

# INTEGRATING FUZZY TIME SERIES AND ICHIMOKU KINKO HYO FOR STOCK MARKET FORECASTING AND TRADING SIGNAL IDENTIFICATION: EVIDENCE FROM THE JAKARTA COMPOSITE INDEX

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*The rapid growth of digital investment platforms has increased public participation in stock market investments, creating a need for accurate forecasting and decision-support methods. This study aims to forecast the daily closing prices of the Jakarta Composite Index (JKSE) and provide investment recommendations by integrating the Fuzzy Time Series (FTS) Chen model and the Ichimoku Kinko Hyo indicator. The dataset consists of 1,201 daily JKSE closing price observations collected from Yahoo Finance, covering the period from June 7, 2021, to June 5, 2026. The FTS model was employed to forecast future price movements, while Ichimoku Kinko Hyo was used to identify market trends and trading signals. The results indicate that the FTS model achieved high forecasting accuracy with MAPE, RMSE, and MSE values of 0,0136, 117,79, and 13.875,19, respectively. Furthermore, the Ichimoku analysis revealed a recent shift from a bullish to a bearish trend, suggesting a cautious investment strategy. Overall, the integration of FTS and Ichimoku Kinko Hyo provides an effective framework for stock market forecasting and investment decision-making.*

**Keywords** - Fuzzy Time Series, Ichimoku Kinko Hyo, Stock Forecasting, Investment Decision.

## I. INTRODUCTION

The rapid advancement of digital trading platforms, financial technology (fintech), and artificial intelligence has fundamentally transformed investment activities by enabling investors to access real-time market information and execute transactions more efficiently. This digital transformation has significantly increased participation in capital markets, particularly among retail investors, while

simultaneously creating a growing demand for accurate stock market forecasting methods to support investment decision-making under uncertain market conditions [1]. As one of the most important financial markets, the stock market is characterized by high volatility and complex nonlinear behavior resulting from interactions among macroeconomic conditions, corporate performance, investor sentiment, and global economic events. Consequently, developing reliable forecasting models capable of predicting stock price movements has become an important research topic in financial analytics and computational intelligence [2].

One of the most important investment instruments in the digital economy is the stock market. Stocks represent ownership in a company and provide investors with opportunities to gain returns through capital appreciation and dividends. In Indonesia, the stock market plays a crucial role in supporting economic growth and capital allocation. The performance of the Jakarta Composite Index (JCI), which reflects the overall movement of stocks listed on the Indonesia Stock Exchange, is widely used as an indicator of market conditions and investor [3]. Consequently, the ability to accurately forecast stock price movements and market trends has become increasingly important for investors seeking to optimize investment decisions and manage risks effectively.

Despite its importance, stock market forecasting remains a challenging task due to the dynamic, nonlinear, and uncertain nature of financial markets. Stock prices are influenced by numerous factors, including macroeconomic conditions, corporate performance, investor psychology, and global market events [4]. These factors often create complex patterns that are difficult to model using conventional statistical approaches. Therefore, researchers have increasingly explored intelligent forecasting techniques capable of handling

uncertainty and nonlinear relationships within financial time series data. Among these approaches, Fuzzy Time Series (FTS) has emerged as an effective method for forecasting under uncertain environments. Unlike traditional time series methods that rely on precise numerical values, FTS represents historical data using linguistic variables and fuzzy sets, allowing uncertainty and vagueness to be modeled more effectively [5]. Previous studies have demonstrated the applicability of FTS in forecasting financial data, including stock prices, exchange rates, and market indices. Furthermore, recent developments in FTS focus on improving forecasting accuracy through enhanced clustering techniques, such as Fuzzy C-Means, Robust Clustering, and Firefly Algorithm-based clustering methods [6]. These improvements contribute to more effective partitioning of data and more accurate fuzzy logical relationship construction.

