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Analysis of Determination of Sea Toll Routes in Eastern Indonesia (KTI) Using Dynamic Programming

Abstract : The sea highway program is part of the fourth pillar, namely the pillars of the maritime economy, infrastructure and increasing welfare, one of the seven pillars of Indonesia's Maritime Policy (KKI). The aim of the Sea Highway Program is to grow the maritime economy by turning the sea into a production and marketi ng center between the Indonesian territory and the islands and surrounding areas. This study aims to analyze the decision of maritime highway routes in Eastern Indonesia Region (KTI) in order to provide the best route with a minimum distance. Four shipping highway routes from Surabaya to Eastern Indonesia Region, namely route T-13 (Tanjung Perak-Rote (Ndao)-Sabu (Biu)-Tanjung Perak), T-14 (Tanjung Perak-Lembata (Lewoleba)-Tabilota/Larantuka- Tanjung Perak), T-15 (Cape Perak-Makassar (Soekarno Hatta)-Jailolo-Morotai (Daruba)-Tanjung Perak), and T-18 (Tanjung Perak-Badas-Bima-Merauke (Kelapa Lima)-Tanjung Perak) combined into 1 (one) route from Tanjung Perak to Merauke, resulting in 1 (one) optimal route with the minimum distance obtained from the smallest value at each stage . This study uses quantitative methods and Multistage Graph problem-solving techniques with Dynamic Programming backward or bottom-up methods, and primary data collection through interviews and secondary data such as: documents/journals/books. The selected optimal route is (Tanjung Perak-Makassar-Tabilota/Larantuka-Sabu (Biu)-Merauke (Kelapa Lima)) with a distance from Tanjung Perak to Makassar is 437 Nm. Makassar to Tabilota/Larantuka is 340 Nm. Tabilota/Larantuka to Sabu (Biu) is 163.8 Nm. Sabu (Biu) to Merauke (Kelapa Lima) is 1261.24 Nm. So that the total shipping distance from Tanjung Perak to Merauke is 2202.04 Nm.

Keywords : sea toll route, eastern indonesia region, dynamic programming

INTRODUCTION

State defense, which is also known as national defense, is a combination of forces (civil and military) of a State that guarantees its territorial integrity, protects its people, and/or safeguards its interests. There are 2 (two) types of national defense groups, namely: military defense and non-military/non-military defense (Indonesian Defense White Paper, 2015). To achieve national goals, Indonesia's state defense is built on a universal defense system. Universal defense essentially refers to defense that applies to all citizens based on their respective roles, duties and obligations. The involvement of every citizen is motivated by a sense of love for the motherland and a shared desire to defend it, including government policies in the field of maritime defense related to the idea of a global maritime axis. According to the Presidential Regulation of the Republic of Indonesia Number 16 of 2017 concerning Indonesian Maritime Policy, Indonesia is actually becoming a sovereign, modern, strong and independent maritime country capable of making a beneficial contribution to the oceans. The Global Maritime Axis is Indonesia's destination. Indonesia's maritime strategy prioritizes national interests, national security and defense,

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as well as regional and global peace (Zaccone et al, 2018; Zhao et al., 2016; Zhang et al, 2016).

Presidential Regulation of the Republic of Indonesia Number 34 of 2022 regulates the Indonesian Marine Policy Action Plan 2021-2025. On February 22, 2022, President Joko Widodo signed this Perpres. Programs and activities under the KKI action plan are arranged in a matrix format according to the seven pillars of the KKI. One of the seven pillars is marine resource management and human resource development. The other six pillars are maritime governance and institutions, maritime economy, improving infrastructure and welfare, management of marine areas and protection of the marine environment, as well as maritime culture and maritime diplomacy. The sea highway program is part of the fourth pillar, namely the pillars of the maritime economy, infrastructure, and increasing welfare, one of the seven pillars of the KKI. In order to increase connections and development in an Indo-centric way, the government is implementing a marine and maritime infrastructure development and development program (Kamalanathsharma et al., 2013; Kusuma et al., 2019; Theocharis et al., 2019).

The aim of the Sea Highway Program is to grow the maritime economy by turning the sea into a production and marketing center between Indonesian territory and the islands and surrounding areas. The guiding concept for the Sea Highway program is to support accessibility with delivery connectivity, availability, and affordability of the different costs needed by the community. The government hopes that the sea highway program can reduce logistics costs which are the main cause of price disparities between Java and other islands. As a result, it is possible to maintain stable prices for commodities and goods across the region. The implementation of the sea highway program from Surabaya to eastern Indonesia with a quantitative approach is the only focus of this study and uses dynamic programming calculations. The purpose of this study is to analyze the determination of sea toll routes in Eastern Indonesia (KTI) to obtain the optimal route with the minimum mileage.

