Comparison of Fuzzy Time Series and Fuzzy Time Series-Particle Swarm Optimization Methods in Predicting Bank BCA Share Price

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ABSTRACT

Investment is an investment activity that aims to enable investors or capital owners to benefit from the results of the investment or investment made. One of the profitabel investments is stock investment. PT Bank Central Asia (BBCA) is a private company engaged in banking finance. The Fuzzy Time Series method is a forecasting method that uses artificial intelligence with the ability to capture patterns from past data and then use it to predict future data using fuzzy logic principles. Particle Swarm Optimization is a simple and good optimization algorithm in solving optimization problems. The objective of this research is to compare the Fuzzy Time Series and Fuzzy Time Series-Particle Swarm Optimization methods in predicting the stock price of PT Bank Central Asia (BBCA) from January 3, 2022, to May 9, 2023. Based on the analysis, the sMAPE value obtained for the Fuzzy Time Series method is 1.4701%, while the sMAPE value for the Fuzzy Time Series-Particle Swarm Optimization method is 1.3678%%. From the analysis results, it can be concluded that optimization using Particle Swarm Optimization in the Fuzzy Time Series method produces more optimal prediction values.

Keywords: *BBCA Stock, Fuzzy Time Series, Particle Swarm Optimization, sMAPE*

1. INTRODUCTION

The capital market plays a highly significant role in the global economy, and Indonesia, as one of the countries experiencing economic growth, is no exception. The capital market is a crucial component within the context of Indonesia's economy, serving as a means to raise funds, an alternative avenue for investment through stock trading and bond issuance, and also serving as a crucial indicator for measuring macroeconomic stability [1]. Investment is an action of deploying capital, whether directly or indirectly, with the aim of enabling investors or capital owners to gain profits from the investment or capital allocation made [2]. The goal of investors in making capital investments or allocating funds in the capital market is to achieve maximum profit while considering a combination of various investment risks [3].

One of the profitable and highly popular investments among the Indonesian community is stock investment. Stocks are one form of investment in the capital market that allows investors to gain profits or returns. However, stocks are one of the investments with relatively high risk. This happens because stocks are highly vulnerable to economic conditions that can affect stock price fluctuations. For this reason, before buying stocks, investors need to carefully evaluate to reduce the risk of potential losses. One consideration that investors should make is by looking at the movement of stock prices based on previous stock price history and the company's performance. The banking industry is one of the sectors that attracts the attention of investors [4].

PT Bank Central Asia (BBCA) is a private company that operates in the banking sector. According to the IDN Financials website, BBCA is a financial company with

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the highest stock price in May 2023 [5]. According to the Infovesta website, on May 11, 2023, BBCA's stock ranked eighth out of 45 stocks in the LQ45 stock index, with a closing stock price of Rp 8,825 on May 11, 2023 [6]. Historical stock data for BBCA obtained from the website https://id.investing.com/ displays a series of BBCA's closing stock prices over time, which fluctuate daily. Based on this, investors need to actively monitor and analyze historical data regarding the company's stock price movements in the face of daily fluctuations. Before making an investment, investors need to have knowledge of stock investment analysis. Without proper analysis, investors are at risk of incurring losses. This analysis is crucial to understand the future prospects of the company's stock prices. Therefore, conducting stock price forecasting in the banking sector is highly necessary to reduce the risks that investors may face. Forecasting is a structured process of predicting future events based on information from the past and present. The primary objective of forecasting is to minimize the difference between the estimated outcomes and the future reality as much as possible [7]. Forecasting is an analytical method that investors can utilize to assist in making strategic decisions aimed at achieving profits [8]. Through forecasting, investors can gain insights into the anticipated future stock price prospects of a company. The closing stock price data of BBCA serves as an example of time series data, indicating that it is collected at specific time intervals. In such time series data, forecasting can be carried out by identifying patterns that emerge in historical data to make projections into the future. Generally, there are three common types of patterns found in time series data, namely horizontal patterns, trends, and seasonal patterns [9].

