{sxk} = weight (*cost*) side of *s* to x_k

$f_k\ (s, x_k)$ = total track weight of *s* to x_k

$f_k\ (s)$ = minimum value of $f_k\ (s, x_k)$

The goal of *backward* dynamic programming is to get f_1 (1) by finding f_3 (s), f_2 (s) first.

III. RESULT AND DISCUSSION

In this study, it was limited to the Indonesian Archipelagic Sea Lanes III (IASL III), namely Indonesia Archipelagic Sea Lane III-A from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait, and Sawu Sea. Indonesia Archipelagic Sea Lane Branch III B: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, and Leti Strait to the Indian Ocean. Indonesia Archipelagic Sea Lane Branch III C: from the Pacific Ocean across the Maluku Sea, Seram Sea, and Banda Sea to the Arafura Sea. Indonesia Archipelagic Sea Lane Branch III D: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait, and Sawu Sea to the Indian Ocean. Indonesia Archipelagic Sea Lane Branch III E: from the Indian Ocean across the Sawu Sea, Ombai Strait, Banda Sea, Seram Sea, and Maluku Sea which will be combined into 1 route from the Pacific Ocean to the Indian Ocean. To produce several alternative routes, in this case, the author provides the numbering of these routes to determine the optimal route with the minimum distance using dynamic programming calculations or the backward dynamic programming method as shown in Figure 1.

