BAREKENG: Journal of Mathematics and Its Applications
June 2025 Volume 19 Issue 2 Page 1023–1036
P-ISSN: 1978-7227 E-ISSN: 2615-3017
https://doi.org/10.30598/barekengvol19iss2pp1023-1036

FORECASTING THE NUMBER OF SEARCH AND RESCUE OPERATIONS FOR SHIP ACCIDENTS IN INDONESIA USING FOURIER SERIES ANALYSIS (FSA)

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ABSTRACT

Article History:

Received: 29th December 2024
Revised: 30th January 2025
Accepted: 28th February 2025
Published: 1st April 2025

Keywords:

Forecasting;
FSA;
Search and Rescue;
Ship Accident.

As an archipelago country, Indonesia is a national and international route. This position makes high ship mobility which also increases the risk of ship accidents. To address this issue, based on these conditions, a prediction is required to forecast ship accidents in Indonesia for the upcoming period using an effective method. Through data forecasting, we can map the readiness of Basarnas resources in conducting search and rescue operations for ship accidents. Forecasting data for search and rescue operations in ship accidents is important because it can predict the quantity of needed search and rescue operations. These can be effective measures to reduce casualties in accidents of this type. This research uses the Fourier Series Analysis (FSA) method, which doesn't require parametric assumption. Additionally, the FSA method can be used for data with unknown patterns. The data used is divided into training data and testing data. The training data used in this research is the number of search and rescue operations from January 2021 to December 2022, while the testing data is from January 2023 to December 2023. The analysis results of this study indicate that forecasting using the FSA method has a MAPE of 25.758%, which falls into the category of reasonable forecasting accuracy and with an optimal $\lambda = 23$ *and a GCV of 166.586. The results of future predictions are in the form of a mathematical model that can be used by entering the time variable that you want to predict. The anticipated benefits of this research are to contribute to Basarnas's planning and execution of search and rescue operations for shipwrecks, enrich academic literature on forecasting methodologies, and enhance public awareness of search and rescue operations in Indonesia*

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How to cite this article:

R. Recylia, T. Saifudin, and N. Chamidah, "FORECASTING THE NUMBER OF SEARCH AND RESCUE OPERATIONS FOR SHIP ACCIDENTS IN INDONESIA USING FOURIER SERIES ANALYSIS (FSA)," *BAREKENG: J. Math. & App.*, vol. 19, iss. 2, pp. 1023-1036, June, 2025.

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Journal homepage: *https://ojs3.unpatti.ac.id/index.php/barekeng/*
Journal e-mail: *barekeng.math@yahoo.com; barekeng.journal@mail.unpatti.ac.id*

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1. INTRODUCTION

Indonesia is a country consisting of many islands, which makes it the largest archipelagic country in the world [1]. According to the Central Agency of Statistics (BPS), Indonesia have 17.001 islands in 34 provinces in 2022 [2]. This geographical diversity not only creates extraordinary natural beauty but also its own challenges in terms of managing transportation and infrastructure [3]. Indonesia is a global transportation route with different modes of transport that can reach islands [4], states, or even continents, as stipulated in law number 29 of 2014 [5]. This strategic location causes increased mobility and may contribute to more accidents [6].

At the same time, Indonesia as a Republic must always protect all its people and lives by ensuring their safety and security. This responsibility not only includes protecting individual rights but also includes preventive efforts in dealing with various threats that could endanger people's lives [7]. According to Search and Rescue Act Number 29/2014 concerning search and rescue operations, it encompasses activities aimed at searching for, assisting, rescuing, and evacuating people facing emergencies and/or dangers during mishaps, disasters, or life-threatening situations [5]. In this context, it is important to understand that every search and rescue operation is not just a response to an incident but also reflects the country's commitment to protecting its citizens [8].