While forecasting future price movements is essential, investors also require practical tools to identify trading opportunities. Technical analysis provides various methods for determining market trends and generating buy and sell signals. One of the most widely recognized trend-following indicators is Ichimoku Kinko Hyo. This indicator consists of five components that collectively provide information regarding trend direction, momentum, support and resistance levels, and potential entry and exit points [7]. The interaction among Tenkan-sen, Kijun-sen, Senkou Span A, Senkou Span B, and Chikou Span enables investors to evaluate market conditions comprehensively and identify trading signals more effectively than many single-indicator approaches.

Although numerous studies have investigated Fuzzy Time Series and Ichimoku Kinko Hyo independently, limited research has explored the integration of these two approaches in stock market forecasting and trading signal identification. Existing FTS studies primarily focus on improving prediction accuracy, while Ichimoku-based studies generally emphasize trend confirmation and signal generation. Consequently, there remains a gap in the literature regarding how forecasting models and technical indicators can be combined to provide both accurate market predictions and actionable trading decisions.

Furthermore, investors often face difficulties in determining optimal entry and exit points during periods of high market volatility [8]. Forecasting models may predict future market movements but do not necessarily provide clear trading signals. Conversely, technical indicators can generate trading signals but may suffer from lagging effects and market noise. Integrating Fuzzy Time Series with Ichimoku Kinko Hyo may overcome these limitations by combining the forecasting capability of FTS with the trend identification and signal confirmation strengths of the Ichimoku system.

Therefore, this study aims to develop and evaluate an integrated framework combining Fuzzy Time Series and Ichimoku Kinko Hyo for forecasting stock market movements and identifying trading signals in the Jakarta Composite Index. The proposed approach is expected to provide more accurate forecasts, improve the identification of extreme market conditions, and assist

investors in determining optimal investment positions within the Indonesian stock market.

## II. METHOD

This study employed a hybrid approach combining the Fuzzy Time Series (FTS) Chen model and the Ichimoku Kinko Hyo indicator to analyze and forecast stock market movements. The FTS Chen model was utilized to predict future price trends based on historical time-series data by transforming numerical observations into linguistic variables through the processes of defining the universe of discourse, interval partitioning using the Sturges rule, fuzzification, construction of Fuzzy Logical Relationships (FLR), and defuzzification to generate forecast values. The forecasting performance was evaluated using Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE). In addition, the Ichimoku Kinko Hyo technique was applied to identify market trends and generate trading signals through its main components, namely Tenkan-sen, Kijun-sen, Senkou Span A, Senkou Span B, and Chikou Span. The interaction among these components was used to determine buy, sell, and hold signals based on trend direction and momentum. Finally, the results from FTS forecasting and Ichimoku Kinko Hyo analysis were integrated to provide a comprehensive framework for predicting future market trends and supporting investment decision-making.

### A. Fuzzy Time Series (FTS)

Periodic data (time series) is a collection of data arranged according to regular times or dates and chronologically [9]. The time series can be definite by day, week, month, year, etc. Therefore, periodic data are linked to recorded and observed statistical data. Transactions, prices, supplies, performance, exchange rates, inventories, etc within a given time interval market share price [10].

Fuzzy time series is a concept that can be used to forecast problems and cases for which historical data exist formed with linguistic values [11]. This also means that the previous data in the fuzzy time series are linguistic. The resulting actual data are real numbers. The step of forecasting using the method fuzzy time series (FTS) Chen model as written below [12]:

1. Find the universe of discourse (U) with  $D_1$  and  $D_2$  are constant.  $D_{min}$  is describe smallest data from data histories and  $D_{max}$  was definition by biggest data from data histories.
2. Find the interval from divide the discourse universe into several intervals of equal length. That can be used to find out how many need an interval using the Sturges formula as explained below.

$$\text{sum of intervals} = 1 + 3,322 \log(n) \#(1)$$

And the after get value from sum of intervals and then calculate the length of interval using the formula:

$$\text{interval length} = \frac{D_{min} - D_{max}}{\text{sum of intervals}} \#(2)$$

