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Modeling of Ship Sailing Patterns in Maluku to Support the Sea Highway

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Abstract. The low level of the ships' load factor (LF) in the Maluku archipelago region can be attributed to the lack of compatibility between ship loads and the available cargo potential in the region. Therefore, the implementation of an optimal sailing pattern is required. The sailing pattern of the ship can be optimal if it can carry cargo according to the available potential because this circumstance can improve sailing efficiency. The purpose of this study is to determine the optimal sailing pattern according to the potential of the Maluku region to support the maritime highway program in Maluku. Firstly, Fuzzy Multi-Attribute Decision Making (Fuzzy MADM) was used to determine the optimal model of ship operating patterns in the Maluku archipelago region. Secondly, a time series correlation analysis was conducted to identify patterns and correlations among the data. This analysis provides insights into the relationships between different variables over time. Thirdly, another analysis was performed using the Cobb-Douglas production theory to identify the influencing variables on the number of ship visits (Call), ship deadweight tonnage (DWT), and ship cargo potential (Q_S). The results show that the selection of the best ship operating pattern using the recommended Fuzzy MADM method is a mixed sailing pattern, namely regular and tramper sailing. In addition, increasing the productivity of Q_S_R+T and DWT ships will have a positive effect on ship visits in a certain time unit. If the potential growth of positive cargo Q_S_R+T > Call and DWT, then it is important to build new ships with optimal DWT so as to increase ship efficiency in supporting the maritime highway program. This research provides a significant contribution to the development of an efficient and sustainable national logistics system, as well as being a policy reference for decision-making related to the sailing pattern and the development of the maritime highway program in Maluku.

Keywords: Archipelago; Fuzzy MADM; Maritime highway; Sailing patterns

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1. Introduction

The geographical condition of an area greatly influences the development of transportation and tends to be influenced by the characteristics of differences in potential natural resources, human resources, and the availability of existing infrastructure. This condition requires a different development approach for each island region, especially in the Maluku region. However, sea transportation infrastructure, such as ships, ports, networks, and ship operating patterns, must be developed synergistically as the main support for regional development in order to provide optimal services (Tukan *et al.*, 2015). Efficiency is a key condition in operating ships, both passenger ships and cargo ships. Therefore, efficiency becomes the goal of planning the island's transportation system to support the maritime highway service network (Nurkholis *et al.*, 2016).

The operational cycle of sea transportation is determined by the availability of the cargo to be transported, the shipping network and ships, as well as adequate port infrastructure. If one of the parameters does not work optimally, it will have an impact on decreasing other operational performance, so it can be described as a multiplier effect of sea transportation (Tukan *et al.*, 2012), (Jaal and Abdullah, 2012). Transportation has a strong positive influence on economic development, and increased production can be directly related to increased transportation (Tukan, 2021).

The regular shipping pattern consists of fixed routes and schedules which are very suitable for industrial areas with stable production schedules and cargo quotas. Meanwhile, shipping patterns with irregular routes or based on certain port points to other port points are usually applied to non-container route ships that are always changing. Therefore, a mixed shipping pattern between Regular and Tramper can increase the amount of cargo carried. From the results of observations, differences were found in shipping patterns in the archipelago. Therefore, the purpose of this research is to evaluate the efficiency of shipping patterns in Maluku to support the maritime highway policy in Indonesia.

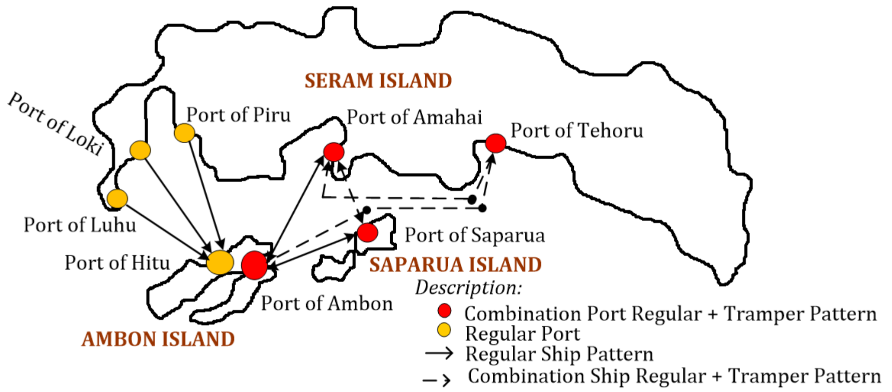

Figure 1 Voyage Pattern of Ships in Maluku

In this study, the pattern of sailing in the island region of Maluku Province can be seen in Figure 1. The illustration in Figure 1 shows that the port of Luhu, Loki port, and Piru port to Hitu port is carried out regularly. On the other hand, at Saparua port, Amahai port, Tehoru port, to Tulehu port, sailing is carried out in combination between regular and tramper. Therefore, it is necessary to analyze the feasibility of the region's economic potential to ensure the most efficient industrial policy (Zhogova, Zaborovskaia, and Nadezhina, 2020) so that it can also be carried out on industrial shipping, also the importance of interaction between island regions to drive regional economic growth (Kozonogova, Dubrovskaya, and Dubolazova, 2020).