Forecasting data for search and rescue operations in ship accidents is important because it can predict so that it is hoped that mitigation can be carried out [9]. These can be effective measures to reduce casualties in accidents of this type [10]. Previous research, such as [11], has highlighted the application of deep learning techniques for data within the context of maritime safety, especially considering the rising number of ship accidents in Indonesia. According to the *Basarnas Statistical Book* 2023, Basarnas conducted 846 search and rescue in maritime operations, demonstrating their ability to enhance the accuracy of predictions related to ship trajectories and operational safety. Additionally, research from [12] underscores the importance of reporting operations for ship-related incidents, an increase from 823 incidents in 2022 [13]. The data on search and rescue operations for ship accidents forms a time series and is analyzed using forecasting methods. Accurate forecasting of these operations is vital to predict the required number of operations in the coming periods, supporting better preparedness and resource allocation in Indonesia

Forecasting can be done in several ways, including Fourier Series Analysis (FSA) method. FSA is a seasonal forecasting technique that decomposes periodic signals generated from a function into sine and cosine signals [14]. Data fitting towards the Fourier series model will have no predictable patterns but some repeating patterns [15]. The FSA method was chosen because this method is suitable for predicting data that has fluctuating characteristics compared to other methods. Previous research on FSA primarily includes the prediction of non-oil and gas export prices in Indonesia with the use of the Fourier Series method and SVR by Purwoko et al. [16], with a MAPE value of 15.26%. Also, a study of salinity and seawater temperature prediction using the VAR method and bi-response Fourier series estimator by Faisol et al. [17], with a MAPE value of 0.00496. The next research is a comparison of rice price prediction results in East Java using the Fourier Series Estimator and Gaussian Kernel Estimator Simultaneously by Sadikin et al. [18] with a MAPE value of 1.872354%.

From previous research, there has been no research on this matter and it is still one of the topics that has never been discussed openly regarding forecasting ship accident search and rescue operation data. Therefore, the author is interested in conducting a study entitled "Forecasting the Number of Ship Accident Search and Rescue Operations in Indonesia Using Fourier Series Analysis (FSA)". Therefore, this study aims to predict ship accidents in Indonesia using the Fourier Series Analysis (FSA) method. It is hoped that this study can provide new insights into forecasting and be a consideration for increasing awareness of ship accidents in Indonesia.

2. RESEARCH METHODS

The method used in this study is the Fourier Series Analysis (FSA) method. The data used for FSA forecasting is 36 months from January 2021 to December 2023. The total data will be divided into training data and testing data, covering 66.7% of training data, namely the number of search and rescue operations for 24 months from January 2021 to December 2022, while 33.3% of test data is 12 months from January 2023 to December 2023. The reason for choosing the Fourier Series Analysis (FSA) method is because this method is suitable for forecasting data that has fluctuating characteristics, so it is expected to produce good forecasts.

2.1 Fourier Series Analysis (FSA) Method

The method of Fourier Series Analysis (FSA), also called the spectral regression model, is a prediction method that represents a periodic function using specific patterns that are typically approximated by trigonometric functions [15]. Nonparametric regression employs one of the approaches, i.e., Fourier series. A flexible model is defined as a Fourier series, which is a trigonometric polynomial, and it's still useful for data with an unknown pattern or seasonal patterns [19].

Suppose there is observation data $(\boldsymbol{t_r}, \boldsymbol{y_r})$ that follows a general regression model as follows [20]:

$$y_r = m(t_r) + \varepsilon_r, \qquad r = 1,2, \dots, n \tag{1}$$

where the form of the regression function $\boldsymbol{m(t_r)}$ is unknown and will be estimated using a nonparametric regression approach with a Fourier series estimator. Assume that $\boldsymbol{m(t_r)} \in \boldsymbol{L_2}[\boldsymbol{a}, \boldsymbol{b}]$, which is a Hilbert space. From **Equation (1)**, $\boldsymbol{m(t_r)}$ can then be expressed as follows [20]:

$$m(t_r) = \sum_{j=1}^{\infty} \beta_j x_j(t_r), \qquad r = 1,2, \dots, n \tag{2}$$

If $\boldsymbol{\beta_j}$ is a scalar, then:

$$y_r = \sum_{j=1}^{\infty} \beta_j x_j(t_r) + \varepsilon_r, \qquad r = 1,2, \dots, n \tag{3}$$

