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OPTIMIZATION OF TUG SERVICES IN TANJUNG PERAK PORT USING ASSIGNMENT MODEL BASED ON FORECASTING RESULTS OF TUG SERVICES

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Abstract. *Optimizing adequate tugboat services is needed to support the operational improvement of the Tanjung Perak port. This study uses the triple exponential smoothing method to predict the number of tug service demands in 2021 and the assignment model to determine the optimal level of operating tugboats. The data used in this study is data on demand for tugboat services for small, medium, and large ships from 2019 to 2020. Forecasting results show that the highest demand for small ship services is 4551, and the lowest is 3235. The highest demand for medium ship services is 479, and the lowest is 365. Meanwhile, the highest demand for large ship services was 61 and the lowest at 40. The assignment results show the optimization of Tanjung Perak port by operating 13 tugboats every day.*

Keywords: *port, forecasting, tugboat, triple exponential smoothing, optimization.*

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1. INTRODUCTION

Tanjung Perak port is included in the largest and second busiest port after Tanjung Priok port [1]. In supporting services at the port, various aspects are needed, one of which is the service of tugboats. Tugboats are ships that assist large ships in leaning, exiting, or shifting [2]. Tugboats function to pull, push, and hold large vessels so that they don't damage the pier when they dock at the port [3]. The demand for tugboat services continues to increase every year due to the increasing number of large-scale ships. In addition, the scale of the port area and the density of port traffic also affect the efficiency of tugboat services [4].

The efficiency of tugboat service providers significantly affects port performance. Therefore, the port authority requires an adequate number of tugboats. If the number of tugboats at the port is inadequate, there will be congestion at the port, which will result in port revenues [5]. If the number of tugboats in the harbour is adequate, the port's performance will continue to increase, and the port's revenue benefits will also increase [6]. Therefore, optimization of tugboats is used to reduce the number of queues for tug service requests for incoming and outgoing vessels.

The port requires optimizing the provision of adequate tugboats to reduce the number of queues for tug service requests. Several studies have examined the optimization of tugboats, such as that conducted by [7], who studied the optimization of tugboat configurations. In addition, research conducted by [8] examined the operation of tugboats in transporting large surface ships. A study was conducted by [9] to analyze the process of tugboats and their towing costs.

The optimization level of tugboats is obtained by combining the assignment model with the forecasting method. The forecasting method predicts the number of tug service requests in the next period. The forecast results will be used in the assignment model to see the level of optimization. One method used for forecasting is the triple exponential smoothing method. The triple exponential smoothing method is a forecasting method developed from single exponential smoothing and double exponential smoothing [10]. The advantage of this method is what can be used on stationary and non-stationary data [11]. In addition, this method can adjust the pattern of changing trends and seasonal components [12]. This study uses the triple exponential smoothing method because it is widely used in forecasting cases, such as research conducted by [13] which predicts revenue in water companies to produce MAPE of 9.54%. In addition, a study conducted by [14] indicated the number of tourists visiting Jatim Park, which resulted in a MAPE of 7%. At the same time, the research conducted by [12] predicts the number of hospitalized patients who produce MAPE of 3.1%.

Based on some of the literature above, this research applies the triple exponential method and model assignment. The triple exponential smoothing method is used to predict tug service requests. At the same time, the assignment model determines the levels of operating tugboats by looking at the number of queues, the length of time waiting for the line and the utilization of activity on the tugboats. We hope that this research will provide solutions for service providers to improve operations by delivering good tugboats so that port performance can continue to improve.

2. RESEARCH METHODS

This research combines the assignment method with the triple exponential smoothing method. This study uses data on monthly tug service requests from 2019-2020, which are grouped by ship type and each type of ship. The data used in this study are shown in Table 1.

Table 1. Tugboat service request data

Month	Tugboat Service Request					
	2019			2020		
	Small Ship	Medium Ship	Large Ship	Small Ship	Medium Ship	Large Ship
January	2928	444	52	3474	448	66
February	3533	419	46	3442	430	50
March	3996	477	54	3526	478	62
April	3484	391	58	3301	438	64
May	2949	451	74	3035	363	73

Month	Tugboat Service Request					
	2019			2020		
	Small Ship	Medium Ship	Large Ship	Small Ship	Medium Ship	Large Ship
June	2707	328	58	3194	421	62
July	3556	432	66	3279	411	56
August	3091	423	72	3656	446	64
September	2215	408	64	3594	434	60
October	3480	479	58	3926	447	58
November	3172	407	62	3644	398	56
December	3986	456	75	3561	464	56

Based on Table 1 shows that the highest demand for tugboat services from small ships occurred in March 2019 with a total of 3996, and the lowest occurred in September 2019 with a total of 2215. Meanwhile, the highest demand for medium ships occurred in October 2019 as many as 479, and the lowest occurred in June 2019. The highest service for large ships occurred in December 2019 with a total of 75, and the lowest was in February 2019 with a total of 46.