The transportation network has a positive causal effect on the rate of per capita growth in all sectors. Therefore, the availability of infrastructure must have a significant impact on the performance of the transportation network and changes in economic behavior. This argument relies on the simple logic that individuals first need to have access to transportation in order to benefit from it (Banerjee, Duflo, and Qian, 2020). The maritime infrastructure approach model can be used to measure economic growth with infrastructure improvements that can ensure loading and unloading operations, reduce port operating costs and increase product competitiveness on the island (Tukan *et al.*, 2015). Thus, it can be said that the maritime sector is an important economic route. It is also considered a window to support trade and attract investment (Esmail, 2016). All the above explanations, of course, must be supported by a good ship sailing pattern.

The hypothesis in this study found that there is a relationship between sailing patterns and ship efficiency, so this study will identify the parameters of sailing patterns and ship operating efficiency in typical island areas. By taking the port of Hitu, Luhu port, Loki port and Piru port as well as Saparua port, Amahai port, Tehoru port and Tulehu port, as examples of cases where the correlation between dimensions of sea transport and ship sailing patterns, dead weight tonnage (DWT), number of visits ship (Call) per unit time and potential shipload (Q_S) have an impact on the operational efficiency of ships on an island.

In general, the operation of ships on small islands has its own unique characteristics. Some operations are carried out regularly, while others are conducted through trampers, or sometimes a combination of both regular and tramp services. Therefore, in this research, a study on the modeling of ship sailing patterns at of ports will be carried out to support Indonesia's maritime highway policy. Determination of ship operations will be selected based on four criteria, namely cargo depending on seasonal factors (Cr1), industrial product cargo (Cr2), annual average shipload above 60% (Cr3), and ship visits per unit time (Cr4). Therefore, determining the pattern of ship operation in these small islands is a complex problem, so it is necessary to develop a decision support system that will provide the best decision solution based on the consideration of several predetermined criteria.

Based on previous research related to multi-criteria decision-making, many researchers have done this, as was done by (Lumaksono, 2018) for selecting suitable fishing gear for fishermen on Madura Island using Fuzzy AHP and Fuzzy TOPSIS. (Hozairi *et al.*, 2019) Regarding the study of the most influential factors on Indonesian maritime security using the Fuzzy Analytical Hierarchy Process. (Tukan *et al.*, 2020) regarding a decision support system for determining the location of floating docks in the Maluku Islands using AHP-TOPSIS. (Amelia, Lathifah, and Yasa, 2021; Santos, Portugal, and Ribeiro, 2021) on evaluating the performance of highway concessions through public-private partnerships using a fuzzy multi-criteria decision-making procedure. (Xu *et al.*, 2022), (Goodarzi, Abdollahzadeh, and Zeinalnezhad, 2022) on risk assessment for environmentally friendly integrated energy systems using Fuzzy MCDM. This problem can be solved by combining the multi-criteria decision-making method and an intelligent system, namely Fuzzy SAW. Based on previous research studies on the application of the Fuzzy-SAW method to solve complex problems to determine the most influential criteria and the most appropriate decision alternatives, so that in the problem of determining ship operating patterns in the small islands, the Fuzzy-SAW method is chosen as a tool for resolve decision-making problems related to the assessment of ship operating models in existing archipelagic areas. For this reason, a sailing pattern is needed that can increase the load factor (LF) and sailing efficiency on small islands. (Wang and Wang, 2011) concluding in the future how shipping companies form global sailing networks.

2. Methods

The research methodology consists of three steps. The first step is to analyze sailing patterns in archipelago ports to support maritime highway policy using Fuzzy-SAW. The second step is to analyze the correlation between the increase in the number of ship calls (Call) and deadweight tonnage (DWT), potential ship loading (QS) using time series methods. The final step is to analyze the performance of the ship's sailing pattern using the Cobb-Douglass production theory.

The operation of ships on small islands is characterized by its unique attributes. Some operations occur on a regular basis, while others utilize trampers. Alternatively, a combination of regular services and trampers is implemented. Regular patterns often occur in large island areas where goods are produced from industrial products and are carried out routinely and on a scheduled basis (such as on the large island of Java). Meanwhile, the tramper pattern only occurs in island areas (such as the Maluku Islands) where production results come from the traditional agricultural, plantation and livestock sectors where the results are more influenced by seasons or natural factors (Tukan, 2021). This problem can be described as a causal relationship between shipping patterns and cargo availability which can be modeled as shown in Figure 2.

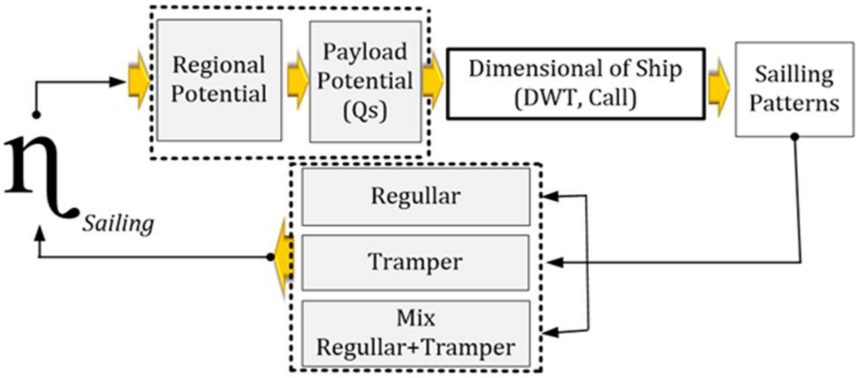

Figure 2 Efficiency Model of Sailing Patterns in the Island Region

The efficiency of sailing (η sailing) is determined by the size of the potential area and the potential for cargo that is in synergy with the ship's DWT and ship's Call. From this point, the ship pattern is determined as more efficient in terms of operation and optimal related to income to ensure the continuity of ship operations. For this reason, the ship pattern can be chosen whether the ship operates with a regular ship pattern, tramper and a combination of regular and tramper. While choosing a ship pattern, the Fuzzy-SAW method can be implemented.