If **Equation (3)** is expressed in matrix form, then:

$$\boldsymbol{y} = \boldsymbol{X_\lambda \beta_\lambda} + \boldsymbol{\varepsilon} \tag{4}$$

with

$$\boldsymbol{y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, \boldsymbol{X_\lambda} = \begin{bmatrix} e^{2\pi i(-\lambda)1} & e^{2\pi i(-\lambda+1)1} & \dots & e^{2\pi i \lambda 1} \\ e^{2\pi i(-\lambda)2} & e^{2\pi i(-\lambda+1)2} & \dots & e^{2\pi i \lambda 2} \\ \vdots & \vdots & \ddots & \vdots \\ e^{2\pi i(-\lambda)n} & e^{2\pi i(-\lambda+1)n} & \dots & e^{2\pi i \lambda n} \end{bmatrix}, \text{dan } \boldsymbol{\beta_\lambda} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_n \end{bmatrix}, \boldsymbol{\varepsilon} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

$$Q = \boldsymbol{\varepsilon}^t \boldsymbol{\varepsilon} = (\boldsymbol{y} - \boldsymbol{X_\lambda \beta_\lambda})^t (\boldsymbol{y} - \boldsymbol{X_\lambda \beta_\lambda})$$

$$= \boldsymbol{y}^t \boldsymbol{y} - 2\boldsymbol{\beta}_\lambda^t \boldsymbol{X}_\lambda^t \boldsymbol{y} + \boldsymbol{\beta}_\lambda^t \boldsymbol{X}_\lambda^t \boldsymbol{X}_\lambda \boldsymbol{\beta}_\lambda$$

Since the least squares method aims to minimize the sum of squared errors, we have:

$$\frac{\partial Q}{\partial \beta_\lambda} = 0 - 2X_\lambda^t y + 2X_\lambda^t X_\lambda \beta_\lambda = 0$$

$$X_\lambda^t X_\lambda \beta_\lambda = X_\lambda^t y$$

$$\hat{\beta}_j = \left(X_\lambda^t X_\lambda\right)^{-1} X_\lambda^t \tag{5}$$

Given that $\boldsymbol{X_\lambda^t}$ is the transpose of $\boldsymbol{X_\lambda}$, then:

$$X_\lambda^t X_\lambda = \begin{bmatrix} n & 0 & \dots & 0 \\ 0 & n & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & n \end{bmatrix} = n \times I$$

$$(X_\lambda^t X_\lambda)^{-1} = \frac{1}{n} I$$

$$X_\lambda^t y = \sum_{r=1}^{n} y_r e^{-2\pi i j t_r}$$

The Fourier series estimate of $\boldsymbol{m(t)}$ is:

$$\widehat{m}(t) = \sum_{j=-\lambda}^{\lambda} \left(n^{-1} \sum_{i=1}^{n} y_i e^{-2\pi i j t_i} \right) e^{-2\pi i j t_i} \tag{6}$$

where $[a, b] = [0,1]$ and t_r is equally spaced in $[0,1]$, so t_r can be expressed as:

$$t_r = \frac{(r-1)}{n} \quad r = 1,2, \dots, n \tag{7}$$

Let $a_j = \hat{\beta}_j + \hat{\beta}_{-j}$ and $b_j = i(\hat{\beta}_j + \hat{\beta}_{(-j)})$, where $\hat{\beta}_{(-j)}$ is the complex conjugate of $\hat{\beta}_j$, and $e^{ix} = \cos(x) + i \sin(x)$ and $e^{-ix} = \cos(x) - i \sin(x)$. The Fourier series estimate of $\widehat{m}(t_r)$ is:

$$\widehat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{\lambda} \left[a_j \cos\left(\frac{2\pi j(r-1)}{n}\right) + b_j \sin\left(\frac{2\pi j(r-1)}{n}\right) \right] \tag{8}$$

where $\hat{\beta}_0 = \frac{(\sum_{i=1}^{n} y_i)}{n}$

$$a_j = \frac{2}{n} \sum_{r=1}^{n} y_r \cos\left(\frac{2\pi j(r-1)}{n}\right) \tag{9}$$

$$b_j = \frac{2}{n} \sum_{r=1}^{n} y_r \sin\left(\frac{2\pi j(r-1)}{n}\right) \tag{10}$$