The steps taken in this research are:

1. Collecting data on tug service requests from 2019-2020.
2. Calculating forecasts using the triple exponential smoothing method. Before forecasting, determine the value by using trial error. The equation used in calculating triple exponential smoothing is as follows[15]:

$$S_t = \alpha \, . \frac{x_t}{(c_t - L)} + (1 - \alpha)\,(S_{t-1} + b_{t-1}) \quad (1)$$

$$b_t = \beta\,.(S_t - S_{t-1}) + (1 - \beta).\,b_{t-1} \quad (2)$$

$$c_t = \gamma\,.\frac{x_t}{S_t} + (1 - \gamma)c_{t-L} \quad (3)$$

$$F_{t+m} = (S_t + m\,.\,b_t)c_{t-L+m} \quad (4)$$

Explanation:
St = Smoothing of the whole period to t
bt = trend smoothing t period
ct = Seasonal smoothing period t
α = Data smoothing weighting (0 <α< 1)
β = Trend smoothing weighting (0 <β< 1)
γ = Seasonal smoothing weighting (0 <γ< 1)
L = Seasonal length
xt = Data to t
m = Number of forecast periods

3. Calculating forecasting evaluation
Forecasting evaluation is needed so that the results obtained are more accurate [16]. Forecasting evaluation is obtained by calculating the error value of the built model, and then the smallest error value is taken [17]. This study uses MAPE as an evaluation of the forecast. The equation for calculating MAPE is as follows:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{Yt - \hat{Y}t}{Yt}\right| x\ 100\% \quad (5)$$

Explanation:
Yt = Time-series value in period t
$\hat{Y}t$ = Forecast value of Yt
n = Number of data periods
Forecasting evaluation using MAPE has several criteria, shown in Table 2 [18].

Table 2. MAPE Criteria

Value	Description
$< 10\%$	High forecasting
$11\% - 20\%$	Good forecasting
$21\% - 50\%$	Reasonable forecasting
$> 50\%$	Weak forecasting

4. Build a scenario
   Building several scenarios were carried out to optimize the number of tugboats operating at the port. The constructed scenarios are as follows:
   a. Scenario 1: 12 tugboats operate daily as currently implemented at the port, with 4 tugboats being refueled or under repair and 3 no longer working.
   b. Scenario 2: 13 tugboats operate every day, with 3 tugboats being refueled or under repair and 3 no longer working.
   c. Scenario 3: 14 tugboats operate every day, with 2 tugboats being refueled or under repair and 3 no longer working.
5. After building several scenarios, we assign these scenarios to see the number of queues, the length of waiting time, and the utilization level.

3. RESULTS AND DISCUSSION

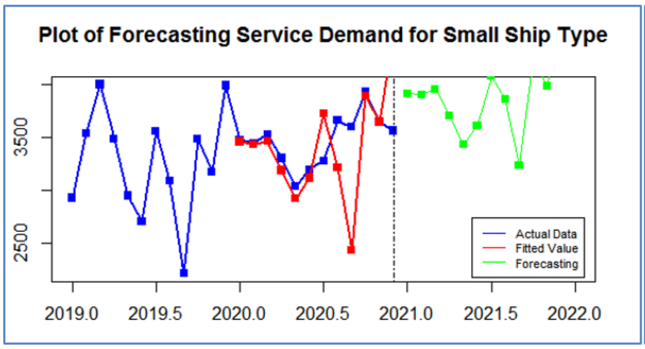
3.1. Forecasting *Triple Exponential Smoothing*

In this study, the forecasting method used is the triple exponential smoothing method. This method requires three smoothing parameters namely α, β γ. Parameter value α, β γ obtained by trial error to find the smallest value. The development parameters will be shown in Table 3.

