

Implementation of Holt's Linear Exponential Smoothing in Predicting Stock Prices

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Abstrak

Historical data of the daily closing price of Bank Tabungan Negara (BBTN) shares for the 2019-2025 period was processed using Holt's Linear Exponential Smoothing method to generate short-term trend projections. The modeling process was carried out by calculating the level component, trend component, and predicted values based on predetermined smoothing parameters α and β . Model performance evaluation was conducted using the Mean Absolute Percentage Error (MAPE), yielding a value of 4.46%, which falls into the excellent category ($<10\%$). This prediction system was implemented as an interactive web application allowing users to upload data, configure calculation parameters, and display prediction results in tables and graphs. The research results show that the used method can provide accurate stock price estimates and can be used to support trend analysis and short-term investment decision-making.

Kata Kunci: *Holt's LES, Prediksi Saham, BBTN, MAPE, Time Series.*

1. Introduction

Advances in information technology have driven the acceleration of digitalization in various sectors, including capital market investment. Currently, stock trading activities can be conducted online through various platforms, making it easier for investors to access data and conduct transactions. In this context, the banking sector plays a crucial role as the mainstay of the national economy. PT Bank Tabungan Negara (Persero) Tbk (BBTN), as one of the state-owned banks (BUMN) focused on housing finance, shows a relatively high level of stock price volatility. These fluctuations are influenced by external factors, such as macroeconomic conditions, government policies, and market responses to strategic issues in the financial sector. Changes in BBTN's stock price are a concern for investors and market analysts. Therefore, a prediction method capable of modeling stock price movement patterns with good accuracy is needed to support investment decision-making. One statistical method commonly used in time series analysis is Holt's Linear Exponential Smoothing, which is an extension of single exponential smoothing. This method is effective in handling data with a linear trend, making it suitable for predicting stock prices that tend to change gradually. In line with digital business transformation, the number of retail investors in Indonesia continues to increase through the use of online stock trading platforms (Hidayat, 2021). Data from the Indonesia Stock Exchange (IDX) shows that in the last five years, the number of stock investors has increased significantly, including interest in BBTN shares as one of the strategic state-owned enterprises (Indonesian Ministry of State-Owned Enterprises, 2022).

The openness of real-time stock price data through various platforms creates higher transparency but also demands more sophisticated analysis methods (Wijaya, 2022). Modern investors need prediction tools capable of processing large amounts of data accurately and efficiently. Holt's Linear Exponential Smoothing is considered appropriate due to its ability to capture the trend component in time series data. Several studies also prove that this method can provide prediction results with adequate accuracy for stock price movements. On the other hand, stock trading carries unavoidable risks, especially errors in investment decision-making. These errors can cause losses due to a lack of investor caution and prudence. Therefore, a prediction system is needed that can help investors analyze stock trends simply, effectively, and relevantly for short-term needs

(Indriyani Putri et al., 2021). One commonly used technique is forecasting based on historical data, using methods such as Holt's Linear Exponential Smoothing (Indriyani et al., 2023).

2. LITERATURE REVIEW

2.1 Stock Market

Generally, a market is understood as a venue where sellers with goods meet buyers with capital to conduct buying and selling activities. In a broader sense, a market is not limited to physical meetings but also includes the space or media where transactions occur between sellers and buyers even if they do not meet face-to-face. Current information technology development allows buying and selling activities to be conducted online, so sellers and buyers can transact without being in the same location. Meanwhile, a stock is proof of capital ownership or a form of participation by an individual or business entity in the capital of a company or limited liability company (Dewi Umi Latifah & Sriwidjayanto, 2022).

2.2 Stock Price

Stock price is the value of a share formed from the interaction between supply and demand in the capital market. Changes in stock prices are highly influenced by company conditions, government policies, interest rates, inflation, and global economic dynamics. In the capital market, stock prices are an important indicator reflecting a company's performance and are a primary reference for investors in making investment decisions. According to financial theory, stock prices reflect the expected value of future cash flows discounted at a certain rate. Therefore, stock prices are fluctuating and can change in a short time. Internal factors such as financial reports, management performance, and company business strategies, as well as external factors such as macroeconomic conditions, political situations, and market sentiment, will influence stock price movements. In the context of this research, the main focus is on the stock price movement of PT Bank Tabungan Negara (Persero) Tbk (BBTN), which tends to have high volatility. Understanding the dynamics of stock prices is very important to support the application of forecasting methods, so investors can get a more accurate picture of future stock price trends.

