Determination of Ship Fuel Inventory at Jakarta Port Terminal Using Additive Decomposition Method and Sugeno Fuzzy Logic

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Abstract. In February 2023, there was no supply activity resulting in a decrease in ship fuel transportation and the cancellation of several shipping requests. So it is necessary to apply optimal forecasting methods to stabilize supply and demand as well as the transportation of ship fuel, and predict raw material inventories at the Jakarta Port Terminal. This study aims to determine the optimal need for ship fuel supply so that stability between supply and demand and transportation of fuel runs smoothly. The use of Ship Fuel distribution data at the Jakarta Port Terminal from January to December 2022, and focuses on supply, transportation, initial inventory, and ending inventory data. The results of forecasting analysis using the time series analysis method showed that the additive decomposition method and the fuzzy logic approach of the Sugeno method were the most accurate methods, with MAPE of 21.06% and 08.62% respectively. Results showed that the ship's fuel stock in February 2023 was unavailable due to a delay in stock delivery which caused the supply sale to be shifted to the following month. In determining stock planning, the three input variables used are initial inventory, supply, and lifting. To use the Sugeno Fuzzy Logic method, the stages carried out are the formation of fuzzy sets, the formation of fuzzy basic rules, the composition of rules with the maximum method, and defuzzification. By following these stages, forecasting and prediction can be done with a high degree of accuracy.

Keywords: Forecasting, Additive Decomposition, Fuzzy Logic, Stock, Supply.

1 Introduction

The increase in the number of passengers and goods transported using sea transportation continues to grow every year. Indonesia as an archipelagic country has economic development spread throughout the region. The interaction between regions and economic relations between islands are highly dependent on sea transportation. Data from the Central Statistics Agency (BPS) in 2019 shows that the number of passengers using domestic and foreign sea transportation reached 56.6 million people[1]. In addition, the amount of loading and unloading of goods both domestically and abroad reached 1,262.1 million tons. Domestic passengers recorded 22.6 million people arriving and 23 million people departing, while international passengers reached 5.6 million people arriving and 5.4 million people departing. For loading and unloading goods, domestic details reached 445 million tons of unloading and 363.5 million tons of loading, while abroad reached 104.5 million tons of unloading and 349.1 million tons of loading. The high activity of passenger shuttle and loading and unloading processes at Indonesian ports requires ship fuel.

Bunkers are the provision of fuel for use by ships and include ship logistics to load fuel and distribute it among available bunker tanks[2]. Bunker is an activity inside the ship that aims to refuel the ship. Ship fuel can be marine, fuel oil, diesel or diesel oil.. The measurement and calculation of the bunker supply on board states that the bunker supply is the process of

meeting fuel needs on board a ship owned or chartered from the ship's captain through the Marine Region or Ship Operation to making an analysis and evaluation of the ship's performance.

Jakarta Port is one of the FT (fuel terminals) with the largest number of requests for supply and lifting of ship fuel from January 2022 to December 2022 where ships carrying out supply activities are 50 ships with a quantity of 72,525 KL and ships carrying out lifting activities are 217 ships with a quantity of 66,679 KL Therefore, it is necessary to apply optimal forecasting methods to supply demand to stabilize supply demand & lifting ship fuel in the future and predict raw material inventory (final stock) at the Jakarta Port Terminal.

2 Research Methodology

Forecasting method to obtain data on future needs, and with a fuzzy logic approach, namely the Sugeno method with Set Formation, Basic Rules, Rule Composition, and Defuzzification[3].

Fig. 1. Stages and Flow of Research.

3 Results and Discussion

The use of the forecasting approach in this study consists of some coverage is Analysis of Selected Forecasting Methods using Tracking Signals and Moving Range[4]. And for the Sugeno approach, the Fuzzy Logic Method consists of Set Formation, Basic Rules, Rule Composition, and Defuzzification.

3.1 Analysis of Selected Forecasting Methods

Table 1 Historical Data of Ship Fuel Supply Demand.