2.1. Modelling of ship operation patterns using Fuzzy MADM

More efficient and optimal modeling of sailing patterns can be obtained using the fuzzy method, where the information is full of uncertainty. However, through such a method, fuzzy numbers can employ arithmetical operations (Kumar, Maheshwari, and Sharma, 2015). The basic concept of a fuzzy decision support system is rooted in the relationship between elements within the system, which is represented as a set that captures the relationship between two or more sets, where the ship's operating pattern is determined by the availability of cargo. It can be done using a multi-attribute decision making (MADM) approach by evaluating alternatives m Ai (i = 1,2,..n) in which each criterion is Cj (j = 1, 2,… n) and each attribute is independent of one another. The decision matrix for each alternative especially for the attribute X = attribute for the ship's operating pattern is described in equation 1.

$$X = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \cdots & \dots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix}, \quad (1)$$

where X_{ij} is the ith performance rating on attribute j. The weight value shows the level of importance relative to the attribute, which is described as W as shown in equation 2.

$$W = (W_1, W_2, ..., W_n), \quad (2)$$

Where the pattern of shipping efficiency is determined by the load factor (LF) of the ship in relation to the cargo being transported. If LF < 60, then the ship will lose money. Moreover, it will not be able to bear its operational costs. For this reason, an alternative optimal sailing pattern is sought. The optimal sailing pattern is the number of ship visits (Call) required for cargo per unit time with LF > 60% (Tukan *et al.*, 2012).

Ship operation decision-making in which preference information about alternatives provided by the decision maker is represented in two different formats, namely multiplication preference relationship and fuzzy preference relationship, in order to minimize the gap between collective opinion and preference relationship. The opinions of each decision maker were used to integrate the two different formats of preference relationships and to calculate the collective rating scores of the alternatives. Thus the ranking of the most desirable alternative or alternative (X) is obtained directly from the calculated collective ranking value. Next, numerical examples are also used to illustrate the application of the proposed approach.

Performance rating (X) and weighted score (W) are the main values representing an absolute preference for decision-making. The ranking process is carried out by using multi attributes decision-making (MADM) to obtain the best-obtained alternative based on the overall preferences given. Simple Additive Weighting (SAW) is one of the methods in MADM that is used to normalize the decision matrix (X) to a scale that can be compared with all available alternative ratings associated with equation 3.

$$r_{ij} = \frac{Xij}{\text{Max } Xij} \text{ if j is the benefit attribute, and}$$
$$r_{ij} = \frac{\text{Min } Xij}{Xij} \text{ if j is the cost attribute,} \quad (3)$$

Where r_{ij} = Normalized performance rating of the A_i alternatives on the attribute C_j; i = 1, 2,…m and j = 1, 2,…m. Equation 3 in this study focuses more on the cost attribute. Then the preference value for each alternative V is given as following equation 4.

$$V_i = \sum_{j=1}^{n} W_j r_{ij}. \quad (4)$$

A larger V_i value indicates that the alternative A_i is preferred. In this study, the ship's operating pattern was selected, where A1 = Regular pattern, A2 = Tramper pattern, A3 = Mixed pattern, and + tramper pattern. The suitability rating of each alternative depends on the level of importance of each criterion assessed with a weight of 1 to 5. Where in this study, 4 criteria were chosen as decision-making materials, including Cr1= cargo that depends on seasonal factors. In the case of a bountiful harvest season, the assigned weights for different harvest conditions are as follows: a weight of 5 for abundant harvests, a weight of 4 for sufficient harvests, a weight of 3 for moderate harvests, a weight of 2 for less substantial harvests, and a weight of 1 for very poor harvests. For Cr2 = cargo of industrial products, if the resulting production takes place continuously, it gets a weight of 5, moderate production weighs 4, moderate production weighs 3, very poor production weighs 2, and the production is very underweight 1. Cr3= shipload per year on average above 60 %. If LF of ship > 80 % by weight 5, LF of ship >70% and <79.9% by weight 4, LF of ship >60 % and < 69.9 % by weight 3, LF of ship > 50 % and < 59.9 % by weight 2, LF ship <50% weight 1. Lastly, about Cr4 = ship visits (Call) per unit time, if ship visits occur every week, a weight of 5, ship visits every month weights 4, ship visits every 3 months weight 3, ship visits every 5 months get a weight of 2, ship visits every 6 months weights 1. The suitability rating of each alternative on each criterion can be followed in Table 1 below.

Table 1 The suitability rating of each alternative on each criterion.

Alternatif	Cr.1	Cr.2	Cr.3	Cr.4
The Reguler	3	4	2	2
Tramper	3	3	3	3
Reguler+Tramper	5	5	4	4

Each value given to each alternative for each criterion is a suitability value according to the weight of its importance so that each given criterion is assumed to be the best criterion. The results of the assessment by experts who are experienced in managing sailing management give preference weights as W = (4, 4, 5, 3). So for that, we can create a match matrix and table as follows:

$$X = \begin{bmatrix} 3 & 4 & 2 & 2 \\ 3 & 3 & 3 & 4 \\ 5 & 5 & 4 & 4 \end{bmatrix}$$

The first step is to normalize the X matrix based on equation 3. The following results are obtained, as in Table 2 below.