2.2 Determination of Optimal Bandwidth

The choice of bandwidth is important as it can determine the nonparametric regression model in the Fourier series. The best value λ for a smoothness parameter will give the number of Fourier harmonics to be used for the estimation. If too low, an excessively rough and wobbly regression curve may result Conversely, a bandwidth that is too large can produce a regression curve that is overly smooth and does not match the data pattern. Criterion values depend on where exactly this bandwidth lies in terms of the Fourier series approximation [21]. Finally, the classical GCV method selects the optimal value of a bandwidth that minimizes GCV (Generalized Cross Validation). It can be stated as follows by [21]:

$$GCV\ (\lambda) = \frac{MSE\ (\lambda)}{(n^{-1} trace[I - A])^2} \tag{11}$$

$$MSE\ (\lambda) = \frac{\sum_{i=1}^{n} (y_i - \hat{y}_l)^2}{n}$$

2.3 Forecasting Accuracy with Mean Absolute Percentage Error (MAPE)

If $\boldsymbol{X_t}$ is the actual data for the $\boldsymbol{t}$-th period and $\boldsymbol{F_t}$ is the forecast result for the same period, then MAPE can be calculated using the following formula [22]:

$$\boldsymbol{MAPE} = \frac{\sum_{t=1}^{N} \left| \left(\frac{\boldsymbol{X_t} - \boldsymbol{F_t}}{\boldsymbol{X_t}} \right) \times \mathbf{100\%} \right|}{\boldsymbol{N}} \tag{12}$$

with

$\boldsymbol{X_t}$ **:** $\boldsymbol{t}$-th time series data

$\boldsymbol{F_t}$ **:** $\boldsymbol{t}$-th time forecast result data

$\boldsymbol{N}$: amount of data

The interpretation of the MAPE value can be seen in Table 1 below [23]:

Table 1. Interpretation Of MAPE Values

MAPE (%)	Interpretation
$MAPE < 10$	High accuracy forecast
$10 \leq MAPE < 20$	Good forecast
$20 \leq MAPE < 50$	Decent forecast
$MAPE \geq 50$	Inaccurate forecast

2.4 The Analysis Procedure

The steps for conducting forecasting in this research can be explained as follows:

1. Input the data into R Software.
2. Split data training data used from January 2021 to December 2022 and testing data from January 2023 to December 2023.
3. Find the optimal λ that minimizes the training data's GCV value in Equation (11).
4. Calculate the estimator value according to equation $a_j = \frac{2}{n} \sum_{r=1}^{n} y_r \cos\left(\frac{2\pi j(r-1)}{n}\right)$ and $b_j = \frac{2}{n} \sum_{r=1}^{n} y_r \sin\left(\frac{2\pi j(r-1)}{n}\right)$.
5. Calculate $\widehat{m}(t_r)$ in Equation (8).
6. Plot the observation and prediction values for the training data.
7. Forecast the testing data using the Fourier series estimator.
8. Plot the observation and prediction values for the testing data.
9. Evaluate forecasting accuracy using Mean Absolute Percentage Error (MAPE) in Equation (12).
10. Predictions for the future from January to December 2024.

3. RESULTS AND DISCUSSION

The data used for FSA forecasting includes training data from January 2021 to December 2022 in Table 2:

Table 2. Search and Rescue Operations for Ship Accidents in Indonesia for The Period of January 2021 to December 2022

No	Period	2021	2022
1	January	72	68
2	February	58	74
3	March	71	71
4	April	59	48
5	May	68	62
6	June	54	72
7	July	63	91
8	August	64	74
9	September	82	68
10	October	53	63
11	November	60	58
12	December	107	74
Quantity		**811**	**823**

***Data source**: Basarnas Statistical Book*

and testing data (from January 2023 to December 2023) in **Table 3**:

Table 3. Search and Rescue Operations for Ship Accidents in Indonesia for The Period of January 2023 to December 2023

No	Period	2023
1	January	69
2	February	76
3	March	62
4	April	68
5	May	84
6	June	70
7	July	94
8	August	93
9	September	69
10	October	55
11	November	41
12	December	65
Quantity		**846**