Until it forms certain amount of linguistic values to presented a fuzzy set on the intervals that comes from the universe of discourse (U) was calculated with:

$$U = \{u_1, u_2, \dots, u_n\} \#(3)$$

3. Combine Fuzzy sets was definition before with fuzzification of historical data
4. Determining Fuzzy Logic Relationship and make grouping based from time. Fuzzy Logic Relationship for  $A_i \rightarrow A_j$ , determined from value of  $A_i$  which was already determined before from previous step, where  $A_i$  is year definition and  $A_j$  is year  $n + 1$  period definition in time series data. For example, if fuzzy logic relationship have formed  $A_1 \rightarrow A_2, A_1 \rightarrow A_1, A_1 \rightarrow A_3, A_1 \rightarrow A_1$ , then from this can find best of fuzzy logic relationship grup was formed by  $A_1 \rightarrow A_1, A_2, A_3$ .
5. The the procces for defuzzification from giving function  $F(t) = A_1, A_2, \dots, A_n$  was continued with final prediction value was definition by equation as written below :

$$\hat{y}(t) = \frac{\sum_{i=1}^n m_i}{k} \#(4)$$

#### B. Ichimoku Kinko Hyo

Ichimoku Kinko Hyo was definition the equilibrium at a glance. This technique was introduced by a reporter name Goichi Hosoda at year 1968 which do development of candlestick analysis techniques [13]. When he have profesion on reporter, he using other name called "Ichimoku Sanjin" which the first kanji character of his name means "glimpse" and the next character stands for a person standing in the mountains. Thus the name gives nuance to the point of view and clarity of the type of graph it offers.

Ichimoku Kinko Hyo have many component are *tenkan sen*, *kijun sen*, *senkou span A*, and *senkou span B*. Let definition *tenkan sen* have symbolized in green in the graph below is formed based on the following calculation formula as below [14]:

$$\text{tenkan sen} = \frac{\text{high price} + \text{low price}}{2} \#(5)$$

In example for the 9 periods where using high price and low price here shows that Ichimoku calculated value of price changes in that periods. That's meaning 9 period is definite the calculation of the nine periods that have occurred. for the past 9 periods. So if you use a chart with a 1 hour time frame then the calculation is done is nine hours back. The other parameter is *Kijun Sen* or base line is definite a symbolized by the Yellow line and formed according to the formula as follows [15]:

$$\text{Kijun Sen} = \frac{\text{high price} + \text{low price}}{2} \#(6)$$

Difference of *tenkan sen*, the *Kinjun sen* is calculated using 26 different periods already occurred. 6 periods in the default settings on the Ichimoku Kinko Hyo indicator is twenty-six working days according to when Ichimoku Kinko Hyo was first introduced in Japan who use 6 working days for one week. While nine periods are used because based on trial and error and backtesting it was found that nine periods is the most appropriate period to be combined with twenty-six periods [16].

The use of nine and twenty six periods as if it does not exist relationship with any period, but if there is a period

that is replaced then other periods may also have to be replaced. The *tenkan sen* and *kijun sen* characters are capable shows a trend where the intersection between the two is a sign of a trend transition from up to down, or etc. If the *tenkan sen* is above the *kijun sen*, then you can it is said that the price is in an uptrend [17]. Vice versa, when tension the *sen* is below the *kijun sen*, meaning the price is in a downtrend.

The slope of the *Tenkansen* and *Kijunsen* lines able to show the strength of a trend that is formed [18]. The higher angle slope of line, the stronger trend will continue. Where is the corner the ideal slope for the *kijun sen* is between 33 to 45 degrees. The *Chikou Span* or *Lagging Span*, represented by the brown line, is formed from the current price chart rewinding 26 periods. The *Chikou Span* line is exactly the same like a price chart. This line shows price momentum or in other words a line. It shows whether a trend will emerge or not. *Senkou span A* or *leading span A* with blue line color and *Senkou Span B* or *Leading Span B* with a red line. These two lines form the cloud or *kumo* like the shaded part of red or blue. *Kumo* red color indicates a signal down trend, on the other definition *kumo* was Blue color giving an up trend signal. *Senkou Span A* and *Senkou Span B* calculations are determined based on calculations as follows [19]:

$$\text{Senkou Span (A,B)} = \frac{\text{Tenkan sen} + \text{Kijun sen}}{2} \#(7)$$