Table 2 The results of the normalization of the X matrix are based on equation 3

$r_{11} = 0{,}60$	$r_{21} = 0{,}80$	$r_{31} = 0{,}50$	$r_{41} = 0{,}50$
$r_{12} = 0{,}60$	$r_{22} = 0{,}60$	$r_{32} = 0{,}75$	$r_{42} = 0{,}75$
$r_{13} = 1{,}00$	$r_{23} = 1{,}00$	$r_{33} = 1{,}00$	$r_{43} = 1{,}00$

From Table 2, the normalized matrix R is obtained as follows

$$R = \begin{bmatrix} 0{,}60 & 0{,}80 & 0{,}50 & 0{,}50 \\ 0{,}60 & 0{,}60 & 0{,}75 & 0{,}75 \\ 1{,}00 & 1{,}00 & 1{,}00 & 1{,}00 \end{bmatrix}$$

By using equation (4), the V value is obtained as follows:

$V_1 = (4).(0{,}60) + (4).(0{,}60) + (5).(1{,}00) = 9{,}80,$

$V_2 = (4).(0{,}80) + (4).(0{,}60) + (5).(1{,}00) = 10{,}60,$

$V_3 = (4).(1{,}00) + (4).(1{,}00) + (5).(1{,}00) = 13{,}00$

From the results of calculations using the Simple Additive Weighting (SAW) method, the value of V3 = 13 is the highest, indicating that the ship's operating pattern is suitable for archipelagic areas where production factors tend to come from natural sources such as the agricultural, plantation, forestry, and fisheries sectors. These tend to be influenced by the seasons so the optimal sailing pattern is a sailing pattern that combines a regular sailing pattern and a tramper sailing pattern.

2.2. Ship Visits, Ship Size and Cargo Volume

There is a strong correlation between the increase in the number of ship visits (Call), ship size (DWT) and cargo growth (Q_S), where the greater volume of cargo will have an impact on ship visits and ship size in an area, (Tukan *et al.*, 2015). From statistical data, the increase in the number of ship visits and ship size on cargo growth can be analyzed using econometric methods. The availability of shipload volume described as potential shipload

(Q_S) is able to increase the number of ship visits (Call) and ship size (DWT), and can be modeled as equation (5).

$$Q_S = f\ (\sum \text{Call, DWT}) \quad (5)$$

Therefore, the optimization method can be employed to calculate the availability of maximum Q_S cargo, as well as the number of ship visits (Call) and the load capacity (DWT). The following equation (6) can be written to explain it.

$$\text{Maximum } (Y) = X_1 + X_2 + \ldots.\ X_n \quad (6)$$

where (Y) = Q_S is an objective function.

Goal :

To find the most influential sailing parameters that can provide efficiency to the operational performance of the ship, with the question of how far these variables influence each other.

Variable:

X_1 = number of ship visits (Call),

X_2 = ship load capacity (DWT),

X_3 = the amount of cargo on the ship (Q_S).

Constraint:

If $Q_S \leq$ Call and DWT where Call and DWT are the maximum dimensions in one year, it can be ascertained that the ship's sailing operation is inefficient (LF<60). However, the availability of cargo in an area is largely determined by the production function that is carried out, whether it comes from industries that can guarantee the availability (quota) and continuity of production or agricultural, plantation and fishery products which are more influenced by natural factors and season. Then the availability of charge shows a non-linear production function. It becomes the linear function through a logarithmic transformation. Therefore, the Cobb-Douglas function becomes equation 7.

$$\text{Ln}(Y)=\ln\beta o+\ln\beta_1 X_1+\ln\beta_2 X_2+\ldots..\ln\beta n Xn+\mu \quad (7)$$

whatever ln(Y) = Y*, ln(βo) = βo*, lnX_1 = X_1* then the model will by the following equation 8.

$$Y^* = \beta o^*+\beta_1 X_1^* + \beta_2 X_2^* + \ldots\ldots\beta n Xn^* + \mu, \quad (8)$$

Where the regression coefficient is the quantity of load production elasticity, namely the percentage change in output as a result of a one percent change in input βo and β_1, β_2, ...βn referred to as Call and DWT parameters. βo is the intercept when the value X_1 equals zero. β_1, β_2, ...βn is also known as the slope. Slope states how much the Call changes (β_1), and DWT (β_2), during the load growth rate changes by one unit. In economic mathematics, the amount of elasticity can be obtained by the following equation 9.

$$E_{xi} = \frac{Y}{X_i}\,. \quad (9)$$

AP_{xi} is the average product for the input x (Q_S) which is obtained by the following equation (10).

$$AP_{xi} = \frac{MP_{xi}}{AP_{xi}}\,. \quad (10)$$

Thus the equation for loading and unloading elasticity for input x (QS) is formed as following equation 11.

$$E_{xi} = \frac{MP_{xi}}{AP_{xi}} = \frac{\beta_1\beta_0 x_i^{\beta_1 - 1}}{y/x_i} = \frac{\beta_1 x_i^{-1}\beta_0 x_i^{\beta_1}}{y/x_i} = \frac{\beta_1 x_i^{-1} x y_1}{y} = \beta\,. \quad (11)$$

If in a loading and unloading process at the port: where is the output (Y) = Q_S, an area of unity time (ton), and input (X_i) = a number of the unit time ship visits (Call), so that it is able to carry out a certain amount of cargo per unit time, a ship with a certain carrying capacity (DWT) is needed.