Time series analysis is one of the approaches used to predict future events by considering related historical data over time. The Fuzzy Time Series method is a forecasting method that combines artificial intelligence to identify patterns in historical data and apply them to predict future data [10]. One advantage of the Fuzzy Time Series method is its ability to be used with time series data that exhibit both trend and stationary patterns [11]. The Fuzzy Time Series method is already quite effective in making predictions, but in the Fuzzy Time Series method, the determination of the interval length used can affect the level of accuracy and prediction results obtained. An interval that is too long can result in suboptimal predictions. To address the issues in the Fuzzy Time Series method, the use of optimization algorithms is required to find the optimal value of the Fuzzy Time Series interval. One optimization method that can be utilized is Particle Swarm Optimization (PSO) for optimizing the interval function in the Fuzzy Time Series method [12]. Particle Swarm Optimization (PSO) is a simple yet effective optimization algorithm for solving optimization problems. PSO consists of a group of particles that search for the best positions in feature space to solve optimization problems. PSO has several advantages, including a simple concept, ease of implementation, and computational efficiency compared to other heuristic optimization algorithms [13].

2. LITERATURE REVIEW

2. 1 *Fuzzy Time Series*

The prediction technique known as Fuzzy Time Series (FTS) was first introduced by Song and Chisson in 1993. This method is based on fuzzy set theory and linguistic variable concepts developed by Zadeh. The fundamental principle of FTS is to utilize historical data and apply fuzzy logic for forecasting or prediction [14]. In the fuzzy time series method, the first step is to calculate the universe of discourse (U). To determine the relevant universe of discourse, the necessary steps involve finding the maximum value (D_{max}) and the minimum value (D_{min}) from historical data [14].

$$U = (D_{min} - D_1, D_{max} + D_2)$$

Explanation:

D_{min} : the lowest value in historical data

D_{max} : the highest value in historical data

D_1 D_2 : specified positive numbers

After determining the universe of discourse, the next step is to divide it into n intervals of equal size. The process of determining the intervals is carried out by following the following steps [15]:

- To determine the number of class intervals, you can use the Sturges formula:

$$K = 1 + 3.322 \times \log n$$

Explanation:

K : the number of class intervals

n : the number of data

- The length of a class interval that can be calculated using the following equation:

$$l = \frac{[(D_{max} + D_2) - (D_{min} - D_1)]}{the\ number\ of\ class\ intervals\ (K)}$$

Next is to form a fuzzy set for the universe of discourse. To create a fuzzy set, the division of the universe of discourse (U) is used. Let U = $[U_1, U_2, U_3, U_4, \dots \dots U_n]$ with U_1 as the possible values of U, and let A_i be a fuzzy set within the universal set U. Then, the fuzzy set A_i can be formulated as follows [15]:

$$A_i = \frac{\mu_{Ai}(u_1)}{u_1} + \frac{\mu_{Ai}(u_2)}{u_2} + \frac{\mu_{Ai}(u_3)}{u_3} + \cdots + \frac{\mu_{Ai}(u_n)}{u_n}$$

In this case, $\mu_{Ai}(u_j)$ refers to the degree of membership of u_j in the fuzzy set Ai. Fuzzy sets will be used to determine fuzzification in the fuzzy time series method. Based on the fuzzification values of historical data, Fuzzy Logic Relationships (FLR) are generated. If F(t-1) is fuzzified as A_1 and F_t is fuzzified as A_2, then A_1 is related toA_2 and can be represented with the following notation:

$A_1 \rightarrow A_2$

Next is to determine the Fuzzy Logic Relationship Group (FLRG) formed by combining the same relationships between the Fuzzy Logic Relationships (FLR) at the current state (F(t-1)) into one relationship group [14]. Suppose there are Fuzzy Logic Relationships (FLR) as follows:

- $A_1 \rightarrow A_1$
- $A_1 \rightarrow A_3$
- $A_1 \rightarrow A_2$

Then the Fuzzy Logic Relationship Group (FLRG) can be formed as follows:

$G_1: A_1 \rightarrow A_1, A_2, A_3$

The results of the Fuzzy Logic Relationship Group (FLRG) obtained are then used in the next step, which is the process of defuzzification and calculation of forecasted values using the Fuzzy Time Series method. The forecasted values are calculated using equations as shown in the following example:

$$F(t) = \frac{m_{u_1} + m_{u_2} + \cdots + m_{u_n}}{n}$$

Explanation:

m_{u_n} : the midpoint value of the i-th interval

n : the number of fuzzy sets

2. 2 Particle Swarm Optimization

In 1995, Kennedy and Eberhart introduced the Particle Swarm Optimization (PSO) Algorithm for the first time. This population-based approach, known as "Particle Swarm Optimization," is inspired by natural phenomena such as a flock of birds and a school of fish (Swarm). Each particle in the Particle Swarm Optimization Algorithm has a movement velocity that follows the search space, and this velocity is dynamically adjusted based on the particle's historical behavior. Therefore, during the search process, particles tend to move towards better search areas [16]. The goal of the Particle Swarm Optimization (PSO) Algorithm is to find the particle positions that have optimal values for the objective fitness function. Each particle in PSO stores information about its own best-reached position (pbest) and the best-reached position of neighboring particles (gbest) [17].

Because the velocity of each particle greatly influences their movement from one location to another, a dynamic velocity formula is required to obtain the best location [18]. In each iteration, the update of particle velocities is performed for each particle using the following equation:

$$v_i^{t+1} = w.v_i^{t} + c_1 r_1 \left(x_{p_i}^{t} - x_i^{t}\right) + c_2.r_2.\left(x_{gi}^{t} - x_i^{t}\right)$$

Explanation:

v_i^{t+1} : velocity of particle i at iteration t+1

v_i^{t} : velocity of particle i at iteration t

i : Particle index

w : Inertia weight

t : Current iteration

$x_{p_i}^{t}$: Best position of particle i (pbest) at iteration t

x_{gi}^{t} : Best position of all particles (gbest) at iteration t

$c_{1,2}$: Learning rate/velocity constants

$r_{1,2}$: Random numbers (between 0 and 1)

After obtaining the velocity, the next step is to update the position using the equation

$$x_i^{t+1} = x_i + v_i^{t+1}$$

Explanation:

x_i : position of particle i

v_i : velocity of particle i

The process of updating particle positions aims to determine the latest positions of each particle.

2. 3 Symmetric Mean Absolute Percentage Error (sMAPE)

Symmetric Mean Absolute Percentage Error (sMAPE) is a method used to measure the prediction error rate by comparing the percentage difference between actual values and forecasted values. This method is used as a way to evaluate the accuracy of predictions by taking into account the magnitude of the estimated variables [19]. The formula used to calculate the sMAPE value is as follows [20]

$$sMAPE = \frac{2}{n}\sum_{t=1}^{n} \frac{|F_t - A_t|}{(|A_t| + |F_t|)} \times 100\%$$

Explanation:

n : Sample size

A_t : Actual data

F_t : Forecasted data

The Symmetric Mean Absolute Percentage Error (sMAPE) has the rule that the smaller the sMAPE value obtained, the better and more accurate the forecast is [20]. The criteria for the value of sMAPE are the same as the criteria for the value of MAPE, which are as follows [21]:

Table 1. sMAPE value criteria

sMAPE Value	Accuracy of Forecasting
<10%	The forecasting results are very good
10%-20%	The forecasting results are good
20%-50%	The forecasting results are fairly good

>50%	The forecasting results are poor

3. METHODOLOGY

3. 1 Data Structure

The data used in this research is derived from secondary data sources obtained from the website https://id.investing.com/. The variables to be used in this study are the closing stock price data (close price) of PT Bank Central Asia (BBCA) from January 2022 to May 2023, totaling 328 data points.

3. 2 Stages of Data Analysis

The following is the research analysis procedure using the Fuzzy Time Series method and the Particle Swarm Optimization algorithm:

1) Determining the universe of discourse and the length of the interval to be used in the analysis
2) The steps in calculating Fuzzy Time Series are as follows:
    a. Determine the length of the universe of discourse interval
    b. Formulate fuzzy sets for the universe of discourse
    c. Perform fuzzification to convert numeric data into linguistic variables
    d. Determine Fuzzy Logic Relationships (FLR) using discovered data patterns
    e. Determine Fuzzy Logic Relationship Groups (FLRG) based on the results of Fuzzy Logic Relationships (FLR)
    f. Perform defuzzification to generate more accurate prediction values
    g. Calculate prediction error values using the Symmetric Mean Absolute Percentage Error (sMAPE) method
3) The steps in calculating Fuzzy Time Series-Particle Swarm Optimization are as follows:
    a. Initialize Particle Swarm Optimization parameters such as the number of particles, the number of iterations, inertia weight (w), and combinations of c_1,2 and r_1,2
    b. Initialize the initial velocity of particles by setting the initial velocity of all particles to 0 in the initial iteration or the first iteration
    c. Initialize the initial positions of particles, generate initial random positions in the initial iteration or the first iteration
    d. Perform prediction calculations using the Fuzzy Time Series method
    e. Calculate fitness values using the sMAPE value from the initial particle positions.
    f. Determine Personal Best (pBest), where the pBest value is equal to the initial particle position.
    g. Determine Global Best (pBest), where the gBest value is obtained from the pBest value with the smallest sMAPE.
    h. Update particle velocities and positions.
    i. Calculate the sMAPE value from the updated Particle Swarm Optimization particle positions.
    j. Repeat steps (d) through (j) until the maximum specified iteration is reached
4) Compare the sMAPE results between the Fuzzy Time Series method and the Fuzzy Time Series-Particle Swarm Optimization method.

4. RESULT

4. 1 **Descriptive Statistic**

Descriptive statistics is a type of statistics that describes or provides an overview of the subject or research being studied or investigated without analyzing it and can draw general conclusions [22].

Table 2. Descriptive statistics

Variabel	Mean	Std. Deviasi	Min	Max	Median
BBCA	8162.5	541.3555	7000	9300	8200

The average closing stock price of PT Bank Central Asia during the period from January 3, 2022, to May 9, 2023, is 8162.5. The minimum closing stock price of PT Bank Central Asia is 7000, while the maximum is 9300. The standard deviation of the closing stock price of PT Bank Central Asia is 541.3555.

4. 2 **Implementation of the Fuzzy Time Series Method**

4. 2. 1 To determine the universal set (U)

The values D_1 and D_2 used in this research are D_1=25 and D_2=10 where the minimum value D_{min}=7000 and maximum value D_{max}=9300, Therefore, the universal set that will be generated is as follows:

$$U = (D_{min} - D_1, D_{max} + D_2)$$
$$U = (7000 - 25, 9300 + 10)$$
$$U = (6975, 9310)$$

4. 2. 2 Determining the Number of Class Intervals

To determine the number of class intervals, the Sturges formula can be used:

$$K = 1 + 3.322 \times \log n$$

$$K = 1 + 3.322 \times \log (328)$$

$$K = 9.35 \sim 9 \text{ class}$$

Determining the Length of Class Intervals Using the Following Equation:

$$l = \frac{[(D_{max} + D_2) - (D_{min} - D_1)]}{the\ number\ of\ class\ intervals(K)}$$

$$l = \frac{[(9300 + 10) - (7000 - 25)]}{9}$$

$$l = 259.4$$

After obtaining the number of class intervals and the length of class intervals, the next step is to create a class based on these values. The following table shows the interval classes formed based on the research data:

Table 3. Division of Class Intervals

Interval	Lower Bound		Upper Bound	Midpoint
U1	6975.000	-	7234.444	7104.722
U2	7234.444	-	7493.889	7364.167
U3	7493.889	-	7753.333	7623.611
U4	7753.333	-	8012.778	7883.056
U5	8012.778	-	8272.222	8142.500
U6	8272.222	-	8531.667	8401.944
U7	8531.667	-	8791.111	8661.389
U8	8793.333	-	9051.667	8922.5
U9	9051.667	-	9310	9180.833

4. 2. 3 Forming a Fuzzy Set

To form a fuzzy set, the division of the universe of discourse (U) is used. Let U = [$U_1, U_2, U_3, U_4, \ldots\ldots U_n$] with U_1 as the possible values of U, and let A_i be a fuzzy set within the universal set U. Then, the fuzzy set A_i can be formulated as follows:

$$A_1 = \frac{\mu_{A1}(u_1)}{u_1} + \frac{\mu_{A2}(u_2)}{u_2} + \cdots + \frac{\mu_{A9}(u_9)}{u_9}$$

In this case, $\mu_{A1}(u_1)$ refers to the degree of membership of u_1 in the fuzzy set A_1. The obtained degrees of membership are organized to form a linguistic variable as follows:

$$A_1 = \frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0}{u_8} + \frac{0}{u_9}$$

$$A_2 = \frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0}{u_8} + \frac{0}{u_9}$$

$$\vdots$$

$$A_9 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0{,}5}{u_8} + \frac{1}{u_9}$$