***Data source**: Basarnas Statistical Book*

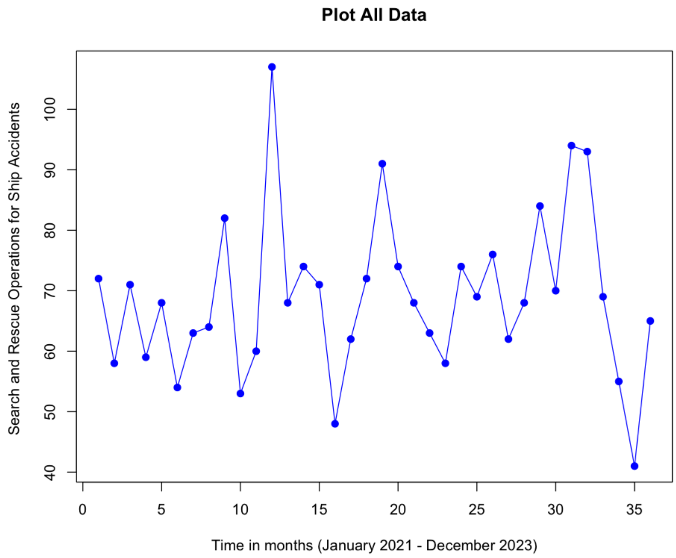

Figure 1. The Plot of All Data Search and Rescue Operations for Ship Accidents in Indonesia for The Period of January 2021 to December 2023

From Figure 1, it can be seen that the Search and Rescue Operations for Ship Accidents in Indonesia data for the Period of January 2021 to December 2023 has a fluctuating pattern, where this data tends to be suitable for modeling with the FSA method. The initial step in forecasting the data is to find the optimal bandwidth (λ) and GCV from the training data using R Studio. The obtained bandwidth (λ) value is presented in Table 4:

Table 4. Bandwidth (λ) and GCV Values for The FSA Method

Bandwith (λ)	GCV	*Bandwith* (λ)	GCV
1	189.3232	31	7182.988
2	222.2012	32	6523.012
3	243.4871	33	5940.471
4	241.2168	34	5442.71
5	292.6313	35	4992.69
6	363.4272	36	4597.293
7	440.3095	37	4248.51
8	456.7158	38	3956.201
9	645.1981	39	3684.038
10	401.2046	40	3450.491
11	1156	41	3232.46
12	1156	42	3031.334
13	401.2046	43	2847.994
14	645.1981	44	2694.475
15	456.7158	45	2546.98
16	440.3095	46	2404.91
17	363.4272	47	2275.925
18	292.6313	48	8165.211
19	241.2168	49	7741.305
20	243.4871	50	7348.251

***Bandwith* (λ)**	**GCV**	***Bandwith* (λ)**	**GCV**
21	222.2012	51	6991.941
22	189.3232	52	6668.094
23	166.586	53	6355.508
24	17228.72	54	6065.254
25	14789.91	55	5797.282
26	12831.96	56	5551.398
27	11260.37	57	5315.345
28	9981.174	58	5099.318
29	8884.862	59	4888.774
30	7962.305		

Based on **Table 4**, the optimal bandwidth $\lambda = 23$ with a $GCV = 166.586$, and the plot of the optimal bandwidth λ versus GCV in **Figure 2**:

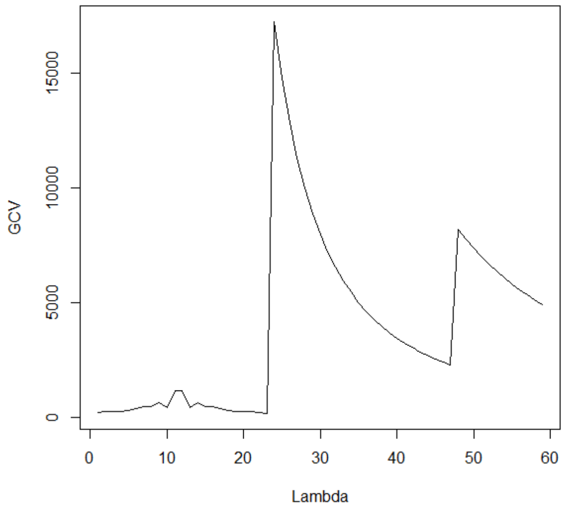

Figure 2. The Plot of The Optimal Bandwidth λ Versus GCV

Next, the estimation of a_j and b_j was performed using the training data in R Studio, resulting in the following in **Table 5:**