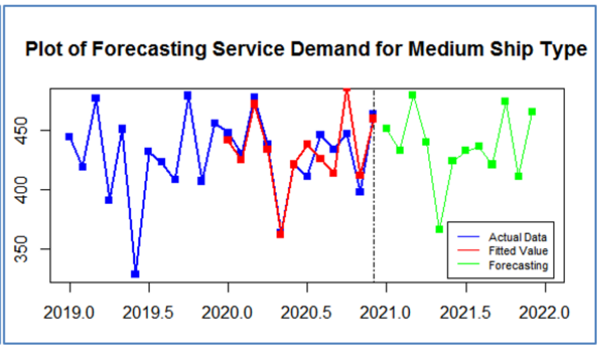
Table 3. Test value α, β, γ

Ship Type	α	β	γ	MAPE
Small	0.1	0.2	0.3	**8.08**
	0.2	0.3	0.4	9.12
	0.3	0.4	0.5	10.09
	0.4	0.5	0.6	11.03
Medium	0.1	0.2	0.3	**2.84**
	0.2	0.3	0.4	2.99
	0.3	0.4	0.5	3.17
	0.4	0.5	0.6	3.36
Large	0.1	0.2	0.3	5.90
	0.2	0.3	0.4	**5.82**
	0.3	0.4	0.5	8.47
	0.4	0.5	0.6	6.67

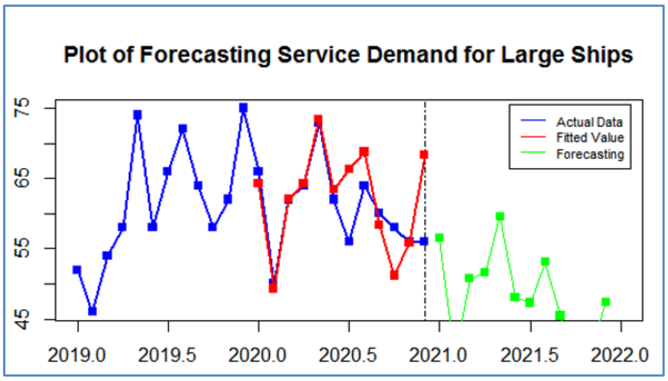
In this study, the parameters used for forecasting small and medium ships are α=0.1, β=0.2, γ=0.3 generate MAPE requests for small ships 8.08%, and MAPE, the demand for medium ships is 2.84%. Meanwhile, the parameters used for forecasting large ships are α=0.2, β=0.3, γ=0.4 generate MAPE 5.82%. Based on the results of the three types of ships, the MAPE obtained is less than 10% classified in the high forecasting category, as shown in Table 2. The best model of forecasting evaluation is used to calculate forecasting using the triple exponential smoothing method. What will show the results of the forecasting calculations in Table 4 and Figure 1.



(a)



(b)



(c)

Figure 1 (a) The plot of the results of forecasting the demand for small ship services
(b) The plot of the results of forecasting the demand for the service of medium ships
(c) The plot of the results of forecasting the demand for the service of large ships

Table 4. Forecasting tugboat service request

Month	Forecasting Tugboat Service Request for 2021		
	Small	Medium	Large
January	3911	451	56
February	3899	433	40
March	3952	479	52
April	3697	439	53
May	3428	365	61
June	3609	423	50
July	4071	432	51
August	3860	436	56
September	3235	421	48
October	4256	474	41
November	3977	411	43
December	4551	465	53

Based on Table 4 and Figure 1(a), it is known that the highest demand for tug services for small ships occurs in December 2021 with a total of 4551, and the lowest occurs in September 2021 with a total of 3235. Meanwhile, Tables 4 and 1(b) show the forecasting results. The highest demand for medium ship services occurred in March 2021 with 479, and the lowest occurred in May 2021 with 365 marks. Table 4 and Figure 1(c) show that the highest forecast for large ship services demand will occur in May 2021, with a total of 61. The lowest occurred in February 2021. The capacity is 40. In Figure 2, the blue plot shows the actual data from tug service requests for each type of ship. Meanwhile, the red plot shows the fitted value, and the green plot shows the forecasting results.

3.2. Assignment Model

The assignment model will be executed after forecasting the tug service request. The assignment model is run by applying several scenarios that have been made to determine the length of waiting time in the queue, the number of lines, and the utilization level of each tugboat. The system performance is good if the average waiting time is small, the number of queues is small, and the utilization rate of tugboats is high.