Advanced for 26 periods where the calculation result that appears in the current period. This is obtained from 26 periods backwards. And the current price calculation will be used to determine the *Senkou Span A* point in the next 26 periods. Meanwhile on *Senkou Span B* also uses the same formula as *Senkou Span A*. The difference is that the value obtained from calculations for the past 52 periods to be advanced for 26 future period. Formation of *Senkou Span A* and *Senkou Span B* which were withdrawn 26th day from current *Kumo* and future. So that there are 2 *Kumo*, namely the current *Kumo* this (current *Kumo*) and future *Kumo* (future *Kumo*). Both kinds of *Kumo* can used because each can provide information.

### III. RESULT AND DISCUSSION

This section presents the results obtained from the implementation of the Fuzzy Time Series (FTS) and Ichimoku Kinko Hyo. The dataset consists exclusively of trading-day observations spanning from June 7, 2021, to June 5, 2026, therefore, non-trading days, including weekends and public holidays, are not included, and no interpolation or imputation was performed. Prior to the forecasting process, the dataset is chronologically divided into two subsets, with 80% of the observations used as the training data for model construction and the remaining 20% reserved as the testing data for out-of-sample performance evaluation. The FTS model is first developed using the training dataset, while forecasts for the testing dataset are generated through a rolling one-step-ahead forecasting procedure, where each new actual observation is sequentially incorporated into the historical series to simulate real-world forecasting conditions and avoid

look-ahead bias. The discussion begins with an overview of the dataset characteristics through descriptive statistical analysis, followed by the forecasting results generated by the FTS model on both the training and testing datasets. Subsequently, the forecasting performance is evaluated using several accuracy metrics, including Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE), to assess both the in-sample fitting ability and out-of-sample predictive accuracy of the proposed model. Finally, trading signals and investment decisions are analyzed based on the Ichimoku Kinko Hyo indicator to provide insights into future market trends and potential investment opportunities.

#### A. Descriptive Statistics

This subsection provides descriptive statistical information of the JKSE closing price data used in this study. Statistical measures such as the minimum, maximum, mean, median, and standard deviation are presented to describe the distribution and variability of the historical stock market data.

Table 1. Descriptive Statistics of Daily JKSE Closing Prices (June 2021–June 2026)

| Statistics         | Value   |
|--------------------|---------|
| n                  | 1201.00 |
| mean               | 7080.21 |
| Standard deviation | 587.05  |
| median             | 7007.05 |
| min                | 5594.77 |
| max                | 9134.70 |
| range              | 3539.93 |

Table 1 presents the descriptive statistics of the daily closing prices of the Jakarta Composite Index (JKSE) from June 2021 to June 2026, comprising 1,201 observations. The average closing price during the study period was 7,080.21 points, while the median value was 7,007.05 points, indicating that the central tendency of the data was concentrated around the 7,000-point level. The standard deviation of 587.05 points suggests that the JKSE experienced moderate fluctuations around its mean value throughout the observation period. The lowest closing price recorded was 5,594.77 points, whereas the highest closing price reached 9,134.70 points. Consequently, the range of 3,539.93 points reflects substantial variation in market performance over the five-year period. Overall, these descriptive statistics indicate that the JKSE exhibited notable price movements and volatility, providing a suitable basis for forecasting and trend analysis using the Fuzzy Time Series and Ichimoku Kinko Hyo methods.

#### B. Forecasting Results

This subsection presents the forecasting results obtained using the Fuzzy Time Series (FTS) model. The model is first constructed using the training dataset, which comprises 80% of the historical daily JKSE closing prices arranged chronologically. The trained FTS model is then employed to generate forecasts. The predicted values are subsequently compared with the actual closing prices to illustrate the model's ability to capture market movements, identify future trends, and assess its forecasting accuracy under realistic market conditions.