Partially, all variables have a significant effect on economic growth. For every one percent increase in cargo volume (Q_S), ceteris paribus can encourage the growth of ship visits (Call) which can be modeled as depicted in equation 12.

$$\text{Ln } Q_S = \beta_0 + \beta_1 \text{LnCall} + \mu. \quad (12)$$

Here the increase in Q_S also has a strong correlation with the increase in shipload capacity (DWT), which can be modeled equation 13.

$$\text{Ln } Q_S = \beta_0 + \beta_1 \text{LnDWT} + \mu \quad (13)$$

The increase in ship loading capacity (DWT) affects the amount of cargo availability (Q_S) of goods, which can be modeled into equation 14.

$$\text{Ln DWT} = \beta_0 + \beta_1 \text{Ln } Q_S + \mu , \quad (14)$$

Where the Cobb-Douglas production function can be employed to determine the global optimum in selecting the best model for the development of potential cargo in an island area, taking into account transportation dimensions such as Call and DWT, these factors play a crucial role in determining the sailing pattern of ships in small islands.

2.3. Model Analysis

Analysis of sailing patterns using production theory where the sailing performance time series data shown in Figure 3.

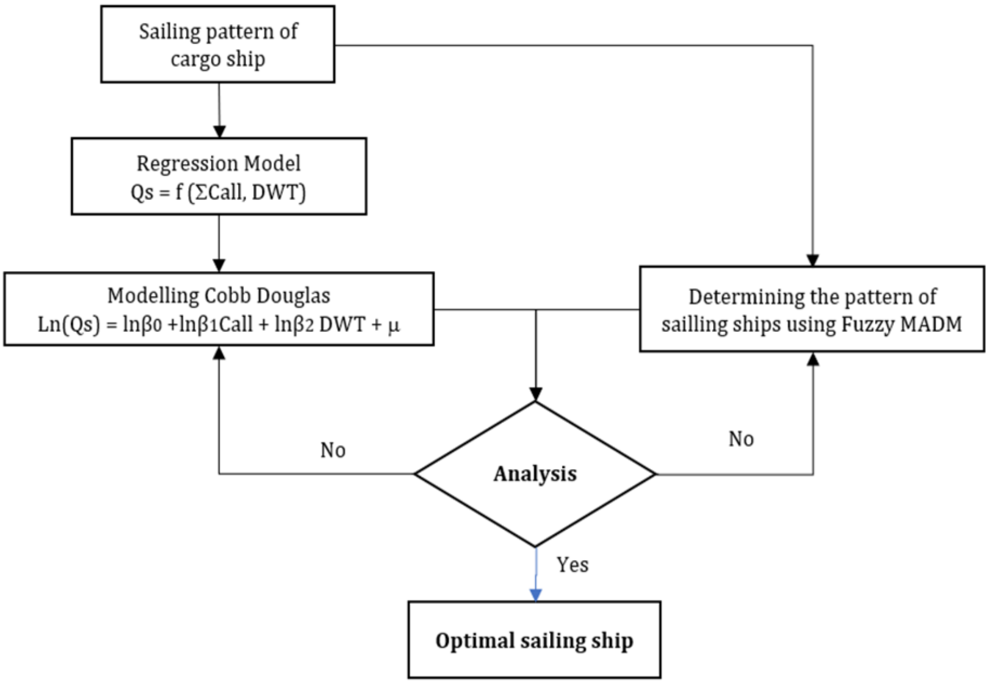

Figure 3 Phase Diagram Analysis

The number of ship visits (Call), ship capacity (DWT) and potential payload (Q_S) are inputs that are processed in the form of multilinear regression and then converted into Cobb Douglas form. This step is an input to find the maximum Q_S condition with minimum Call and DWT. It is also necessary to find the optimal solution for selecting ship sailing patterns with Fuzzy MADM. The above steps are carried out to obtain optimal shipping conditions according to the potentially available shiploads. To calculate the Q_S and the number of call ships needed in a certain period of time and also a certain DWT can be done by using a regression model that is modified on the Cobb Douglass production theory model. The results of the analysis using the two methods above can determine the appropriate shipping pattern for the island region.

2.4. Data

This study uses port performance data (Q_S, Call, DWT) on conditions of sailing that are carried out regularly or combined regular pattern + tramper pattern in the 2011-2021 period in the Maluku archipelago, as shown in Table 3.

Table 3 Transport performance data of ports in Ambon Island

Year	Reguler Pattern (Hitu Port specific data: Luhu, Loki, Piru)			Reguler + Tramper Pattern Mix (Tulehu Port specific data: Saparua, Amahai, Tehoru)		
	Q_S	Call	DWT	Q_S_R+T	Call	DWT
2011	2.111	737	11.876	23.664	728	21.840
2012	2.260	749	12.090	29.680	742	22.260
2013	2.733	777	12.268	33.840	750	24.064
2014	2.738	786	12.360	38.808	792	25.344
2015	4.370	1.031	19.471	52.624	1.012	35.420
2016*	4.406	1.002	19.750	52.702	1.023	35.455
2017*	4.392	1.042	19.752	54.801	1.037	35.560
2018*	4.405	1.048	19.760	55.014	1.052	37.002
2019*	4.762	1.062	19.802	57.021	1.074	37.105
2020*	4.980	1.095	19.895	57.132	1.098	37.252
2021*	4.810	1.071	19.826	57.094	1.076	37.194

Source: Ministry of Transportation RI Hitu Port RIP document 2016. and *additional data on institutional research at Pattimura University in 2022, which was re-analyzed.