MET ODE

Multistage Graph problem solving techniques with Dynamic Programming and primary data collection through interviews and secondary data such as: documents/journals/books. In this study the authors use the Dynamic Programming method backward or bottom - up . _ There are several important things in the backward method, namely:

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

Calculation of dynamic programming or *dynamic programming backward* method , namely calculating the distance backwards (from *source*). Let X_1, X_2, X_3, X_4be vertices 1 visited at step *k* (*k* = 1, 2, 3, 4). Then the route to be followed is: 1→ $X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_4$in this case X_4= 11. Merauke. Step (k) is the procedure for selecting the next node destination (there are 4 stages). Graph nodes represent the state(*s*) connected to each step. Shortest route from state (*s*) toX_4 on step *k* is represented by the recurrence relationship shown below :

$f_4(s) = C_{sx4}$(Base)

$f_k(s) = \min_{xk} \{C_{sxk} + f_{k+1}(x_k)\}$, k = 1,2,3 (recurrences)

Information:

x_k= decision variable at stage *k* (*k* = 1, 2, 3)

C_{sxk}= weight (*cost*) side from *s* tox_k

$f_k(s, x_k)$ = total weight of the path from s to x_k

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

The purpose of *backward* dynamic programming is to get $f_1(1)$ by searching for $f_4(s)$, $f_3(s)$, $f_2(s)$ first .

RESULTS AND DISCUSSION

In this study, it was limited to 4 sea highway routes from Surabaya to Eastern Indonesia, namely T-13 (Tanjung Perak-Rote (Ndao)-Sabu (Biu)-Tanjung Perak) using the KM ship. Kendhaga Nusantara 11, T-14 (Tanjung Perak-Lembata (Lewoleba)-Tabilota/Larantuka-Tanjung Perak) using the KM ship. Kendhaga Nusantara 7, T-15 (Cape Perak-Makassar (Soekarno Hatta)-Jailolo-Morotai (Daruba)-Tanjung Perak) using the KM ship. Nusantara 3 Logistics, and T-18 (Tanjung Perak-Badas-Bima-Merauke (Kelapa Lima)-Tanjung Perak) use the KM ship. Logistik Nusantara 2 which will be combined into 1 route from Tanjung Perak to Merauke. So as to produce several alternative routes, in this case the author provides 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. The details of the route numbering are: (1) Cape of Silver; (2) Makassar (Soekarno Hatta); (3) Jailolo; (4) Morotai; (5) Lembata (Lewoleba); (6) Tabilota/Larantuka; (7) Rote (Ndao); (8) Crystal methamphetamine (Biu); (9) Badass; (10) Bima; (11) Merauke (Kelapa Lima).

The following shows several alternative routes for Tanjung Perak to Merauke from a combination of the 4 sea highway routes, namely T-13, T-14, T-15 and T-18 using dynamic programming calculations, as shown in Figure 1.