4. 2. 4 Fuzzification Process

The fuzzification stage involves the creation based on the effective intervals obtained and the linguistic values that have been calculated. The data will be mapped to certain linguistic values based on their degree of membership, and then the highest value will be selected

Table 4. Fuzzification

No	Date	Data	Fuzzification
1	1/3/2022	7325	A_2
2	1/4/2022	7400	A_2
⋮	⋮	⋮	⋮
328	5/9/2023	8925	A_8

4. 2. 5 Determining Fuzzy Logic Relationship (FLR)

Fuzzy Logic Relationship (FLR) is determined by combining similar relations from the set of Fuzzy Logic

Relationships (FLR) in the current state (F(t-1)) into a single group of relations [14]. Each fuzzy number has a relationship and can be defined as an FLR in the form of $A_i \rightarrow A_j$ where A_i represents the previous observation and A_j represents the current observation in the time series data. The results of Fuzzy Logic Relationships (FLR) can be seen in the table below:

Table 5. Fuzzy Logic Relationship

No	Date	Data	Fuzzification	FLR
1	1/3/2022	7325	A_2	NA→A_2
2	1/4/2022	7400	A_2	A_2→A_2
⋮	⋮	⋮	⋮	⋮
328	5/9/2023	8925	A_8	A_8→A_8

4. 2. 6 Determining Fuzzy Logic Relationship Group (FLRG)

After the Fuzzy Logic Relationship (FLR) is formed, the next step is to determine the Fuzzy Logic Relationship Group (FLRG) that groups each state transition. The results of the Fuzzy Logic Relationship Group (FLRG) can be seen in the table below:

Table 6. Fuzzy Logic Relationship Group

Current State	***Next State***	**FLRG**
$\boldsymbol{A_1}$	A_1, A_2	A_1→A_1, A_2
$\boldsymbol{A_2}$	A_1, A_2, A_3	A_2→A_1, A_2, A_3
⋮	⋮	⋮
$\boldsymbol{A_8}$	A_7, A_8, A_9	A_8→A_7, A_8, A_9
$\boldsymbol{A_9}$	A_8, A_9	A_9→A_8, A_9

4. 2. 7 Determining the Defuzzification of Prediction Values

The following is a forecast for the fuzzy set A_9:

$$F(A_9) = \frac{m_{u_8} + m_{u_9}}{2}$$

$$F(A_9) = \frac{8920,833 + 9180,278}{2}$$

$$F(A_9) = 9050,556$$

Thus, the forecasting results for each data influenced by the fuzzy set A_9 amount to 9050.556. These calculations are performed for each group according to the formed FLRG and yield different results depending on the number of members in the FLRG. The forecast values for Fuzzy Time Series can be seen in the following table:

Table 7. Forecast Results

No	Date	Data	Forecast	sMAPE
1	1/3/2022	7325		
2	1/4/2022	7400	7364,167	0.2427%
3	1/5/2022	7450	7364,167	0.5794%
⋮	⋮	⋮	⋮	⋮
328	5/9/2023	8925	8920,833	0.0233%
	sMAPE Average			1.4701%

The average sMAPE value obtained is 1.4701%, so it can be concluded that the forecast results fall into the category of excellent criteria because they produce an sMAPE value below 10%.

4. 3 Implementation of the Time Series-Particle Swarm Optimization Method

4. 3. 1 Initialization of Particle Swarm Optimization Parameters

The parameters that need to be initialized in Particle Swarm Optimization include the number of iterations, the number of particles, the inertia weight (w), as well as the combinations of c_1 and c_2 which must satisfy the condition $c_1 + c_2 \leq 4$. Additionally, the values of r_1 and r_2 should also be initialized as random numbers in the range of 0 to 1, and the particle dimensions are determined by the number of classes present in the Fuzzy Time Series method minus 1.

Table 8. Parameter Initialization

Parameters	Value
Number of Particles	10
Number of Iterations	5
Particle dimensions	8
Inertial weights (w)	0.5
c1	1.5
c2	1.5
r1	0.26
r2	0.4

4. 3. 2 Initialization of Particle Initial Velocity

In the first iteration, the initial particle velocity is set to 0 because there has been no previous movement, and the particles are still in a stationary state, not yet engaged in any motion.

