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.

1. 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 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. The determination of the TSS is aimed at shipping safety, protection at sea, and avoiding accidents at sea. The traffic separation scheme 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
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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.

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. Therefore, 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: \( bcost(i,j) = \min\{\text{cost}(i-1, i) + c(l,j)\} \)
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:

\[1 \to X_1 \to X_2 \to X_3\]

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:

\[
f_k(s) = \min_{x_k} \{C_{sx_k} + f_{k+1}(x_k)\}, \quad k = 1, 2 \text{ (rekurens)}
\]

Explanation:

- \(x_k\) = decision variables at stage \(k\) \((k = 1, 2)\)
- \(C_{sx_k}\) = 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](image_url). 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 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 blue on their route. Then the Ombai Strait to the Indian Ocean via the Leti Strait, the Arafura Sea, and the Sawu Sea are colored orange on their route. Then 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.

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 $x_1 \rightarrow$ Pacific Ocean and $x_2 \rightarrow$ 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 $x_n$ 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 $f_n (s,x_n^*) = C_2(x_n^*) + f_{n+1}^* (x_{n+1})$.

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 $f_3^* (s, \text{Indian Ocean}) = C_3 (\text{Indian Ocean})$. In the final stage $n=3$, the results are shown in Table 1.
Table 1. Stage 3

<table>
<thead>
<tr>
<th>s_3</th>
<th>Upper</th>
<th>Middle</th>
<th>Lower</th>
<th>f_3(s_3)</th>
<th>x_3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Leti Strait</td>
<td>3.357.77 + 0</td>
<td>3.357.77</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Sawu Sea</td>
<td>2.978.61 + 0</td>
<td>2.978.61</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. In the final stage n=3 the calculation results are shown in Table 2.

Table 2. Stage 2

<table>
<thead>
<tr>
<th>s_2</th>
<th>Upper</th>
<th>Middle</th>
<th>Lower</th>
<th>f_2(s_2)</th>
<th>x_2*</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Ombai Strait</td>
<td>210.35 + 3.357.77 = 3.568.12</td>
<td>826.98 + 3.929.14 = 4.756.12</td>
<td>211.28 + 2.978.61 = 3.189.89</td>
<td>3.189.89</td>
<td>8</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>13.786.44</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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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