Month	Period (t)	Supply (Yt)
Jan-22	1	6.273
Feb-22	2	8.256
Mar-22	3	6.617
Apr-22	4	5.148
May-22	5	4.962
Jun-22	6	7.485
Jul-22	7	2.099
Aug-22	8	8.193
Sep-22	9	5.525
Oct-22	10	8.284
Nov-22	11	2.531
Dec-22	12	7.152

From the data in table 1 is the quantity of historical data results of ship fuel supply demand for Marine Fuel Oil Low Sulphur (MFO LS) in units (KL), the following is a graphical representation of supply demand from January 2022 - December 2022

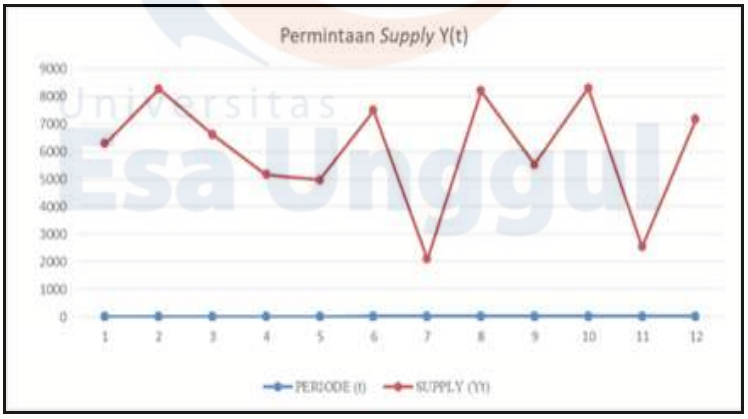

Fig. 2. Graph of Ship Fuel Supply Demand Data

Based on the data pattern in Image 1 above, it can be seen that the supply demand data pattern at the Jakarta Port Terminal is a seasonal pattern. This is because in some periods the data looks up and down in certain periods and is cyclical or repetitive.

Method

Additive Decomposition (seasonal)

Supply Bahan Bakar Kapal Solution

	Demand(y)	time	DIFFERENCI	SEASONAL	SMOOTHED	Unadjusted forecast	(E-Ebar)^2	Error	|Error|	Error^2	|Pct Error|
January	6273	6043,75	229,25	-1857,75	8130,75	6615,71	4757,96	1515,04	1515,04	2295342	24,15%
February	8256	6043,75	2212,25	2180,75	6075,25	6511,72	8692,47	-436,47	436,47	190505,0	5,29%
March	6617	6043,75	573,25	27,25	6589,75	6407,73	6434,96	182,02	182,02	33132,89	2,75%
April	5148	6043,75	-895,75	672,25	4475,75	6303,73	6975,98	-1827,98	1827,98	3341520,0	35,51%
May	4962	6043,75	-1081,75	-2297,25	7259,25	6199,74	3902,49	1059,51	1059,51	1122562	21,35%
June	7485	6043,75	1441,25	1274,75	6210,25	6095,75	7370,5	114,5	114,5	13111,03	1,53%
July	2099	6043,75	-3944,75	-1857,75	3956,75	5991,75	4134,0	-2035,0	2035,0	4141239	96,95%
August	8193	6043,75	2149,25	2180,75	6012,25	5887,76	8068,51	124,49	124,49	15497,58	1,52%
September	5525	6043,75	-518,75	27,25	5497,75	5783,77	5811,02	-266,02	266,02	81806,05	5,16%
October	8284	6043,75	2240,25	672,25	7611,75	5679,77	6352,02	1931,98	1931,98	3732530,0	23,32%
November	2531	6043,75	-3512,75	-2297,25	4828,25	5575,78	3278,53	-747,53	747,53	558603	29,54%
December	7152	6043,75	1108,25	1274,75	5877,25	5471,79	6746,54	405,46	405,46	164399,0	5,67%
TOTALS	72525		0	0	72525	6719,71		0	10666,01	15690450	252,75%
AVERAGE	6043,75		0	0	6043,75	0		0	888,83	1307537,0	21,06%
Next perio...							5367,8	(Bias)	(MAD)	(MSE)	(MAPE)
									Std err	1252,62	

Fig. 3. Additive Decomposition Method

The forecasting method selected from the comparison of the smallest MAPE values from several time series analysis methods is the Additive Decomposition Method with a MAPE value of 21.06%.

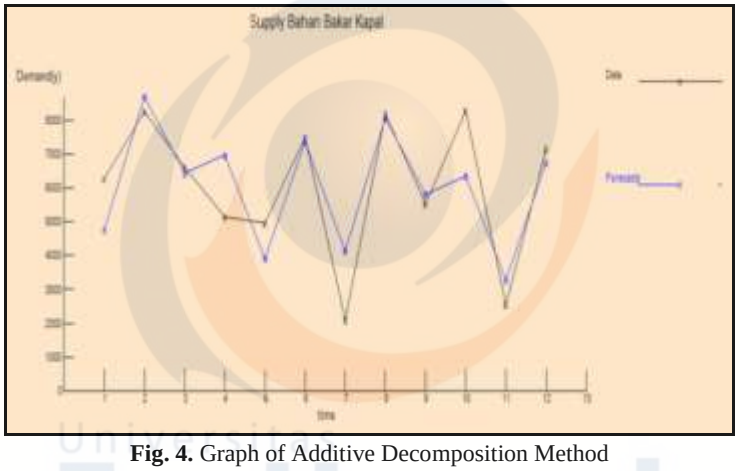

Fig. 4. Graph of Additive Decomposition Method

Based on the graph in the figure above, it shows a data pattern that looks fluctuating as with the data in the period January 2022-December 2022. That way the forecasting results between actual data and forecasting data are still possible to use.