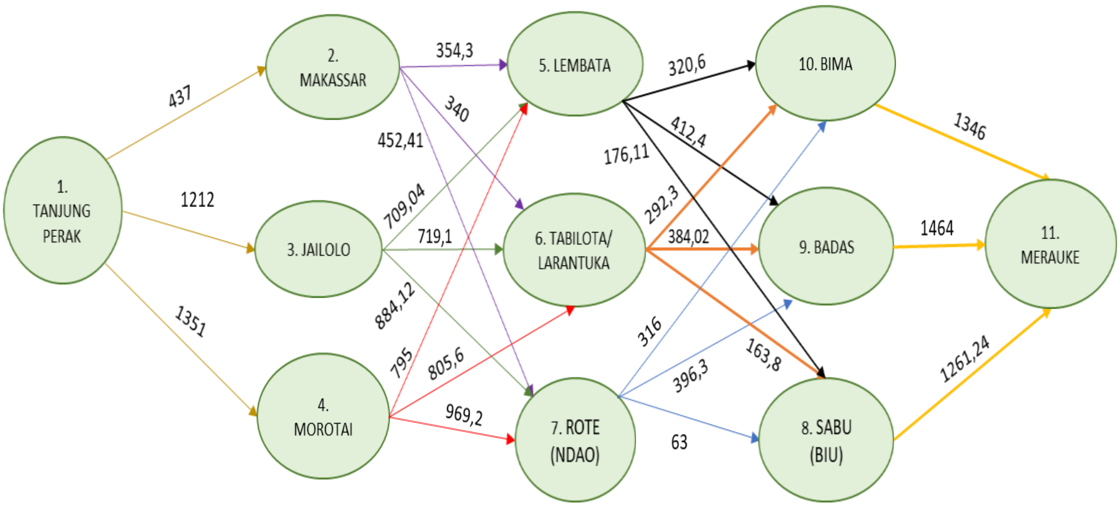

Figure 1. Several alternative routes from Tanjung Perak to Merauke

In Figure 1 there are several alternative routes from Tanjung Perak to Merauke which are colored to facilitate the grouping of stages as shown in Figure 2. Stagesx_4 namely the Bima, Badas, and Sabu (Biu) areas to Merauke are colored yellow on the route. Stagex_3 namely the Lembata area to Merauke via Bima, Badas, and Sabu (Biu) are colored black on the route. Then Tabilota/Larantuka headed for Merauke via Bima, Badas, and Sabu (Biu) colored orange. Then Rote (Ndao) goes to Merauke via Bima, Badas, and Sabu (Biu) is colored blue on the route. The stage $x_2$is the Makassar area to Merauke via Lembata, Tabilota/Larantuka, Rote (Ndao) is colored purple on the route. Then Jailolo headed for Merauke via Lembata, Tabilota/Larantuka, Rote (Ndao) was given a green color on the route. Then Morotai headed for Merauke via Lembata, Tabilota/Larantuka, Rote (Ndao) was colored red on the route. The stage x_1, namely the Tanjung Perak area to Merauke via Makassar, Jailolo, Morotai, is 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 4 stages from Tanjung Perak to Merauke on the shipping chart.

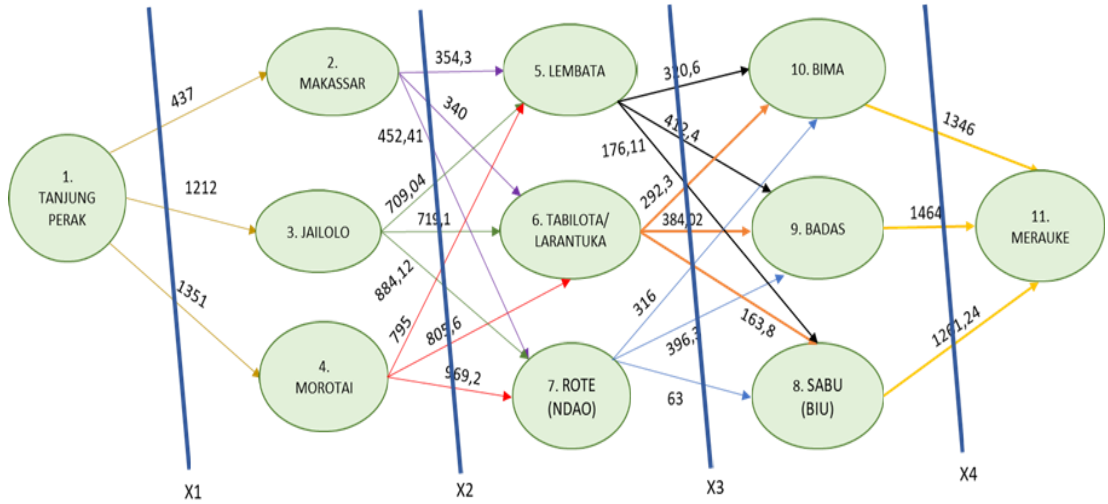

Figure 2. Grouping of 4 stages on the shipping map from Tanjung Perak to Merauke

To determine the best route from Tanjung Perak to Merauke , there are 2 (two) things that need to be done , namely:

1. In stage n, choose a decision variablex_n (n=1,2,3,4) as the area that must be taken. So the total route is x_1→Tanjung Perak and Merauke x_4→.
2. When the tracer/browser arrives at state s, ready to proceed to stage n, select (f_ns) , $x_n$as the total policy cost of the next stage, and choose x_n as the next goal .

In condition s and n step, use $x_n{}^*$ as any minimum value $f_n(s, x_n)$, use it $f_n{}^*$ (S) as the minimum value of $f_n(s, x_n)$. So, $f_n{}^*$ (S) = min $f_n(s, x_n)$, = $f_n(s, x_n{}^*)$, where $f_n(s, x_n)$ is the current cost at stage n, plus the cost of the next stage, namely stage n+1 and so on, with the equation $f_n(s, x_n) = C_s(x_n) + f_{n+1}{}^*(x_n)$. In the final stage n=4, the trip is completely determined only by the current s conditions, namely the Bima, Badas, Sabu (Biu) area and the final destination is Merauke. So $f_n{}^*(s$, Merauke)= C_s(Merauke). In the final stage n=4, the results are shown in Table 1 .