2.3 Stock Price Prediction With Holt's LES

Holt (1957) developed an extended Exponential Smoothing method to enable prediction of data that has a trend. This approach utilizes one prediction equation and two smoothing equations, for the level and trend components (Omer et al., 2021). The exponential smoothing method is essentially an iterative calculation procedure that is continuously updated based on the latest data, giving exponentially decreasing weight to historical data. This technique is considered effective for both medium and long-term forecasting, especially when the data shows a clear trend pattern. Holt's Linear Exponential Smoothing falls into the category of weighted moving average methods, where each past data point is given different emphasis to produce the next forecast value. Thus, exponential smoothing can be used on time series data to produce more representative predictions, as more recent data will have a greater influence on the forecasting results (Andini & Nabilla, 2023).

2.4 Review of Previous Research

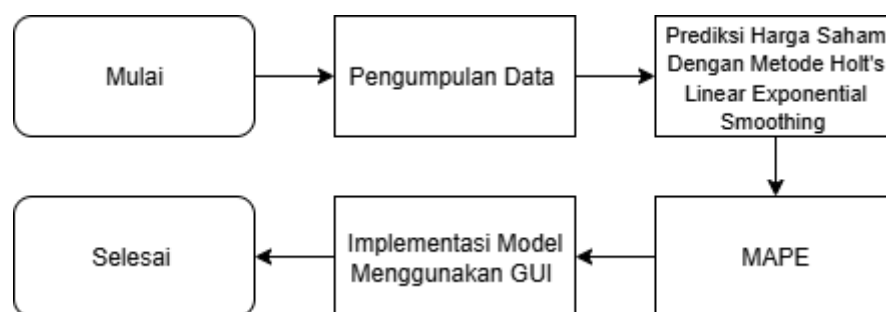
Various previous studies have applied time series forecasting methods, including Holt's Linear Exponential Smoothing, to analyze stock price movement trends and support investment decision-making processes. (Alfinatuzzahro et al., 2024) forecasted the Gross Domestic Product (GDP) of the furniture industry in Indonesia using the Double Exponential Smoothing-Holt method. The results showed that with parameters $\alpha = 0.658$ and $\beta = 0.008$, a MAPE value of 0.737% was obtained, so the predicted GDP for 2022 in quarters 1-4 were IDR 7.602 billion, IDR 7.676 billion, IDR 7.759 billion, and IDR 7.822 billion, respectively. Another study by (Retno & Sari, 2022) applied the Double Exponential Smoothing method to monthly inflation data for 2021. The results showed that data from January to December 2021 had a trend pattern, so this method was deemed appropriate. Based on the forecasting results, the predicted inflation for the period January to May 2022 was 1.78%, 1.83%, 1.87%, 1.91%, and 1.96%, respectively, which were lower than the inflation in December 2021. Furthermore, (Santoso Pakpahan et al., 2020) predicted the number of poor people in East Kalimantan using Single and Double Exponential Smoothing methods. The results showed that the

Holt's Double Exponential Smoothing method provided the best forecasting results for 2019 with varying α and β parameter values in each region. For example, Paser City, West Kutai, and Kutai Kartanegara had prediction results of 25,930, 14,018, and 56,486 people with MAPE values of 6.51%, 4.35%, and 5.49%, respectively. Meanwhile, Samarinda City, Bontang, Balikpapan, to Mahakam Ulu also showed fairly accurate prediction results with MAPE ranging from 1.83% to 14.81%. (Irfan Zaky & Padmo Azam Masa, 2024) implemented Holt's Double Exponential Smoothing method for forecasting the Human Development Index (HDI) in East Kalimantan Province and its regencies/cities. The results showed that the predicted HDI for East Kalimantan for the period 2023-2027 was 77.95; 78.46; 78.98; 79.49; and 80.01, respectively. From the optimization results, the smallest MAPE value was 0.229% based on HDI data from 2011-2022, indicating a very good forecasting accuracy level.

Based on various previous studies, time series forecasting methods such as Single, Double, and Holt's Exponential Smoothing have been widely used in various fields, including inflation, Gross Domestic Product (GDP), the number of poor people, and the Human Development Index. However, studies specifically discussing the prediction of stock prices for strategic state-owned enterprises like PT Bank Tabungan Negara (Persero) Tbk (BBTN) are still limited, even though these stocks have high volatility and play an important role for investors. This condition creates a research gap that forms the basis of this study, namely the application of Holt's Linear Exponential Smoothing method to forecast BBTN stock price trends. Through this approach, it is hoped that accurate, simple, and relevant prediction results will be obtained as a tool to assist investors in making short-term investment decisions.

3 RESEARCH METHOD

This research uses a quantitative descriptive approach aimed at designing and implementing a stock price prediction system based on Holt's Linear Exponential Smoothing method. The research object focuses on the stock of PT Bank Tabungan Negara (Persero) Tbk (BBTN), which was chosen because it has a linear trend pattern suitable for the characteristics of the method used. The research data consists of daily stock closing prices obtained from the Investing.com website (<https://www.investing.com/>) as a secondary data source. This data is a daily time series recording stock price movements in chronological order. Changes in BBTN's stock price are influenced by various macroeconomic factors, such as inflation, interest rates, and policies in the financial and housing sectors. The research activity flow is depicted in Figure 1 as the research framework.