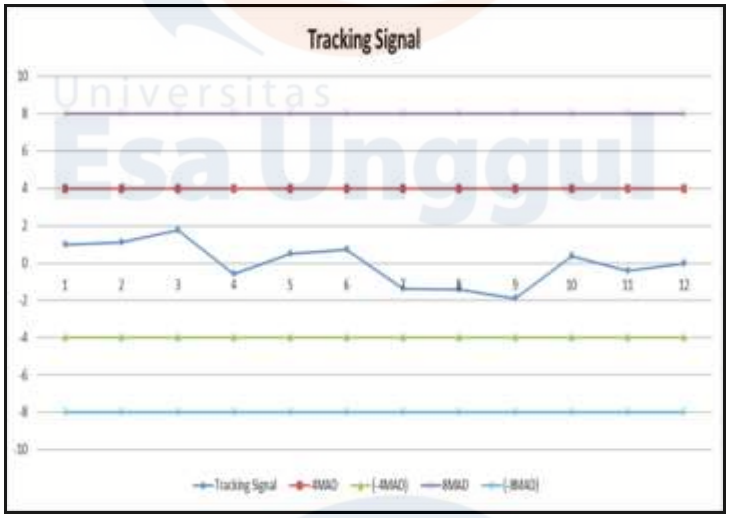

Fig. 5. Tracking Signal Graph

Tracking Signal is a measure of how good a forecasting method is in estimating actual values. Based on the results of the above calculations, the form of the tracking signal graph can be seen in the figure above. Based on the calculation data and the graph above, it can be seen that the Tracking Signal line is in good condition because it does not approach the 4MAD or -4MAD lines, which means that forecasting using the Additive Decomposition Method is still good and worth trying.

Fig. 6. Moving Range Chart

Moving Range is a verification method used for testing the stability of cause-and-effect systems that affect demand[5]. This verification has similarities with Tracking Signal which checks whether there is a significant error value against other error values, but the difference is that Moving Range Chart uses the limit of the average value of one error range with the previous error while Tracking Signal provides a limit with the MAD error value. By looking at the data that has been plotted on the Moving Range Chart graph, it can be seen that the MR pattern forecasting period does not cross the upper or lower control limits.

3.2 Sugeno Method Fuzzy Logic Analysis

Data for supply, lifting, initial inventory and final inventory are presented in KL (kilo liters).

Table 2 Supply, Lifting and Fuel Inventory Data (KL)

Month	Initial Inventory (w)	Supply (x)	Lifting (y)	Ending Inventory
Jan-22	9.313	6.273	5.890	9.695
Feb-22	9.695	8.256	6.000	11.951
Mar-22	11.951	6.617	5.600	12.968
Apr-22	12.968	5.148	5.895	12.221
May-22	12.221	4.962	3.855	13.328
Jun-22	13.328	7.485	5.290	15.523
Jul-22	15.523	2.099	5.250	12.372
Aug-22	12.372	8.193	6.000	14.566
Sep-22	14.566	5.525	7.049	13.041
Oct-22	13.041	8.284	5.900	15.425
Nov-22	15.425	2.531	4.980	12.976
Dec-22	12.976	7.152	4.970	15.158

From table 2 available above, the blue-colored data represents the lowest data from each variable, while the yellow-colored data represents the highest data from each variable to facilitate the next data processing stage.

Table 3 Supply, Lifting and Fuel Inventory Data (KL)

Rule	Initial Inventory	*Supply*	*Lifting*	Implication Function	Ending Inventory
R1	Many	Add	Add	so	Many
R2	Many	Add	Little	so	Many
R3	Many	Little	Add	so	Little
R4	Many	Little	Little	so	Many
R5	Little	Add	Add	so	Little
R6	Little	Add	Little	so	Many
R7	Little	Little	Add	so	Little
R8	Little	Little	Little	so	Little

By applying the zero-order Sugeno method equation formula, the final inventory form is obtained with 8 implication rules using the minimum implication function.