Table 9. Initialize the Initial Velocity of the Particle

	V1	V2	V3	V4	V5	V6	V7	V8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
10	0	0	0	0	0	0	0	0

4. 3. 3 Initialization of Particle Initial Position

In the initialization, the initial position of the particles is randomized within the lower and upper bounds of the Fuzzy Time Series universe of discourse, which have lower and upper limits of 6975 and 9310. Both of these values are not included in the initialization of particle positions as they are fixed values. The table below shows the initialized initial positions of the particles:

Table 10. Initialize the Initial Position of the Particle

Par.	X1	X2	…	X8
1	7219	7443	…	9116
2	7460	7654	…	9152
⋮	⋮	⋮	…	⋮
10	7374	7836	…	9004

4. 3. 4 Calculating the Fitness Value from the Initial Particle Positions in PSO

The steps to calculate the fitness value are the same as the previous fuzzy time series method. Here are the steps to calculate the fitness value of particle 1:

- Interval Formation

The interval formation process uses the same calculation process as before, with the difference being the interval values for each fuzzy set. The interval values are determined using the initialized initial position values of particle 1. For the linguistic variables, it remains the same as in the Fuzzy Time Series method because the number of intervals remains 8 intervals. The initialized values will be used to form the intervals as follows:

Table 11. Division of Class Intervals

Interval	Lower Bound		Upper Bound	Midpoint
U1	6975	-	7219	7097.0
U2	7219	-	7443	7331.0
⋮	⋮	⋮	⋮	⋮
U8	8862	-	9116	8989.0
U9	9116	-	9310	9213.0

- Fuzzification

The fuzzification phase is formed using the determined effective intervals and the calculated linguistic values. The table below displays the data that has undergone the fuzzification process:

Table 12. Fuzzification

No	Date	Data	Fuzzification
1	1/3/2022	7325	A_2
2	1/4/2022	7400	A_2
⋮	⋮	⋮	⋮
328	5/9/2023	8925	A_8

- Determining Fuzzy Logic Relationship (FLR)

The data resulting from the Fuzzy Logic Relationship (FLR) can be seen in the table below:

Table 13. Fuzzy Logic Relationship

No	Date	Data	Fuzzification	FLR
1	1/3/2022	7325	A_2	NA$\rightarrow A_2$
2	1/4/2022	7400	A_2	$A_2 \rightarrow A_2$
⋮	⋮	⋮	⋮	⋮
328	5/9/2023	8925	A_8	$A_8 \rightarrow A_8$

- Determining Fuzzy Logic Relationship Group (FLRG)

The data from the Fuzzy Logic Relationship Group (FLRG) can be seen in the table below:

Table 14. Fuzzy Logic Relationship Group

Current State	***Next State***	**FLRG**
$\boldsymbol{A_1}$	A_1, A_2	$A_1 \rightarrow A_1, A_2$
$\boldsymbol{A_2}$	A_1, A_2, A_3	$A_2 \rightarrow A_1, A_2, A_3$
⋮	⋮	⋮
$\boldsymbol{A_9}$	A_8, A_9	$A_9 \rightarrow A_8, A_9$

- Determining the Defuzzification of Prediction Values

The obtained Fuzzy Logic Relationship Group (FLRG) results are then used for the next step, which is defuzzification and the calculation of the forecasting value for particle 1. The following is an example of forecasting for fuzzy set A_1:

$$F(A_1) = \frac{m_{u_1} + m_{u_2}}{2}$$

$$F(A_1) = \frac{7097 + 7331}{2}$$

$$F(A_1) = 7214$$

Based on the calculations above, the forecasting result for each data influenced by fuzzy set A_1 is Rp 7214. These calculations are performed for each group according to the formed FLRG and yield different results depending on the number of members. The forecast values for particle 1 can be seen in the following table:

Table 15. Prediction Results of the 1st Particle

No	Date	Data	Forecast	sMAPE
1	1/3/2022	7325		
2	1/4/2022	7400	7323.00	0.5230%
3	1/5/2022	7450	7323.00	0.8597%
⋮	⋮	⋮	⋮	⋮
328	5/9/2023	8925	8979.67	0.3053%
	sMAPE Average			**1.57294%**