Table 1. Stage 4

		$f_4(s) = C_{sx4}$			
		11 . Merauke			
x_4 \ s_4	On	Middle	Lower	$f_4(s_4)$	$x_4{}^*$
10 .Bima			1346 + 0 = 1346	1346	10
9.Badas _		1464 + 0 = 1464		1464	9
8 .Sabu (Biu)	1261.24 + 0 = 1261.24			1261,24	8

Table 1 shows that explorers have arrived at Bima, Badas, and Sabu (Biu). Then the *feasible solution* is x_4 = Merauke. At stage X=3, the journey requires some calculations. When explorers arrived at Lembata, Tabilota/Larantuka, Rote (Ndao). The trip can be made via Bima, Badas, and Sabu (Biu), with the costs in stage 3 being C_F(Bima)=1346 or C_F(Badas)=1464 and C_F(Sabu (Biu))=1261.24. In the final stage n = 3 the calculation results are shown in Table 2.

Table 2. Stage 3

$f_3(s, x_3) = C_{sx3} + f_4(x_3)$					
10 . Bima, 9. Badas, 8. Sabu (Biu)					
s_3 / x_3	On	Middle	Lower	$f_3(s_3)$	x_3 *
5 . Lembata	320.6 + 1346 = 1667	412.4 + 1464 = 1876.4	176.11 + 1261.24 = 1437.4	1437, 4	8
6 . Tabilota / Larantuka	292.3 + 1346 = 1638.3	384.02 + 1464 = 1848.02	163.8 + 1261.24 = 1425.04	1425. 04	8
7 . Rote (Ndao)	316 + 1346 = 1662	396.3 + 1464 = 1860.3	63 + 1261.24 = 1324.24	1324, 24	8

The calculation process in Table 2 is the voyage to Merauke 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:

1. Lembata – Bima = 1667
2. Lembata – Badas = 1876.4
3. Lembata – Savu (Biu) = 1437.4
4. Tabilota/Larantuka – Bima = 1638.3
5. Tabilota/Larantuka – Badas = 1848.02
6. Tabilota/Larantuka – Methamphetamine (Biu) = 1425.04
7. Rote (Ndao) – Bima = 1662
8. Rote (Ndao) – Badas = 1860.3
9. Rote (Ndao) – Methamphetamine (Biu) = 1324.24

From Table 2, the most optimal (smallest) value is obtained, namely Rote (Ndao)-Sabu (Biu) with a value of 1324.24. Areas that can be calculated at stage X=2 are Makassar, Jailolo and Morotai by taking into account the minimum values in Table 2. Then the distances from Lembata, Tabilota/Larantuka, and Rote (Ndao) get the cost values shown in Table 3.

Table 3. Stage 2

$f_2(s, x_2) = C_{sx2} + f_3(x_2)$					
5. Lembata , 6. Tabilota/Larantuka . 7. Rote (Ndao)					
s_2 / x_2	On	Middle	Lower	$f_2(s_2)$	x_2 *
2. Makassar	354.3 + 1437.4 = 1792	340 + 1425.04 = 1765.04	452.41 + 1324.24 = 1777	1765.0 4	6
3. Jailolo	709.04 + 1437.4 = 2146.44	719.1 + 1425.04 = 2144.14	884.12 + 1324.24 = 2208.4	2208,4	7
4. Morotai	795 + 1437.4 = 2232.4	805.6 + 1425.04 = 2231	969.2 + 1324.4 = 2294	2231	6

The calculation process in Table 3 is the voyage to Merauke 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:

1. Makassar – Lembata = 1792
2. Makassar – Tabilota/Larantuka = 1765.04
3. Makassar – Rote (Ndao) = 1777
4. Jailolo – Lembata = 2146.44

5. Jailolo – Tabilota/Larantuka = 2144.14
6. Jailolo – Rote (Ndao) = 2208.04
7. Morotai – Lembata = 2232.4
8. Morotai – Tabilota/Larantuka = 2231
9. Morotai – Rote (Ndao) = 2294

From table 3, the most optimal (smallest) value is obtained, namely Makassar-Tabilota/Larantuka with a value of 1765.04. The area to be calculated at stage X=1 is Tanjung Perak taking into account the minimum value in Table 3. Then the distance from Makassar, Jailolo, and Morotai is the cost value shown in Table 4.