Based on the results of the implication function of each rule, the rule composition is used by taking the maximum level of all conclusions of each rule. So that the composition of the max function rules for the final inventory in each period can be seen in the table above which is marked in blue and yellow

Table 4 Rule Composition

Rule	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
Rule-1	0	0,062	0,425	0,493	0	0,449	0	0,493	0,554	0,600	0,070	0,349
Rule-2	0	0,062	0,425	0,361	0,463	0,551	0	0,329	0	0,360	0,070	0,590
Rule-3	0	0,005	0,269	0,507	0	0,129	0,437	0,015	0,446	0	0,352	0,183
Rule-4	0	0,005	0,269	0,361	0,468	0,129	0,563	0,015	0	0	0,648	0,183
Rule-5	0,637	0,671	0,546	0,411	0	0,353	0	0,507	0,154	0,400	0,016	0,349
Rule-6	0,363	0,329	0,454	0,361	0,463	0,353	0	0,329	0	0,360	0,016	0,410
Rule-7	0,325	0,005	0,269	0,411	0	0,129	0	0,015	0,154	0	0,016	0,183
Rule-8	0,325	0,005	0,269	0,361	0,532	0,129	0	0,015	0	0	0,016	0,183
Little	0,637	0,671	0,546	0,507	0,532	0,353	0,437	0,507	0,446	0,400	0,352	0,349
Many	0,363	0,329	0,454	0,493	0,468	0,551	0,563	0,493	0,554	0,600	0,648	0,590

Table 5 Comparison of Realized and Fuzzy Sugeno Final Inventory

Period	Initial Inventory	Supply	Lifting	Ending Inventory	
				Realization	*Fuzzy* Sugeno
Jan-22	9.313	6.273	5.890	9.695	11.811
Feb-22	9.695	8.256	6.000	11.951	11.613
Mar-22	11.951	6.617	5.600	12.968	12.341
Apr-22	12.968	5.148	5.895	12.221	12.568
May-22	12.221	4.962	3.855	13.328	12.423
Jun-22	13.328	7.485	5.290	15.523	13.247
Jul-22	15.523	2.099	5.250	12.372	12.976
Aug-22	12.372	8.193	6.000	14.566	12.568
Sep-22	14.566	5.525	7.049	13.041	12.924
Oct-22	13.041	8.284	5.900	15.425	13.192
Nov-22	15.425	2.531	4.980	12.976	13.472
Dec-22	12.976	7.152	4.970	15.158	13.357

The method used in the output process is a crisp number. in the sugeno method, the affirmation uses a weighted average calculation.

3.3 Determining the MAPE Value

Table 6 Result of MAPE Value

Periode	Yt	Yt'	Yt-Yt'	Yt-Yt'	Yt-Yt'/Yt
Jan-22	9.695	11.811	-2116	2.116	0,218209105
Feb-22	11.951	11.613	338	338	0,028296416
Mar-22	12.968	12.341	627	627	0,048330781
Apr-22	12.221	12.568	-348	348	0,028446976
May-22	13.328	12.423	905	905	0,067925785
Jun-22	15.523	13.247	2276	2.276	0,146604308
Jul-22	12.372	12.976	-604	604	0,048821743
Aug-22	14.566	12.568	1997	1.997	0,137112214
Sep-22	13.041	12.924	117	117	0,008980265
Oct-22	15.425	13.192	2233	2.233	0,144749134
Nov-22	12.976	13.472	-496	496	0,038216297
Dec-22	15.158	13.357	1801	1.801	0,11880045
Jumlah	159.224	152.492			1,034493474

Based on the results obtained in table 6 above, it is known that the MAPE value is 08.62% which is in accordance with the MAPE value table for performance evaluation 08.62% is included in the research results with high accuracy and shows that the Sugeno fuzzy method is feasible to use in determining the fuel inventory ships at the Jakarta Port Terminal.

4 Conslusion

Based on the calculations and analysis carried out, the conclusions of this study are as follows:

1. The data pattern for ship fuel supply for the period January - December 2022 is a seasonal pattern. After several approaches using Time Series Analysis by comparing several methods, the smallest MAPE value was 21.06% using the Additive Decomposition method.
2. Determination of ship fuel stock planning uses three input variables as data, namely: Initial inventory, supply and lifting. Based on the calculation of final stock realization data of 159,224 KL and fuzzy logic of 152,492 KL does not show inventory problems, so timely distribution is needed to anticipate stock shortages.
3. The results of predicting ship fuel supplies with Sugeno fuzzy method get a MAPE value of 08.62%. According to the prediction table, the value of 08.62% is included in research with high accuracy and is very efficient in determining ship fuel supplies.
4. Overcoming delays in ship fuel supply at the Jakarta Port Terminal, the ALD (Accepted Loading Date) date is carried out earlier or not towards the end of the month, so that distribution is calculated in the month of incoming demand and avoids several other inhibiting factors.

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