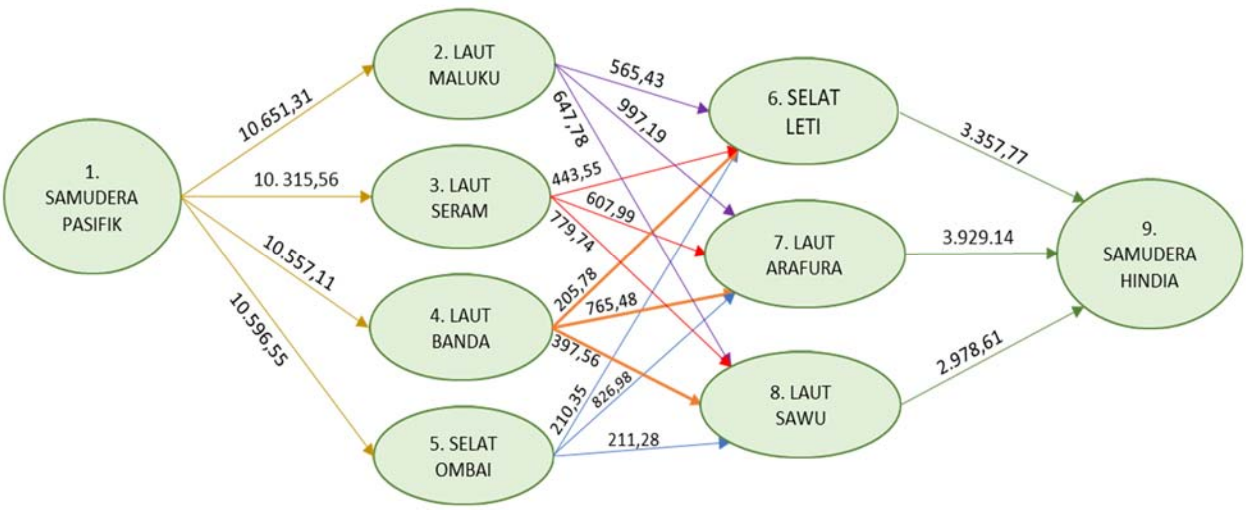

Figure 1. Several alternative routes from the Pacific Ocean to the Indian Ocean

Source: Own Data Processing Results

In Figure 1 there are several alternative routes from the Pacific Ocean to the Indian Ocean which are colored to make it easier to group the stages as shown in Figure 2. Stage x_3 namely the Leti Strait, Arafura Sea, and Sawu Sea to the Indian Ocean are colored green on the route. Phase x_2, namely the Maluku Sea area towards the Indian Ocean via the Leti Strait, the Arafura Sea, and the Sawu Sea is colored purple on the route. Furthermore, the Seram Sea to the Indian Ocean through the Leti Strait, the Arafura Sea, and the Sawu Sea are colored red on their route. Then the Banda Sea to the Indian Ocean via the Leti Strait, the Arafura Sea and the Sawu Sea are colored orange on their route. Then the Ombai Strait to the Indian Ocean via the Leti Strait, the Arafura Sea, and the Sawu Sea are colored blue on their route. Phase x_1, namely the Pacific Ocean area to the Indian Ocean via the Maluku Sea, Seram Sea, Banda Sea, and the Ombai Strait colored gold on the route. The existing path graph is first segmented while finalizing the solution to identify the shortest path or route and get the optimal solution at each stage. Figure 2 shows there are 3 stages from the Pacific Ocean to the Indian Ocean on the shipping chart.

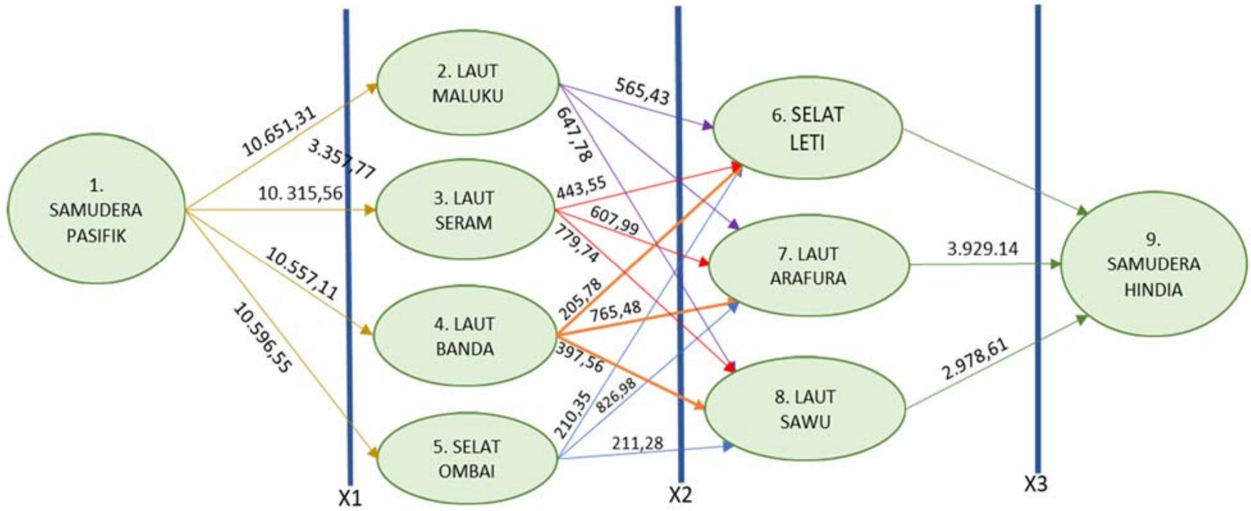

Figure 2. Grouping of the 3 stages on the shipping chart from the Pacific Ocean to the Indian Ocean

Source: Own Data Processing Results

To determine the best route from the Pacific Ocean to the Indian Ocean, there are 2 (two) things that need to be done, namely:

1. In stage n, select the decision variable x_n (n=1,2,3) as the area to be covered. So the total route is $x_1\rightarrow$Pasific Ocean and $x_3\rightarrow$ Indian Ocean.
2. When the browser arrives at state (s), ready to proceed to stage n, selects f_n (s, x_n) as the total policy cost of the next stage, and selects x_n s as the next destination.

In the s condition and n step, use x_n* as any minimum value of f_n (s, x_n), use f_n* (S) as the minimum value of f_n (s, x_n). So, f_n* (S) = min f_n (s, x_n), = f_n $(s,x_n{*})$, with f_n (s, x_n) is the current cost of stage n, plus the cost of the next stage, namely stage n+1 and so on, with the equation f_n (s, x_n)= $\mathrm{C}_s(x_n)$ + $f_{n+1}{*}(x_n)$.

In the final stage n=3, the journey is fully determined only by the current conditions s, namely the area of the Leti Strait, Arafura Sea, Sawu Sea and the final destination is the Indian Ocean. So f_n*(s, Indian Ocean) = C_s(Indian Ocean). In the final stage n=3, the results are shown in Table 1.