Gambar 1 Framework Penelitian

3.1 Data Collection

Data collection in this research was carried out by utilizing historical daily stock price data of PT Bank Tabungan Negara (Persero) Tbk (BBTN) obtained from public sources such as Investing.com and Yahoo Finance. The data selected was the closing price because this value reflects the final position of a stock in each trading session and is often used as the main indicator in analysis and forecasting. The data period used was set from 2019 to 2025 so that the stock movement trend pattern can be seen more clearly and comprehensively. This historical data was then used as a basis for analyzing price fluctuations and building the time series forecasting model.

3.2 Holt's LES

Holt's Linear Exponential Smoothing (LES) is a time series forecasting method used for data with a trend pattern. This method is an extension of Single Exponential Smoothing, which can only be used on data without a trend. In Holt's LES, there are two main components: level (L_t), which indicates the base value at a certain period, and trend (T_t), which represents the direction of data change. This method has three main equations:

$$\begin{aligned} L_t &= \alpha Y_t + (1 - \alpha)(L_{t-1} + T_{t-1}) \\ T_t &= \beta(L_t - L_{t-1}) + (1 - \beta)T_{t-1} \\ F_{t+m} &= L_t + mT_t \end{aligned}$$

This method assigns greater weight to the most recent data, allowing the prediction results to adapt more quickly to changing trends, and is effective for short- to medium-term forecasting.

3.3 MAPE

Mean Absolute Percentage Error (MAPE) is an evaluation measure used to assess the accuracy level of forecasting results. MAPE calculates the average percentage of absolute error between the actual value and the predicted value. Thus, this indicator provides an overview of how far the forecast results deviate from the true value in percentage form. A smaller MAPE value indicates a better prediction accuracy level, while a high value indicates decreased accuracy. The advantage of MAPE is that its results are easy to interpret because they are expressed in percentage units, making it relevant for use on both large and small-scale data.

Mathematically, MAPE can be formulated as follows:

$$MAPE = \frac{100\%}{n} \sum_{t=1}^n \frac{|y_t - F_t|}{y_t}$$

The MAPE value is used to measure the level of prediction error by calculating the average absolute difference between the actual values and the forecasted values, then dividing it by the actual values and expressing it as a percentage. A smaller MAPE value indicates that the forecasting results are more accurate, while a larger MAPE value reflects lower prediction accuracy.

System Design. The design of this stock price prediction application system was carried out utilizing a GUI interface integrated with the Holt's Linear Exponential Smoothing method and a MySQL database. The design process is illustrated through several types of diagrams, including Use Case Diagram, Activity Diagram, Class Diagram, and Entity Relationship Diagram. The preparation of these diagrams aims to facilitate the implementation process and provide a clearer picture of the overall system workflow.

4. RESULTS AND DISCUSSION

This research uses historical data of the daily closing price of PT Bank Tabungan Negara (Persero) Tbk (BBTN) shares for the 2019-2025 period obtained from the Investing.com website. This data was then processed using the Holt's Linear Exponential Smoothing (LES) method to form a prediction model based on level and trend components. The calculation results show that the Holt's LES model was able to provide quite stable prediction results following the movement pattern of the actual data. Accuracy evaluation was performed by calculating the Mean Absolute Percentage Error (MAPE) value. Based on testing, a MAPE value of 4.46% was obtained, which falls into the excellent category (<10%). This value indicates that the difference between the prediction results and the actual data is relatively small, so the model can be trusted to provide an overview of BBTN's stock price trend.

Furthermore, the system implementation results show that the designed prediction application can not only display forecast values in table form but also visualize them into graphs, making it easier for users to understand the direction of stock movement. With high accuracy and a simple interface, this system is considered effective as a tool to assist investors in analyzing stock price trends, especially for the short term after the last data period.

4.1 System Implementation

The stock price prediction system for PT Bank Tabungan Negara (Persero) Tbk (BBTN) was built using the Python programming language with support from a Tkinter-based Graphical User Interface (GUI). Tkinter was chosen based on its ability to build simple yet interactive application interfaces and its ease of integration with the Holt's Linear Exponential Smoothing method used in this research. The system implementation is divided into several main parts to support a comprehensive forecasting process.