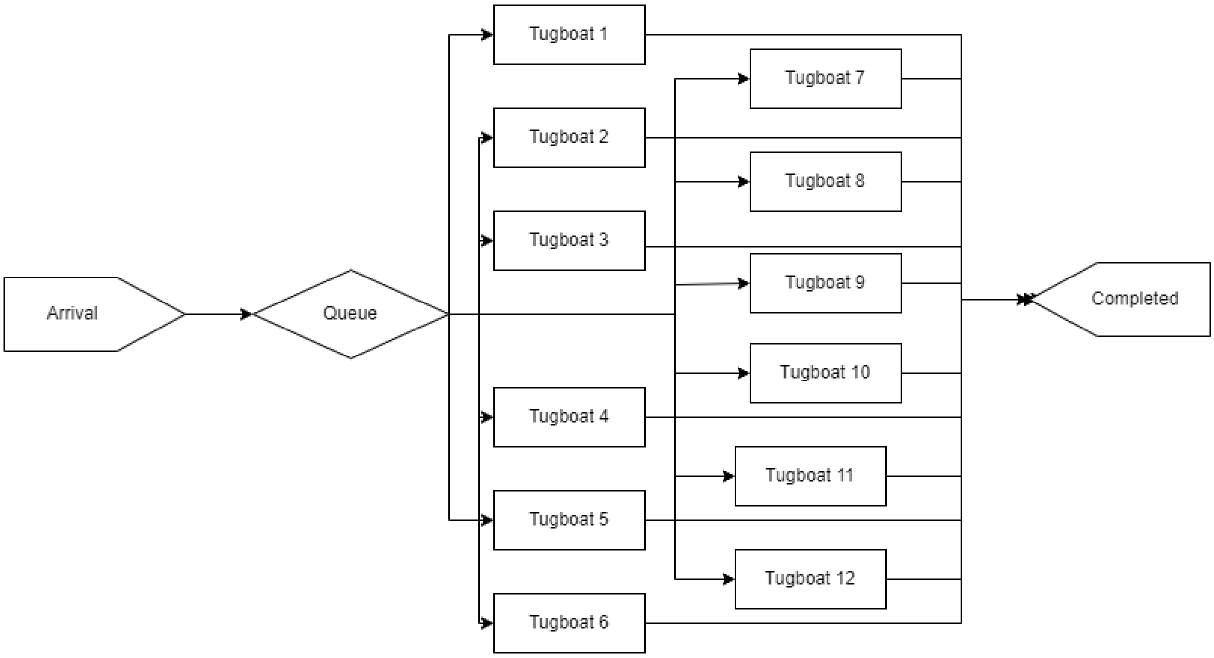


Figure 2. Application of the assignment model

Figure 2. shows the flow of tugboat requests by applying scenario 1. First, the ship arrives and then enters the queue. Then the tugboat service will be carried out where $Tugboat\ 1, Tugboat\ 2, \ldots\ , Tugboat\ 12$ symbolize tugboats 1 to 12. The results of the assignment of waiting times and the number of queues will be shown in Table 5, and the utilization level in Table 6, Table 7, and Table 8.

Table 5. Assignment results for waiting time and queue

Scenario to-	Waiting Time			Queue		
	Mean	Min	Max	Mean	Min	Max
Scenario 1	50 minute	30 minute	102 minute	9	3	20
Scenario 2	45 minute	24 minute	84 minute	5	2	11
Scenario 3	52 minute	26 minute	107 minute	7	3	22

Based on Figure 2 and Table 5, show the assignment results using the first scenario by operating 12 tugboats every day as implemented in the port at this time. The assignment results are an average waiting time of 50 minutes, a minimum waiting time of 30 minutes, and a maximum waiting time of 102 minutes. The average queue in the first scenario is 9, the minimum line is 3, and the maximum column is 20. The application of the second scenario assignment method is the same as the first scenario, only adding 1 tugboat in Figure 2. Table 5 shows the assignment results using the second scenario operating 13 tugboats every day. The assignment results show an average waiting time of 45 minutes, a minimum waiting time of 24 minutes, and a maximum waiting time of 84 minutes. Meanwhile, for an average queue of 5, the minimum line is 2, and the entire string is 11.