Repeat the Fuzzy Time Series calculations for particles 2, 3, 4, 5, 6, 7, 8, 9, and 10. The table below shows the fitness values of each particle calculated using the sMAPE values:

Table 16. sMAPE Average Value from the First Iteration

Par.	X1	X2	…	X8	sMAPE
1	7219	7443	…	9116	1.57294%
2	7460	7654	…	9152	1.50963%
⋮	⋮	⋮	…	⋮	⋮
10	7374	7836	…	9004	1.47401%
	sMAPE Average				**1.52197%**

Based on the table, it can be seen that the average sMAPE value in the first iteration is 1.52197%. With this value, it can be concluded that the forecasting results fall into the category of excellent, as the sMAPE value is below 10%.

4. 3. 5 Determining the Personal Best (pBest)

In the first iteration or initial iteration, the Personal Best (pBest) value is equal to the initial position of the particle, so the pBest value obtained in the first iteration that has been conducted can be seen in the table below:

Table 17. Personal Best (pBest)

Par.	***pBest* 1**	***pBest* 2**	…	***pBest* 8**	sMAPE
1	7219	7443	…	9116	1.57294%
2	7460	7654	…	9152	1.50963%
⋮	⋮	⋮	…	⋮	⋮
10	7374	7836	…	9004	1.47401%

4. 3. 6 Determining the Global Best (gBest)

The Global Best (gBest) value is obtained from the Personal Best (Pbest) values with the smallest fitness function or sMAPE value. In the first iteration, the particle with the smallest sMAPE value is found in particle 9 with an sMAPE value of 1.39696%. The gBest value in the first iteration can be seen in the table below:

Table 18. Global Best (gBest)

Par.	***pBest* 1**	***pBest* 2**	…	***pBest* 8**	sMAPE
9	7127	7281	…	8816	1.39696%

4. 3. 7 Update of the Particle Velocity

In the first iteration, the calculation process for updating the velocity of particle 1 can be seen as follows:

$$v_{1,1}(1) = 0.5 \times 0 + 1.5 \times 0.26\,(7219 - 7219) + 1.5 \times 0.4\,(7127 - 7219)$$

$$v_{1,1}(1) = -55.2$$

Repeat the calculation for each particle, which are particles 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. The results of the velocity update calculation for the second iteration can be seen in the table below:

Table 19. Update of the Particle Velocity

Juml. Par.	V1	V2	…	V7	V8
1	-55.2	-97.2	…	-129	-180
2	-199.8	-223.8	…	-117	-201.6
3	75.6	55.8	…	-67.8	-243
⋮	⋮	⋮	⋮	⋮	⋮
9	0	0	…	0	0
10	-148.2	-333	…	-208.8	-112.8

4. 3. 8 Update of particle position

The calculation of particle 1's position update in the first iteration is as follows:

$$x_{1,1}(1) = x_i(0) + v_{1,1}(1)$$

$$x_{1,1}(1) = 7219 + (-55.2)$$

$$x_{1,1}(1) = 7163.8$$

Repeat the calculation for each particle, which are particles 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. The results of the position update calculation for the second iteration can be seen in the table below:

Table 20. Update of particle position

Juml. Par.	X1	X2	…	X7	X8
1	7163.8	7345.8	…	8733	8936
2	7260.2	7430.2	…	8725	8950.4
3	7076.6	7243.8	…	8692.2	8978
⋮	⋮	⋮	⋮	⋮	⋮
9	7127	7281	…	8647	8816
10	7225.8	7503	7881.6	8786.2	8891.2

4. 3. 9 Determining the Fitness Value from Particle Position Update in PSO

The calculation of the fitness value using the sMAPE value is done as in the previous steps. The sMAPE in the following iterations is as follows:

- Iteration 2

The average sMAPE obtained in the second iteration can be seen in the following table:

Table 21. sMAPE Average Value from the Second Iteration

Juml. Par.	X1	X2	…	X8	sMAPE
1	7163.8	7345.8	…	8936	1.49898%
2	7260.2	7430.2	…	8950.4	1.58810%
⋮	⋮	⋮	…	⋮	⋮
10	7225.8	7503	…	8891.2	1.41664%
		sMAPE			**1.47794%**

- Iteration 3

The average sMAPE obtained in the third iteration can be seen in the following table:

Table 22. sMAPE Average Value from the Third Iteration

Juml. Par.	X1	X2	…	X8	sMAPE
1	7121.8	7382.2	…	8802.6	1.3944%
2	7166.0	7439.9	…	8876.1	1.3434%
…	…	…	…	…	…
10	7100.1	7327.1	…	8818.2	1.4960%
		sMAPE			**1.4309%**

- Iteration 4

The average sMAPE obtained in the fourth iteration can be seen in the following table:

Table 23. sMAPE Average Value from the Fourth Iteration

Juml. Par.	X1	X2	…	X8	sMAPE
1	7127.3	7435.0	…	8780.0	1.3720%
2	7118.9	7444.8	…	8839.0	1.4613%
⋮	⋮	⋮	…	⋮	⋮
10	7125.8	7375.5	…	8845.0	1.4762%
		sMAPE			**1.4052%**

- Iteration 5

The average sMAPE obtained in the fifth iteration can be seen in the following table:

Table 24. sMAPE Average Value from the Fifth Iteration

Juml. Par.	X1	X2	…	X8	sMAPE
1	7144.0	7428.4	…	8812.5	1.3664%
2	7132.7	7406.4	…	8843.3	1.4193%
…	…	…	…	…	…
10	7192.5	7452.1	…	8881.1	1.4142%
		sMAPE			**1.3678%**

The average sMAPE value in the fifth iteration or the maximum iteration is 1.3678%. Based on this value, it can be concluded that the forecast results fall into the category of very good, as the sMAPE value is below 10%.

4. 4 Comparing the Accuracy Results of Both Methods

Based on the testing and analysis results of the research conducted, the average Symmetric Mean Absolute Percentage Error (sMAPE) values can be seen in the following table:

Table 25. Comparison of Average sMAPE Values

Method	sMAPE Average
Fuzzy Time Series	1.4701%
Fuzzy Time Series-Particle Swarm Optimization	**1.3678%**

Based on the above analysis, it is found that the Fuzzy Time Series-Particle Swarm Optimization method yields a smaller sMAPE value compared to the sMAPE value in the Fuzzy Time Series method. Based on these results, it can be concluded that the use of the Particle Swarm Optimization algorithm for optimizing intervals in Fuzzy Time Series successfully improves the forecasting accuracy

Based on the accuracy comparison between the Fuzzy Time Series method and Fuzzy Time Series-Particle Swarm Optimization, it can be determined that the Fuzzy Time Series-Particle Swarm Optimization method is the best method for forecasting the stock price of PT Bank Central Asia. Here are the forecasted results of PT Bank Central Asia's stock price for the next 1 period using the Fuzzy Time Series-Particle Swarm Optimization method from particle 5, which is the global best (gbest) in the 5th iteration, as follows:

4. 5 Predicting Stock Prices Using the Best Method

Table 26. PT Bank Central Asia Share Price Forecasting

Date	Forecast
5/10/2023	8896.56

Based on the table above, it can be seen that the forecasted closing stock price of PT Bank Central Asia using the Fuzzy Time Series-Particle Swarm Optimization method with 5 particles, which is the global best (gbest) in the 5th iteration, for predicting the next period on May 10, 2023, is Rp 8896.56. Based on the forecasted value, it can be determined that the closing stock price for the next period on May 10, 2023, has decreased from Rp 8925 on May 9, 2023, to 8896.56 on May 10, 2023.

5. CONCLUSION

Based on the analysis results, there is a comparison of prediction accuracy values between the Fuzzy Time Series method and the Fuzzy Time Series-Particle Swarm Optimization method based on the symmetric Mean Absolute Percentage Error (sMAPE) for PT Bank Central Asia (BBCA) stock prices. The results from the Fuzzy Time Series method showed an sMAPE value of 1.4701%, whereas for the Fuzzy Time Series-Particle Swarm Optimization method, an sMAPE value of 1.3678% was obtained. Based on this comparison, it can be concluded that the Fuzzy Time Series-Particle Swarm Optimization method is superior to the Fuzzy Time Series method in predicting PT Bank Central Asia (BBCA) stock prices. The forecasted stock price of PT Bank Central Asia using the best method, which is Fuzzy Time Series-Particle Swarm Optimization with 5 particles, which is the pbest in the 5th iteration, is Rp 8925 for the next period on May 10, 2023.

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