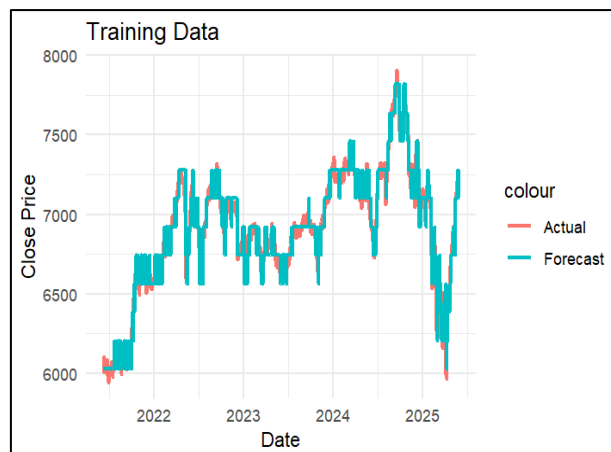


Figure 1. Actual and Forecasted JKSE Closing Prices Using the Fuzzy Time Series (FTS) Model

Figure 1 presents the comparison between the actual and forecasted daily closing prices of the Jakarta Composite Index (JKSE) on the training dataset, which comprises 80% of the historical observations used to construct the Fuzzy Time Series (FTS) model. The forecasted values closely overlap with the actual closing prices throughout the training period, indicating that the proposed FTS model is capable of effectively learning the historical price patterns and underlying market dynamics.

During the training period, the JKSE exhibited an overall upward trend, increasing from approximately 6,000 points in mid-2021 to around 7,700 until 7,900 points in 2024, although several short-term fluctuations and corrections were observed. A notable decline occurred toward the end of the training period, where the index dropped to approximately 6,000 points, followed by a moderate recovery. Despite these fluctuations, the forecasted series consistently follows the direction of the actual observations with only minor deviations, particularly during periods of rapid price movements and increased market volatility.

The close agreement between the actual and forecasted values demonstrates that the FTS model successfully captures both the long-term trend and short-term variations of the JKSE within the training dataset. This result indicates that the model has learned the historical relationships effectively and provides a reliable basis for subsequent out-of-sample forecasting on the testing dataset. Nevertheless, slight discrepancies during highly volatile periods suggest that abrupt market movements remain challenging to predict, which is a common characteristic of fuzzy time series forecasting models.

#### C. Model Evaluation

This subsection evaluates the out-of-sample forecasting performance of the proposed Fuzzy Time Series (FTS) model using the testing dataset, representing 20% of the historical observations not used during model training. Forecasts are generated through a rolling one-step-ahead forecasting strategy to simulate real-world forecasting conditions and avoid look-ahead bias. The model performance is assessed using Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE), providing a comprehensive evaluation of the model's predictive accuracy and reliability on previously unseen data.

Table 2. Forecasting Performance Evaluation of the Fuzzy Time Series (FTS) Model

| Metrics | Value     |
|---------|-----------|
| MAPE    | 0,0166    |
| RMSE    | 166,59    |
| MSE     | 27.752,97 |

Table 2 presents the forecasting performance of the Fuzzy Time Series (FTS) model based on three evaluation metrics: Mean Absolute Percentage Error (MAPE), Root Mean Squared Error (RMSE), and Mean Squared Error (MSE). The model achieved a MAPE value of 0,0136, indicating that the average forecasting error was approximately 1,36% if expressed as a percentage, which demonstrates a very high level of forecasting accuracy. Furthermore, the RMSE value of 117,79 suggests that the average deviation between the actual and forecasted JKSE closing prices was relatively small compared to the average index level of approximately 7.080 points.

Similarly, the MSE value of 13.875,19 indicates that the overall forecasting errors remained low throughout the study period. These results demonstrate that the FTS model was able to accurately capture the movement of JKSE closing prices and produce reliable forecasts, making it a suitable approach for stock market trend prediction and investment analysis.

#### D. Trading Signal and Investment Decision Analysis Based on Ichimoku Kinko Hyo

This subsection analyzes market trends and trading signals generated by the Ichimoku Kinko Hyo indicator. The interpretation of Tenkan-sen, Kijun-sen, Senkou Span A, Senkou Span B, and Chikou Span is used to identify buy, sell, or hold opportunities. Furthermore, the trading signals are combined with the forecasting results to support investment decision-making and provide insights into future market conditions.