The application of the assignment method for the second scenario is the same as the first scenario, only adding 2 tugboats in Figure 2. The results of applying for the 3rd scenario show an average waiting time of 52 minutes, a minimum waiting time of 26 minutes, and a maximum waiting time of 107 minutes. The average results for the third scenario queue are 7, the minimum line is 3, and the maximum column is 22. The assignment results will show the utilization level in each scenario in Table 6, Table 7, and Table 8.

Table 6. Scenario 1 utilization assignment results

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Mean	14%	14%	18%	17%	17%	12%	15%	15%	15%	13%	20%	12%
Min	4%	8%	9%	8%	10%	1%	4%	12%	7%	4%	6%	5%
Max	21%	22%	32%	24%	25%	27%	23%	20%	25%	20%	37%	20%

Table 7. Scenario 2 utilization assignment results

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
Mean	13%	14%	11%	14%	11%	12%	11%	12%	13%	14%	12%	13%	14%
Min	5%	8%	5%	6%	8%	5%	2%	7%	3%	6%	7%	7%	5%
Max	20%	25%	26%	22%	15%	18%	24%	21%	24%	26%	21%	45%	28%

Table 8. Scenario 3 utilization assignment results

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
Mean	8%	13%	13%	13%	13%	12%	8%	12%	12%	12%	14%	11%	25%	9%
Min	3%	7%	2%	4%	8%	0%	2%	2%	2%	2%	5%	4%	1%	0%
Max	18%	20%	23%	21%	15%	17%	19%	15%	18%	20%	23%	15%	12%	15%

Based on Table 6, Table 7, and Table 8 show that the utilization level of tugboats by operating 13 tugboats results in better results than by working 12 or 14 tugboats.

Based on the results of research carried out by service providers, it is necessary to increase the operation of tugboats from 12 to 13 tugboats every year because the demand for tugboat services at the port continues every year to grow. Increasing the number of tugboats operating can reduce the number of queues and the length of waiting time in the line. In addition, it can improve port performance and increase revenue benefits for ports.

This study used the parameters α, β, γ to calculate the forecast using trial error. In further research, the parameters α, β, γ can be determined using optimization as done [19] by using the golden section in double exponential smoothing forecasting.

4. CONCLUSION

Based on the research results that have been done, what can use the triple exponential smoothing method to predict the demand for tugboat services at Tanjung Perak port for 2021. The forecasting results are used to run the assignment model by applying the built scenario. The results obtained in this research are the optimization level of tugboats at the Tanjung Perak port will be further increased if you operate 13 tugboats every day because the demand for tugboat services continues to grow every year. Adding tugboats that are working can reduce the number of queues and reduce the length of waiting time for lines.

REFERENCES

[1] A. D. C. D. Nur, "Kapasitas Dukung Tiang Tunggal Terhadap Beban Lateral Bangunan Gudang Petikemas Pelabuhan Tanjung Perak," *AGREGAT*, vol. 6, no. 1, pp. 493–498, 2021.

[2] W. Wang, T. Zheng, and Y. Peng, "The Study of the Influence of Port Scale on Tugboat Configuration Based on System Simulation," *Adv. Intell. Syst. Res.*, vol. 159, pp. 4–7, 2018, doi: 10.2991/mmsa-18.2018.2.

[3] R. Fajar and M. Basuki, "Perhitungan Berat Kapal Kosong Sebagai Fungsi Hari Daya Mesin Utama," *Semin. Teknol. Kebumian dan Kelaut. (SEMITAN II)*, vol. 2, no. 1, pp. 247–254, 2020.

[4] S. Jia, C. L. Li, and Z. Xu, "Managing Navigation Channel Traffic and Anchorage Area Utilization of a Container Port," *Transp. Sci.*, vol. 53, no. 3, pp. 728–745, 2019, doi: 10.1287/trsc.2018.0879.

[5] F. Hadi, H. Supomo, and T. Achmadi, "A Simulation Study of the Fleet Sizing Problem in Pilotage and Tug Services: Case Study of Tanjung Perak port, Surabaya," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1052, no. 1, p. 012056, 2021, doi: 10.1088/1757-899x/1052/1/012056.

[6] X. Wei, S. Jia, Q. Meng, and K. C. Tan, "Tugboat Scheduling for Container Ports," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 142, no. September, pp. 1–23, 2020, doi: 10.1016/j.tre.2020.102071.