Table 1. Stage 3

$f_3\ (s) = C_{sx3}$					
11. Indian Ocean					
x_3 \ s_3	Upper	Middle	Lower	$f_3\ (s_3)$	x_3*
6. Leti Strait			3.357,77 + 0	3.357,77	6
7. Arafura Sea		3.929,14 + 0		3.929,14	7
8. Sawu Sea	2978,61 + 0			2.978,61	8

Table 1 shows that explorers have arrived at the Leti Strait, Arafura Sea, Sawu Sea. Then the feasible solution is x_3 = Indian Ocean.

At stage X=2, the journey requires some calculations. When explorers arrived at the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait. Travel can be made through the Leti Strait, Arafura Sea, Sawu Sea, with the costs in this stage 2 being C_F (Leti Strait)=3.357,77 atau C_F (Arafura Sea)=3.929,14 dan C_F (Sawu Sea)=2.978,61. n the final stage n=3 the calculation results are shown in Table 2.

Table 2. Stage 2

$f_2\ (s, x_2) = C_{sx2} + f_3\ (x_2)$					
6. Leti Strait, 7. Arafura Sea, 8. Sawu Sea					
x_2 \ s_2	Upper	Middle	Lower	$f_2\ (s_2)$	x_2*
2. Maluku Sea	565,43 + 3.357,77 = 3.923,2	997,19 + 3.929,14 = 4.926,33	647,78 + 2.978,61 = 3.626,39	3.626,39	8
3. Seram Sea	443,55 + 3.357,77 = 3.801,32	607,99 + 3.929,14 = 4.537,13	779,74 + 2.978,61 = 3.758,35	3.758,35	8
4. Banda Sea	205,78 + 3.357,77 = 3.563,55	765,48 + 3.929,14 = 4.694,62	397,56 + 2.978,61 = 3.376,17	3.376,17	8
5. Ombai Strait	210,35 + 3.357,77 = 3.568,12	826,98 + 3.929,14 = 4.756,12	211,28 + 2.978,61 = 3.189,89	3.189,89	8

The calculation process in Table 2 is a voyage to the Indian Ocean through the area shown in the row and through the area shown in the column. The amount of the existing costs, the details are as follows:

a. Maluku Sea – Leti Strait = 3.923,2

b. Maluku Sea – Arafura Sea = 4.926,33

c. Maluku Sea – Sawu Sea = 3.626,39

d. Seram Sea – Leti Strait = 3.801,32

e. Seram Sea – Arafura Sea = 4.537,13

f. Seram Sea – Sawu Sea = 3.758,35

g. Banda Sea – Leti Strait = 3.563,55

h. Banda Sea – Arafura Sea = 4.694,62

i. Banda Sea – Sawu Sea = 3.376,17

j. Ombai Strait – Leti Strait = 3.568,12

k. Ombai Strait – Arafura Sea = 4.756,12

l. Ombai Strait – Sawu Sea = 3.189,89

From table 2, the most optimal (smallest) value is obtained, namely the Ombai Strait - Sawu Sea with a value of 3.189,89.

The area that can be calculated at stage X=1 is the Pacific Ocean taking into account the minimum value in Table 2. Then the distance from the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait gets the cost value shown in Table 3.

Table 3. Stage 1

$f_1\ (s, x_1) = C_{sx1} + f_2\ (x_1)$						
s_1 / x_1	2. Maluku Sea	3. Seram Sea	4. Banda Sea	5. Ombai Strait	$f_1\ (s_1)$	x_1*
1. Pasific Ocean	10.651,31 + 3.626,39 = 14.277,7	10.315,56 + 3.758,35 = 14.073,91	10.557,11 + 3.376,17 = 13.933,28	10.596,55 + 3.189,89 = 13.786,44	13.786,44	5

The calculation process in Table 3 is a voyage to the Indian Ocean through the area shown in the row and through the area shown in the column. The amount of existing costs, the details are as follows:

a. Pasific Ocean – Maluku Sea = 14.277,7

b. Pasific Ocean – Seram Sea = 14.073,91

c. Pasific Ocean – Banda Sea = 13.933,28

d. Pasific Ocean – Ombai Strait = 13.786,44

From table 3, the most optimal (smallest) value is obtained, namely the Pacific Ocean - Ombai Strait with a value of 13.786,44.