Table 5. Estimated Values Of a_j and b_j For Training Data

j	a_j	b_j
1	-3.023644	-2.634865
2	1.53627	-3.002992
3	-2.653385	5.210576
4	7.458333	0.5051815
5	-2.793894	-2.987817
6	0.5	-4.333333
7	3.082569	4.398934
8	-3.458333	-5.845671
9	4.653385	0.210576
10	-5.53627	-3.580342
11	2.734969	-1.021617
12	2.833333	$1.5177\times10^{(-14)}$

j	*a_j*	*b_j*
13	2.734969	1.021617
14	-5.53627	3.580342
15	4.653385	-0.210576
16	-3.458333	5.845671
17	3.082569	-4.398934
18	0.5	4.333333
19	-2.793894	2.987817
20	7.458333	-0.5051815
21	-2.653385	-5.210576
22	1.53627	3.002992
23	-3.023644	2.634865

From the values of a_j, b_j, and $\hat{\beta}_0 = 68.08333$ obtained through the training data, the estimation model equation can be formed as follows:

$$\hat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{\lambda}\left[a_j \cos\left(\frac{2\pi j(r-1)}{n}\right) + b_j \sin\left(\frac{2\pi j(r-1)}{n}\right)\right], \text{ with } t_r = \frac{(r-1)}{n}$$

$$\hat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{23}\left[a_j \cos(2\pi j \cdot t_r) + b_j \sin(2\pi j \cdot t_r)\right]$$

$$\hat{m}(t_r) = \hat{\beta}_0 + a_1 \cos(2\pi t_r) + b_1 \sin(2\pi t_r) + a_2 \cos(4\pi t_r) + +b_2 \sin(4\pi t_r) + \dots + a_{23} \cos(46\pi t_r) + b_{23} \sin(46\pi t_r)$$

$$\begin{aligned}\hat{m}(t_r) = 68.083 &- 3.023644 \cos 2\pi t_r - 2.634865 \sin 2\pi t_r + 1.53627 \cos 4\pi t_r \\ &- 3.002992 \sin 4\pi t_r - 2.653385 \cos 6\pi t_r + 5.210576 \sin 6\pi t_r + 7.458333 \cos 8\pi t_r \\ &+ 0.5051815 \sin 8\pi t_r - 2.793894 \cos 10\pi t_r - 2.987817 \sin 10\pi t_r + 0.5 \cos 12\pi t_r \\ &- 4.333333 \sin 12\pi t_r + 3.082569 \cos 14\pi t_r + 4.398934 \sin 14\pi t_r \\ &- 3.458333 \cos 16\pi t_r - 5.845671 \sin 16\pi t_r + 4.653385 \cos 18\pi t_r \\ &+ 0.210576 \sin 18\pi t_r - 5.53627 \cos 20\pi t_r - 3.580342 \sin 20\pi t_r \\ &+ 2.734969 \cos 22\pi t_r - 1.021617 \sin 22\pi t_r + 2.833333 \cos 24\pi t_r \\ &+ 1.5177.10^{-14} \sin 24\pi t_r + 2.734969 \cos 26\pi t_r + 1.021617 \sin 26\pi t_r \\ &- 5.53627 \cos 28\pi t_r + 3.580342 \sin 28\pi t_r + 4.653385 \cos 30\pi t_r \\ &- 0.210576 \sin 30\pi t_r - 3.458333 \cos 32\pi t_r + 5.845671 \sin 32\pi t_r \\ &+ 3.082569 \cos 34\pi t_r - 4.398934 \sin 34\pi t_r + 0.5 \cos 36\pi t_r + 4.333333 \sin 36\pi t_r \\ &- 2.793894 \cos 38\pi t_r + 2.987817 \sin 38\pi t_r + 7.458333 \cos 40\pi t_r \\ &- 0.5051815 \sin 40\pi t_r - 2.653385 \cos 42\pi t_r - 5.210576 \sin 42\pi t_r \\ &+ 1.53627 \cos 44\pi t_r + 3.002992 \sin 44\pi t_r - 3.023644 \cos 46\pi t_r \\ &+ 2.634865 \sin 46\pi t_r\end{aligned}$$