[7] F. Jiang, Z. Han, and M. Quandang, "The Optimize of Tug Configuration Based on Fuzzy Comprehensive Evaluation and Entropy Weight Analysis," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 809, no. 1, pp. 4–12, 2021, doi: 10.1088/1755-1315/809/1/012018.

[8] S. M. Lee, J. H. Lee, M. Il Roh, K. S. Kim, S. H. Ham, and H. W. Lee, "An Optimization Model of Tugboat Operation for Conveying a Large Surface Vessel," *J. Comput. Des. Eng.*, vol. 8, no. 2, pp. 654–675, 2021, doi: 10.1093/jcde/qwab006.

[9] C. C. Chou, C. C. Wen, and Y. J. Huang, "Analysis of Tugboat Operation and Towage Fees in a Taiwanese Port and Alternatives for Improving Tugboat Operation by the Delphi Method," *Proc. Inst. Mech. Eng. Part M J. Eng. Marit. Environ.*, vol. 235, no. 1, pp. 176–187, 2021, doi: 10.1177/1475090220927246.

[10] T. Niu, L. Zhang, B. Zhang, B. Yang, and S. Wei, "An Improved Prediction Model Combining Inverse Exponential Smoothing and Markov Chain," *Math. Probl. Eng.*, vol. 2020, 2020, doi: 10.1155/2020/6210616.

[11] K. Pulungan, "Penerapan Metode Tripel Exponential Smoothing Dalam Peramalan Keuntungan Perusahaan dalam Tingkat

Penjualan Alat Tulis Kantor," *Build. Informatics, Technol. Sci.*, vol. 3, no. 1, pp. 43–47, 2021, doi: 10.47065/bits.v3i1.166.

[12] F. Lawalata, E. Sediyono, and H. Purnomo, "Analisis Prediksi Jumlah Pasien Rawat Inap di Rumah Sakit GMIM Siloam Sonder Menggunakan Metode Triple Exponential Smoothing," *Jointer - J. Informatics Eng.*, vol. 2, no. 01, pp. 32–26, 2021, doi: 10.53682/jointer.v2i01.28.

[13] D. M. Khairina, Y. Daniel, and P. P. Widagdo, "Comparison of Double Exponential Smoothing and Triple Exponential Smoothing Methods in Predicting Income of Local Water Company," *J. Phys. Conf. Ser.*, pp. 1–10, 2021, doi: 10.1088/1742-6596/1943/1/012102.

[14] S. Madianto, E. Utami, and A. D. Hartanto, "Algoritma Triple Exponential Smoothing Untuk Prediksi Trend Turis Pariwisata Jatim Park Batu saat Pandemi Covid-19," *J. Appl. Informatics Comput.*, vol. 5, no. 1, p. 58, 2021, [Online]. Available: http://jurnal.polibatam.ac.id/index.php/JAIC.

[15] Ramadiani, R. Syahrani, I. F. Astuti, and Azainil, "Forecasting the Number of Airplane Passengers uses the Double and the Triple Exponential Smoothing Method," in *Journal of Physics: Conference Series*, Jun. 2020, vol. 1524, no. 1, doi: 10.1088/1742-6596/1524/1/012051.

[16] I. Nabillah and I. Ranggadara, "Mean Absolute Percentage Error untuk Evaluasi Hasil Prediksi Komoditas Laut," *JOINS (Journal Inf. Syst.*, vol. 5, no. 2, pp. 250–255, 2020, doi: 10.33633/joins.v5i2.3900.

[17] G. Airlangga, A. Rachmat, and D. Lapihu, "Comparison of Exponential Smoothing and Neural Network Method to Forecast Rice Production in Indonesia," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 3, pp. 1367–1375, 2019, doi: 10.12928/TELKOMNIKA.V17I3.11768.

[18] L. Pamularsih, M. Mustafid, and A. Hoyyi, "Penerapan Seasonal Generalized Space Time Autoregressive Seemingly Unrelated Regression (SGSTAR SUR) Pada Peramalan Hasil Produksi Padi," *J. Gaussian*, vol. 10, no. 2, pp. 241–249, 2021.

[19] I. D. Febrianti, M. Hani, and U. D. Rosiani, "Optimasi Double Exponential Smoothing menggunakan Metode Golden Section untuk Peramalan Penjualan Sparepart," *Semin. Inform. Apl. Polinema*, pp. 42–45, 2021.