3. Results and Discussion

Results in the growth of cargo, visits and ship capacity that continues to increase every year, analysis of quantitative approaches in answering regional connectivity and efficiency of sailing patterns in supporting the Sea Tol is an illustration of the sailing performance of the Maluku islands at a low-efficiency level, where many shipping companies have to sail by looking for cargo so that there are areas that are not served because ships are not visited. This makes it difficult for the community to bring agricultural, plantation, forestry and fishery products to be marketed. The pattern of regular sailing at the sample port shows an average growth over the last 11 (eleven) years, including: for Call = 0.041%/year, DWT = 0.061%/year and cargo Q_S_R = 0.116% /year. Meanwhile, the mixed regular+tramper sailing pattern at the sample port shows an average growth of 5 (five) years higher than the regular or tramper pattern. For Call = 0.043%/year and DWT = 0.064%/year, it expenses Q_S_R+T = 0.128%/year.

From the description of the sailing pattern above, it can be seen as described in Figure 4 below, where the amount of cargo carried Q_S_R+T is higher than the usual Q_S_R sailing pattern.

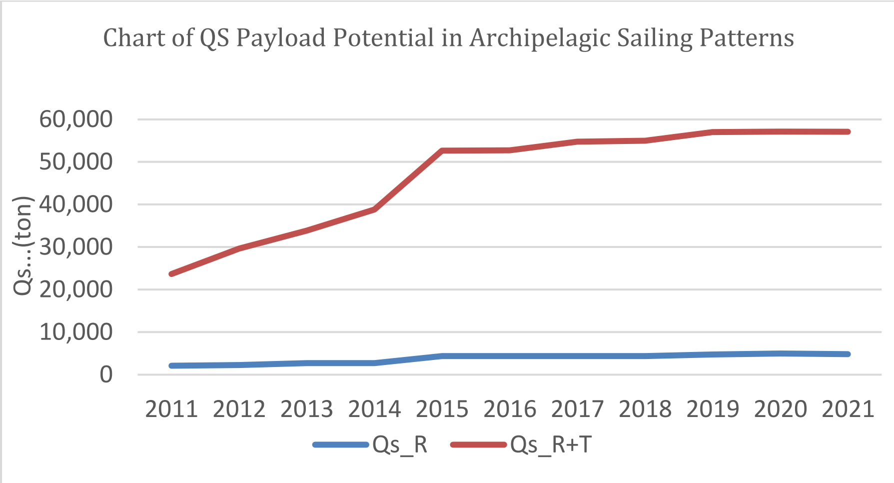

Figure 4 Differences in Q_S Payload Potential in Archipelagic Sailing Patterns

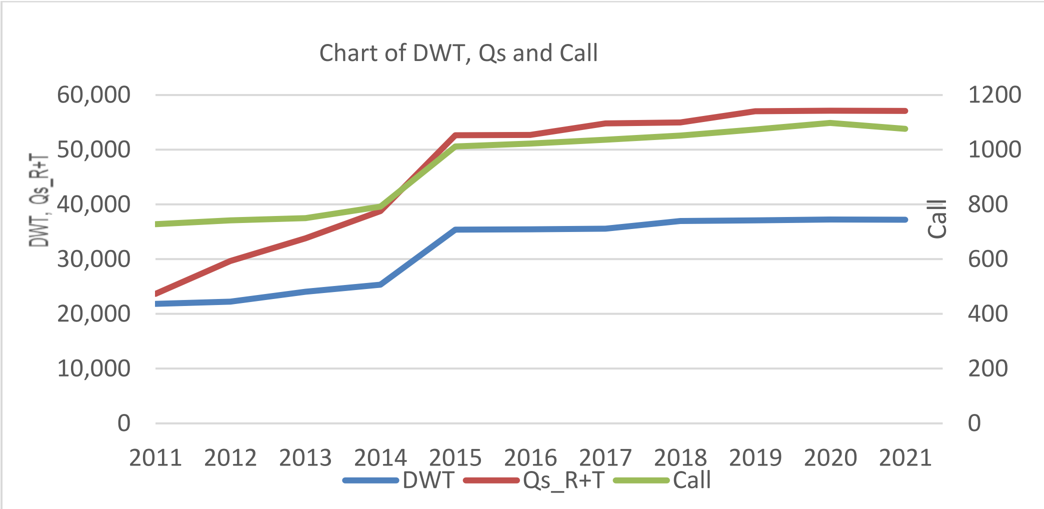

Figure 5 Archipelagic Sailing Pattern Performance

Analysis of the selected sailing pattern is a mixed sailing pattern where on average, there are 3 (three) ships docked at the port (Tulehu Port, Saparua Port, Amahai Port, Tehoru Port). The average size is 35 DWT, with an average payload of 17,687 tonnes/call/port. Figure 5 shows the trend of sailing performance at several ports in the Maluku islands and depicts an insignificant increase. However, the launch of the maritime highway and connectivity by the Indonesian government in 2015 caused a significant increase in 2014–2015. The graph of cargo growth on a mixed pattern Q_S_R+T continues to increase the average number of ship visits per year, fulfilling the need for additional capacity and a number of ships to support the maritime highway.

The results of the analysis between parameters of shipping performance can be seen in Table 4 using Minitab 19. In this table, R^2 is the correlation coefficient which shows how strong the relationship between parameters is, while β0 is the intercept or constant coefficient.