From the model equation above, the forecasting results for the training data in **Table 6**:

Table 6. Forecasting Results for Training Data Using the FSA Method

t	Actual	Forecasting
1	72	75.91667
2	58	47.91667
3	71	73.91667
4	59	49.91667
5	68	67.91667
6	54	39.91667
7	63	57.91667

t	Actual	Forecasting
8	64	59.91667
9	82	95.91667
10	53	37.91667
11	60	51.91667
12	107	145.91667
13	68	67.91667
14	74	79.91667
15	71	73.91667
16	48	27.91667
17	62	55.91667
18	72	75.91667
19	91	113.91667
20	74	79.91667
21	68	67.91667
22	63	57.91667
23	58	47.91667
24	74	79.91667

Additionally, a plot of the training data can be formed in **Figure 3**:

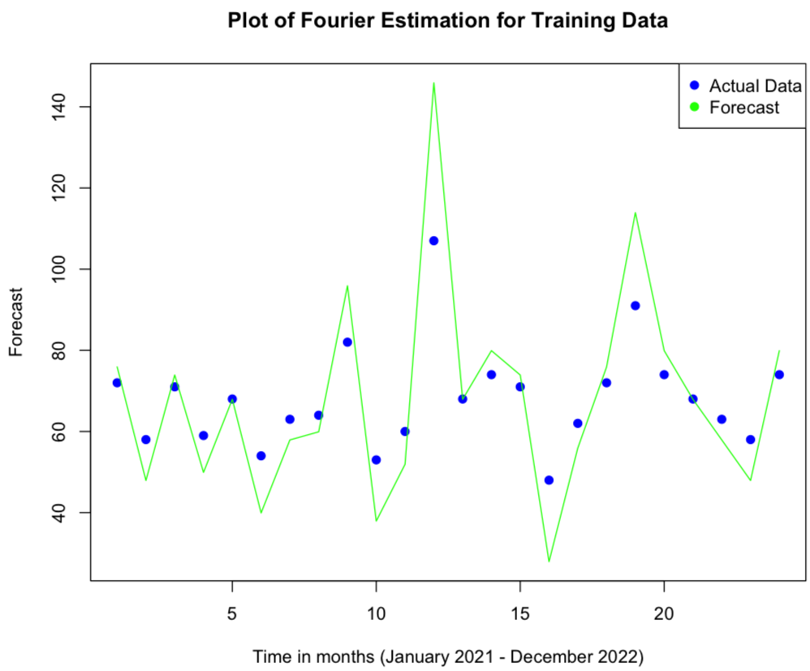

Figure 3. The Plot of Fourier Estimation for Training Data

From **Figure 3**, the given model is quite good at capturing data patterns. With these results, the performance of the model in predicting can be said to be good.

3.1 Results of Fourier Series Analysis (FSA) Forecasting

The next step is to perform forecasting and plot the testing data using the known model equation. Subsequently, the accuracy of the testing data forecast is measured using the Mean Absolute Percentage Error (MAPE) with the following results in **Table 7**.

Table 7. Forecasting Results for Testing Data Using the FSA Method

t	Actual	Forecasting	MAPE
25	69	55.91667	25.758%
26	76	80.03856	
27	62	59.69003	
28	68	113.9167	
29	84	62.39353	
30	70	79.33754	
31	94	67.91667	
32	93	58.77237	
33	69	70.18861	
34	55	47.91667	
35	41	75.41207	
36	65	72.42662	

With the forecasting results for the testing data, the MAPE value is 25.758%. After that, a plot of the testing data forecast results was created and is shown in the following **Figure 4**:

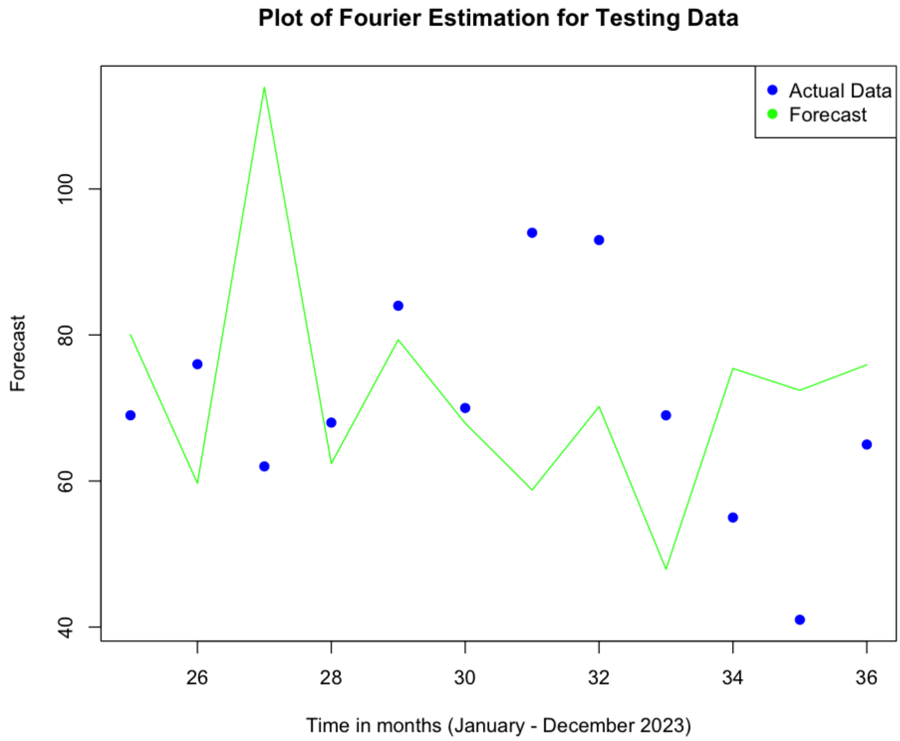

Figure 4. The Plot of Fourier Estimation for Testing Data

From **Figure 4**, the resulting model produces good forecasts for the testing data. The plot line of the prediction can resemble the movement of the actual data pattern. It can be observed from **Table 6** that the forecasting accuracy has a MAPE value of 25.758%. In line with this, the results of this study indicate that forecasting the number of SAR operations using FSA for ship accidents in Indonesia has a relatively good level of accuracy according to the categories listed in **Table 1**. From the test results, we continued by predicting the future from January to December 2024. The following are the prediction results for 2024, presented in **Table 8**.

Table 8. Search and Rescue Operations for Ship Accidents in Indonesia for The Period of January to December 2024

No	Period	2024
1	January	76
2	February	56
3	March	62
4	April	74
5	May	59
6	June	63
7	July	68
8	August	58
9	September	57
10	October	58
11	November	73
12	December	56
Quantity		**760**

From the prediction results for the future in January to December 2024, there tends to be a decrease in the number of Search and Rescue Operations for Ship Accidents compared to the previous year. The results of this prediction are expected to be used by Basarnas to take mitigation actions if necessary.

4. CONCLUSIONS

From this study, it can be concluded that the results of forecasting the number of search and rescue operations predicted using the FSA method have a MAPE value of 25.758%, which is included in the acceptable level according to the categories described in **Table 1** and with an optimal $\lambda = 23$ and a GCV of 166.586. From the lambda, optimal prediction results are obtained, as evidenced by the minimum GCV value, which means that the prediction results provide a small error value. We also suggest that future studies consider why certain correlation coefficients were extracted when looking at the factors concerning search and rescue operations. In addition, from the model that has been obtained, predictions are then made for the future from January to December 2024. The results show that the total Search and Rescue Operations for Ship Accidents in Indonesia has decreased compared to the previous year. It is hoped that the prediction results from this study can provide suggestions or recommendations for Basarnas such as in relation to mitigation or other actions if needed.

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