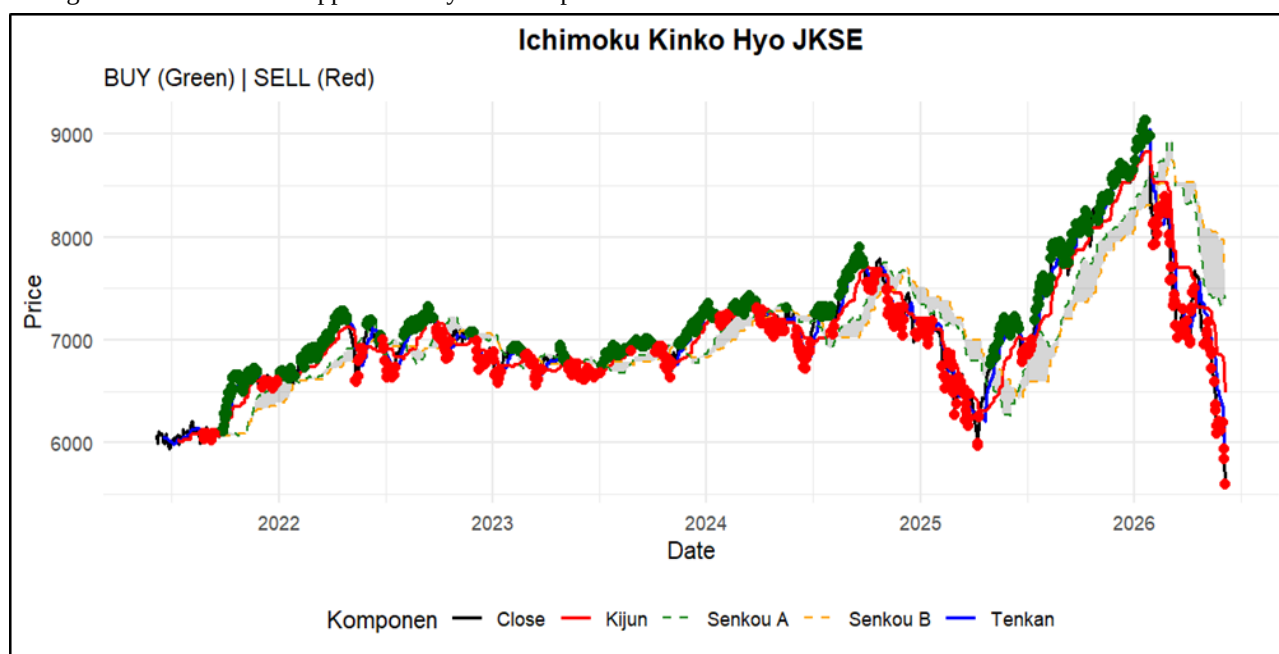


Figure 2. Ichimoku Kinko Hyo Analysis of JKSE with Buy and Sell Signals (June 2021–June 2026)

Figure 2 presents the trend analysis of the Jakarta Composite Index (JKSE) using the Ichimoku Kinko Hyo indicator, where green points represent buy signals and red points represent sell signals. The chart shows that the JKSE experienced a generally upward trend from 2021 to early 2026, as indicated by the dominance of buy signals and the frequent position of the Tenkan-sen above the Kijun-sen. During this period, the closing price also remained above the Ichimoku cloud (Kumo), confirming a bullish market condition. The strongest upward momentum occurred between mid-2025 and early 2026, when the index increased significantly and reached its highest level of approximately 9.100 points.

However, after reaching its peak in early 2026, the market exhibited a substantial downward correction. This trend reversal is reflected by the increasing number of sell signals, the crossover of the Tenkan-sen below the Kijun-sen, and the movement of the closing price toward and below the Ichimoku cloud. The concentration of red signals in the final observation period indicates weakening bullish momentum and growing bearish

pressure. Therefore, based on the latest Ichimoku configuration, the market sentiment shifted from a bullish phase to a bearish phase, suggesting increased caution for investors.