From Table 4, it can be explained from the related parameters that for Call versus Q_S_R+T and DWT, the parameters are known as βo=207.1, β1=0.0007 and β_2 = 0.024. It means that the growth of Q_S_R+T and DWT have a positive effect on Call, and if there is a constant ceteris paribus ,. Then a growth of 1% for Q_S. The DWT will have an impact on changes in Call of Q_S_R+T = 0.001% as well as DWT = 0.024%.

Table 4 Recapitulation Equation Model Parameter Relations between the Q_S_R+T and the Call, DWT. For Regular Mixed sailing Patterns+Trampers

Test Parameters	Equation Model	R^2	β_0
Call vs Q_S_R+T, DWT	Call = β_0 - 0.0007 Q_S_R+T + 0.024 DWT	99.15	207.1
Call vs Q_S_R+T	Call = β_0 + 0.0120 Q_S_R+T	95.98	384.1
Call vs DWT	Call = β_0 + 0.0229 DWT	99.14	216.4
DWT vs Q_S_R+T, Call	DWT = β_0 + 0.1355 Q_S_R+T + 32.35 Call	99.58	-5166
DWT vs Q_S_R+T	DWT = β_0 + 0.5243 Q_S_R+T	97.16	7259
DWT vs Call	DWT = β_0 + 43.17 Call	99.14	-9067
Q_S_R+T vs Call, DWT	Q_S_R+T = β_0 – 16.7 Call + 2.24 DWT	97.20	-8506
Q_S_R+T vs Call	Q_S_R+T = β_0 + 79.85 Call	95.98	-2879
Q_S_R+T vs DWT	Q_S_R+T = β_0 + 1.853 DWT	97.16	-1212

For Call versus Q_S_R+T, the associated parameters are known as β_0=384.1 and β_1= 0.0120. This means that an increase in shiploads will be followed by a growth in ship visits, where if the cargo increases by 1%, the growth in ship capacity will increase by 0.0128%. Meanwhile, Call versus DWT parameters are known as β_0=216.4 and β_1= 0.0229. This means that the increase in DWT will affect the growth of ship visits, where if the DWT increases by 1%, the growth of ship calls will increase by 0.0229%. In such context of the Call and DWT relationship, if the DWT demand increases while the Call for ships is still available in a certain time unit, then the addition of DWT can be done by adding Call up to the maximum point. However, if there is no vessel Call, then it is necessary to build a new ship to meet the growing demand of DWT ships. Likewise, for DWT versus Q_S_R+T and Call known parameters βo=-5166, β_1=0.1355 and β_2=32.35 it means that the growth of Q_S_R+T and Call has a positive effect on DWT, and if there is a constant ceteris paribus, then growth of 1% for Q_S_R+T and Call will have an impact on changes in Call of Q_S_R+T=0.1355% as well as Call=32.35%.

For DWT versus Q_S_R+T with parameters of βo=7259 and β_1=0.5243, the increase in shiploads will be followed by the growth of the ship's DWT, where if the cargo increases by 1%, the growth in ship capacity will increase by 0.5243%. Meanwhile, DWT versus Call parameters with β_0=-9067 and β_1=43.17 that the increase in Call will be followed by DWT growth, where if Call increases by 1%, the DWT growth for ships will increase by 43.17%. In the context of the DWT and Call relationship, if the call request rises while the ship's DWT is still available in a certain time unit, then the addition of a Call is very much determined by the DWT growth up to the maximum point. Furthermore, if there is no growth in the ship's DWT, the ship call can be increased to ensure the fulfillment of transportation goods at a certain time unit.

For Q_S_R+T versus Call parameters with βo=-8506 and β_1=16.7, it describes that–the growth of Q_S_R+T will be negative or non-existent if there are no ship visits in an area, whereas if Call grows by 1%, then the change in Q_S_R+T will occur by 41.1%, and if the growth of Q_S_R+T is positive while the number of calls remains, an increase is required. DWT ship capacity of β_2=2.24% if the Call of the ship is considered constant ceteris paribus. Therefore, to anticipate the growth of Q_S_R+T, it shall be done by increasing the load capacity, which is usually by adding new vessels (making or renting), or it can also be improved by increasing the call frequency of existing ships if possible.

For the relationship Q_S_R+T versus Call with the known parameters of β_0=-2879 and β_1=79.85, the growth of Q_S_R+T will be negative or non-existent if there is no call growth, whereas if the Call occurs by 1%, the change in Q_S_R+T will occur by 79.85%.

For Q_S versus DWT with the known parameters of β_0=-1212 and β_1=1.85, an increase in ship loading capacity will be followed by a growth in cargo, where if the cargo increases by 1%, the growth in ship capacity will increase by 1,85%.

Modeling of operating ship patterns applied in islands to increase shipping efficiency is done by Fuzzy MADM. The results of the three shipping patterns showed that the mixed regular and tramper shipping patterns could improve ship sailing performance with a value of 13.00 higher than the regular value of 9.80 and the tramper of 10.60. And by using the transportation performance data (Q_S_R+T, Call, DWT) in Table 3, it is known that the availability of Q_S_R+T cargoes greatly affects the demand for Call and DWT vessels. The addition of Call and DWT will have a positive impact on the growth of Q_S_R+T to support the Maluku Sea Highway. The implications of this model can be used to measure the growth of transportation performance in islands by determining shipping patterns and dimensions of transportation infrastructure that are universally applicable and can be used in areas that have the same characteristics, especially in the Eastern regions of Indonesia.