Table 4. Stage 1

$f_1(s, x_1) = C_{sx1} + f_2(x_1)$					
2. Makassar, 3. Jailolo, 4. Morotai					
x_1 \ s_1	On	Middle	Lower	$f_1(s_1)$	x_1^*
1. Cape of Silver	437 + 1765.04 = 2202.04	1212 + 2144.14 = 3356.14	1351 + 2231 = 3582	2202.04	2

The calculation process in Table 4 is the voyage to Merauke 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:

1. Tanjung Perak-Makassar (Soekarno Hatta) = 2202.04
2. Tanjung Perak-Jailolo = 3356.14
3. Tanjung Perak-Morotai = 3582

From Table 4, the most optimal (smallest) value is obtained, namely Tanjung Perak-Makassar with a value of 2202.04 . From all the table calculations above, the optimal route with the minimum distance is obtained, namely: (1. Tanjung Perak-2.Makassar-6.Tabilota/Larantuka-8.Sabu (Biu)-11.Merauke (Kelapa Lima)) with a distance of Tanjung Perak-Makassar = 437, Makassar-Tabilota/Larantuka = 340, Tabilota/Larantuka-Sabu (Biu) = 163.8, Savu (Biu)-Merauke (Kelapa Lima) = 1261.24. So the total distance = 437+340+163.8+1261.24= 2202.04 Nm. More details can be seen in Figure 3.

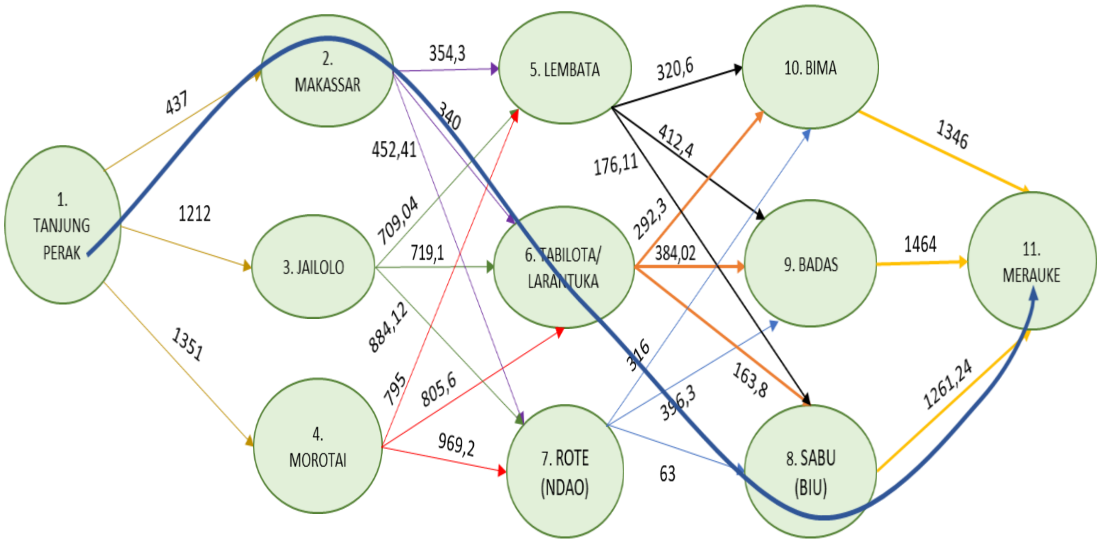

Figure 3. The most optimal route chosen (1. Tanjung Perak - 2. Makassar - 6. Tabilota/Larantuka - 8. Sabu (Biu) - 11. Merauke (Kelapa Lima))

CONCLUSION

Based on the 4 (four) sea highway routes from Surabaya to Eastern Indonesia, namely the T-13 route (Tanjung Perak-Rote (Ndao)-Sabu (Biu)-Tanjung Perak), T-14 (Tanjung Perak-Lembata (Lewoleba)- Tabilota/Larantuka-Cape of Silver), T-15 (Cape of Silver-Makassar (Soekarno Hatta)-Jailolo-Morotai (Daruba)-Tanjung Perak), and T-18 (Cape of Silver-Badas-Bima-Merauke (Kelapa Lima)- Tanjung Perak) which is combined into 1 (one) route from Tanjung Perak to Merauke produces the optimal route with the minimum distance obtained from the smallest value at each stage. The selected route is (Tanjung Perak-Makassar-Tabilota/Larantuka-Sabu (Biu)-Merauke (Kelapa Lima)) with the distance from Tanjung Perak to Makassar which is 437, Makassar to Tabilota/Larantuka which is 340, Tabilota/Larantuka to Sabu (Biu) which is 163.8, and Sabu (Biu) to Merauke (Kelapa Lima) which is 1261.24. So that the total voyage distance is 2202.04 Nautical miles (Nm).

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