**Investment Decision Analysis.** Based on the most recent Ichimoku signals shown in Figure 2, the JKSE is currently in a bearish trend, as evidenced by the predominance of sell signals and the downward movement of the closing price. Consequently, the recommended investment decision is SELL or HOLD, depending on the investor's risk profile. Existing investors may consider reducing exposure or securing profits, while potential investors are advised to wait for a clearer bullish confirmation, such as a Tenkan-sen and Kijun-sen bullish crossover accompanied by the closing price moving above the Ichimoku cloud. If the bearish trend persists, further downward movement may occur before a new upward trend is established.

#### E. Discussion

The results of this study demonstrate that the

integration of the Fuzzy Time Series (FTS) model and the Ichimoku Kinko Hyo indicator provides a comprehensive framework for stock market analysis by combining forecasting capability with technical trend identification. The FTS model achieved a low forecasting error, as evidenced by the MAPE, RMSE, and MSE values, indicating its ability to accurately capture the movement of JKSE closing prices. Furthermore, the forecasting results revealed that the JKSE experienced a long-term upward trend during most of the observation period, although significant volatility and a sharp correction emerged toward the end of the sample period. This finding suggests that while the Indonesian stock market maintained positive growth momentum over the long run, short-term market uncertainty increased substantially during the final stage of the analysis.

The Ichimoku Kinko Hyo analysis complements these findings by providing clearer insights into market sentiment and trend direction. Although bullish conditions dominated the market from 2021 to early 2026, the most recent signals indicate a transition toward a bearish trend. The crossover of the Tenkan-sen below the Kijun-sen, accompanied by the movement of prices below the Kumo cloud, suggests weakening upward momentum and increasing downside risk. These technical indicators imply that investors should exercise caution despite the historically strong performance of the index.

From an investment perspective, the combined results of the FTS and Ichimoku analyses suggest a defensive strategy in the short term. Conservative investors are advised to adopt a HOLD position and wait for stronger bullish confirmation before initiating new investments. Moderate-risk investors may selectively accumulate fundamentally strong stocks once the market shows signs of stabilization and reversal. Meanwhile, aggressive investors may take advantage of short-term price corrections; however, strict risk management and stop-loss strategies should be implemented due to the prevailing bearish market sentiment. Overall, the current market condition does not provide a strong buy signal, and investors should closely monitor future trend confirmations, particularly the recovery of the Tenkan-sen above the Kijun-sen and the movement of prices back above the Ichimoku cloud. Such signals would indicate the potential emergence of a new bullish phase and more favorable investment opportunities in the Indonesian stock market.

#### IV. CONCLUSSION

Based on the results, it can be concluded that the Fuzzy Time Series (FTS) model is effective for forecasting the daily closing prices of the Jakarta Composite Index (JKSE) using historical data from June 2021 to June 2026. The forecasting results indicate that the predicted values closely follow the actual market movements, successfully capturing both long-term trends and short-term fluctuations. Throughout most of the observation period, the JKSE exhibited an upward trend, reaching its peak in early 2026 before undergoing a substantial downward correction. Moreover, the model demonstrated high forecasting accuracy, as reflected by the low error

values. These findings suggest that the FTS model is a reliable approach for stock market forecasting and can effectively support financial analysis and decision-making.

The Ichimoku Kinko Hyo analysis further enhanced the forecasting results by providing insights into market trends and trading signals. Although bullish conditions dominated the market from 2021 to early 2026, the most recent indicators reveal a transition toward a bearish trend, evidenced by the Tenkan-sen crossing below the Kijun-sen and the movement of prices below the Kumo cloud. Consequently, the current market environment calls for a cautious investment strategy, with HOLD or SELL positions being more appropriate than aggressive buying. Investors are encouraged to wait for stronger bullish confirmation, such as a bullish crossover and a price recovery above the Ichimoku cloud, before initiating new positions. Overall, the integration of FTS forecasting and Ichimoku Kinko Hyo technical analysis provides a comprehensive and practical framework for predicting market movements and supporting informed investment decisions in the Indonesian stock market.

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