4. Conclusions

This study aims to determine the optimal shipping pattern in the Maluku region to support the sea Highway program in Indonesia. The results indicate that the best ship operating pattern, determined using the Fuzzy MADM method, is a combination of regular and tramper sailing, known as a mixed sailing pattern. Increasing the productivity of Q_S_R+T and DWT ships will have a positive effect on ship visits in a certain time unit. If the potential growth in positive cargo Q_S_R+T > Call and DWT, then it is necessary to build new ships with optimal DWT to increase ship efficiency in supporting the Sea Highway program. Thus the increase in Call and DWT for ships requires adjustment to cargo availability in the archipelago. The implications of this research can be used as a reference for consideration for policies making on the development of sailing patterns in the archipelago, as well as being able to improve the economy of the archipelagic community through optimal shipping access as an effort to build regional economic strength to overcome economic disparities between archipelagic regions. Suggestion: The need for further studies between the government as policymakers and academics to see how far the impact of sailing has on increasing LF in small island areas where Call, DWT and Qs are variables that influence economic development.

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References

Amelia, P., Lathifah, A., Yasa, I.N.A, 2021. Analysis of the Impact of Maritime Sector Development in Supporting Indonesian Navy Ship Operations. *Procedia Computer Science*, Volume 197, pp. 317–325

Banerjee, A., Duflo, E., Qian, N., 2020. On The Road: Access to Transportation Infrastructure and Economic Growth in China. *Journal of Development Economics,* Volume 145, Volume 2020, p. 102442

Esmail, H.A.H., 2016. Efficiency Assessment of Jazan Port Based on Data Envelopment Analysis. *Mediterranean Journal of Social Sciences*, Volume 7, p. 320

Goodarzi, F., Abdollahzadeh, V., Zeinalnezhad, M., 2022. An Integrated Multi-Criteria Decision-Making and Multi-Objective Optimization Framework for Green Supplier Evaluation and Optimal Order Allocation Under Uncertainty. *Decision Analytics Journal,* Volume 4, p. 100087

Hozairi, Lumaksono, H., Tukan, M., Buhari, 2019. Assessment of the Most Influential Factors on Indonesian Maritime Security Using Fuzzy Analytical Hierarchy Process. *In*: Proceedings - 2019 International Conference on Computer Science, Information Technology, and Electrical Engineering ICOMITEE, pp. 74–81

Jaal, Z., Abdullah, J., 2012. User's Preferences of Highway Landscapes in Malaysia: A Review and Analysis of the Literature. *Procedia - Social and Behavioral Sciences*, Volume 36, pp. 265–272

Kozonogova, E., Dubrovskaya, J., Dubolazova, Y., 2020. Assessment of the Contribution of Inter-Territorial Interaction in the Development of the National Economy. *International Journal of Technology,* Volume 11(6), pp. 1161–1170

Kumar, A., Maheshwari, S., Sharma, S.K., 2015. Fuzzy Logic Optimization of Weld Properties for SAW Using Silica Based Agglomerated Flux. *Procedia Computer Science*, Volume 57, pp. 1140–1148

Lumaksono, H., 2018. The selection of suitable fishing gear for fishermen in Madura Island using Fuzzy AHP and Fuzzy TOPSIS. *Ecoterra*, Volume 15(2), pp. 34–51

Nurkholis, Nuryadin, D., Syaifudin, N., Handika, R., Setyobudi, R.H., Udjianto, D.W., 2016. The Economic of Marine Sector in Indonesia. *Aquatic Procedia*, Volume 7, pp. 181–186

Santos, T.S., Portugal, L.d.S., Ribeiro, P.C.M., 2021. Evaluating The Performance Of Highway Concessions Through Public-Private Partnerships Using A Fuzzy Multi-Criteria Decision-Making Procedure. *Transportation Research Interdisciplinary Perspectives*, Volume 10, p. 100399

Tukan, M., 2021. Optimalisasi Dimensi Transportasi Laut Berbasis Potensi Ekonomi Wilayah Pulau (Optimizing Sea Transportation Dimensions Based on the Economic Potential of Island Regions). *In*: Seminar Nasional Archipelago Engineering 2021

Tukan, M., Achmadi, T., Widjaja, S., 2015. Seaport Dimensional Analysis towards Economic Growth in Archipelagic Regions*. International Journal of Technology,* Volume 6(3), pp. 422–431

Tukan, M., Achmadi, T., Wijaya, S., Ciptomulyono, U., 2012. Modelling Ports Investment and Island Economic Growth. *IPTEK The Journal for Technology and Science*, Volume 23(3), pp. 120–126

Tukan, M., Camerling, B.J., Afifudin, M.T., Hozairi, 2020. Decision Support System for Determining Floating Dock Locations in Maluku Islands Using AHP-TOPSIS. *Journal of Physics: Conference Series*, Volume 1577(1), p. 012001

Wang, C., Wang, J., 2011. Spatial Pattern of The Global Shipping Network and its Hub and-Spoke System. Research in Transportation Economics, Volume 32(1), pp. 54–63

Xu, F., Gao, K., Xiao, B., Liu, J., Wu, Z., 2022. Risk Assessment for The Integrated Energy System Using a Hesitant Fuzzy Multi-Criteria Decision-Making Framework. *Energy Reports*, Volume 8, pp. 7892–7907

Zhogova, E., Zaborovskaia, O., Nadezhina, O., 2020. An analysis of the Indicators of Regional Economy Spatial Development in the Leningrad Region of Russia*. International Journal of Technology,* Volume 11(8), pp. 1509–1518