From all the table calculations above, the optimal route with the minimum distance is obtained, namely: (1. Pacific Ocean-5. Ombai Strait-8. Sawu Sea-9. Indian Ocean) with the distance from Pacific Ocean-Ombai Strait = 10,596.55. Ombai Strait-Sawu Sea = 211.28. Sawu Sea-Indian Ocean = 2,978.61. So that the total distance = 10,596.55 + 211.28 + 2,978.61 = 13,786.44 Nm. More details can be seen in Figure 3.

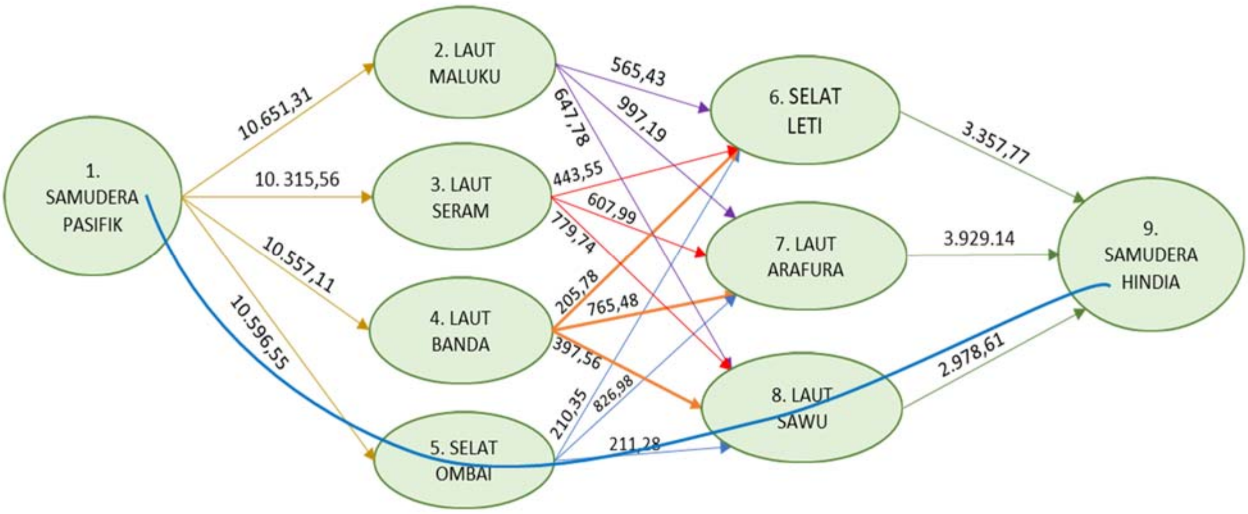

Figure 3. The most optimal route chosen (1. Pacific Ocean-5. Ombai Strait-8. Sawu Sea-9. Indian Ocean)

Source: Own Data Processing Results

IV. CONCLUSION

Based on Indonesian Archipelagic Sea Lanes III, namely the Indonesian Archipelagic Sea Lanes III-A route from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait and Sawu Sea. Indonesian Archipelagic Sea Lanes Branch III B: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea and Leti Strait to the Indian Ocean. Indonesian Archipelagic Sea Lanes Branch III C: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea to the Arafura Sea. Indonesian Archipelagic Sea Lanes Branch III D: from the Pacific Ocean across the Maluku Sea, Seram Sea, Banda Sea, Ombai Strait and Sawu Sea to the Indian Ocean. Indonesian Archipelagic Sea Lanes Branch III E: from the Indian Ocean across the Sawu Sea, Ombai Strait, Banda Sea, Seram Sea and Maluku Sea which are combined into 1 route from the Pacific Ocean to the Indian Ocean resulting in the optimal route with the minimum distance obtained from the smallest value at each stage. The selected route is (1. Pacific Ocean-5. Ombai Strait-8. Sawu Sea-9. Indian Ocean) with a distance from the Pacific Ocean to the Ombai Strait is 10,596.55. The Ombai Strait to the Sawu Sea is 211.28. Sawu Sea to the Indian Ocean is 2,978.61. So that the total voyage distance is 13,786.44 Nautical miles (Nm).

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