4.2 Homepage Display

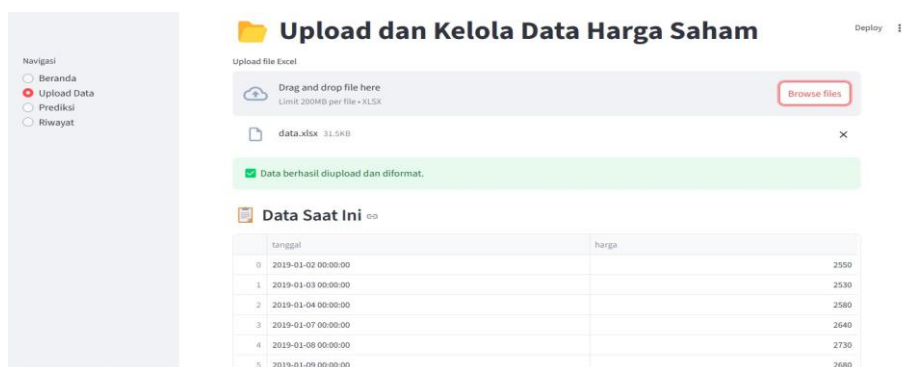
The homepage displays a brief explanation of the application's main purpose, accompanied by navigation buttons directing users to the core features: data upload and stock price prediction. The display is designed to be simple, intuitive, and easy to understand so users do not face difficulties when first using the application. Furthermore, the interface design is also equipped with supporting elements such as information labels and brief instructions, so users get an initial overview of the system usage flow.



Gambar 2 Tampilan Beranda

4.3 Data Upload Display

The data upload page functions as a place to input historical stock price files into the system. Users can upload Excel files containing date and stock closing price data according to the specified format. After successful upload, this page also provides features to edit or delete data before further processing in the prediction stage. The display is designed simply so the upload process can be done quickly and easily, even for users trying the application for the first time. Furthermore, this page includes notifications of success or errors during upload, so users get immediate feedback.



The screenshot shows the 'Edit Data' and 'Hapus Data' sections of the application. On the left is a navigation sidebar with options: Beranda, Upload Data (selected), Prediksi, and Riwayat. The 'Edit Data' section has a dropdown for 'Pilih Tanggal yang Ingin Diedit' set to '2019-01-02' and a text input for 'Harga Baru' set to '0,00'. Below these is a 'Simpan Perubahan' button. The 'Hapus Data' section has a dropdown for 'Pilih Tanggal yang Ingin Dihapus' set to 'Choose an option'. Below this is a 'Hapus Baris Terpilih' button and a 'Lanjut ke Halaman Prediksi' button.

Gambar 3 Tampilan Upload Data

4.4 Prediction Display

The prediction page functions to generate BBTN stock price forecasts based on previously uploaded historical data. On this page, users can set the required parameters, such as determining the *split data* date, manually entering the α and β values, and selecting the end period of the prediction. After the process is run, the system automatically displays the prediction results in a graph comparing actual data with forecast results and calculates the MAPE value as an accuracy measure. Furthermore, this page also provides a feature to download the prediction results into Excel or PDF formats for easy saving or sharing. The interface design is made simple yet informative, so users can understand the analysis results more quickly and clearly.

The screenshot shows the 'Prediksi Saham Holt's' page. It includes a navigation sidebar with options: Beranda, Upload Data, Prediksi (selected), and Riwayat. The main content area has a 'Kembali ke Halaman Upload Data' button and a dropdown for 'Pilih Tanggal Awal Pengujian Data Real (Split Date)' set to '2024/01/01'. Below this is a 'Data Training' section with a table showing historical data.

	tanggal	harga
0	2019-01-02 00:00:00	2550
1	2019-01-03 00:00:00	2530
2	2019-01-04 00:00:00	2580
3	2019-01-07 00:00:00	2640
4	2019-01-08 00:00:00	2730
5	2019-01-09 00:00:00	2680
6	2019-01-10 00:00:00	2680
7	2019-01-11 00:00:00	2730
8	2019-01-14 00:00:00	2740

Navigasi
☐ Beranda
☐ Upload Data
☒ Prediksi
☐ Riwayat

Data Testing

	tanggal	harga
0	2024-01-02 00:00:00	1265
1	2024-01-03 00:00:00	1255
2	2024-01-04 00:00:00	1295
3	2024-01-05 00:00:00	1295
4	2024-01-08 00:00:00	1285
5	2024-01-09 00:00:00	1330
6	2024-01-10 00:00:00	1335
7	2024-01-11 00:00:00	1360
8	2024-01-12 00:00:00	1350
9	2024-01-15 00:00:00	1355

Masukkan nilai Alpha

0,40

Masukkan nilai Beta

0,06

Navigasi
☐ Beranda
☐ Upload Data
☒ Prediksi
☐ Riwayat

6	2024-01-10 00:00:00	1335
7	2024-01-11 00:00:00	1360
8	2024-01-12 00:00:00	1350
9	2024-01-15 00:00:00	1355

Masukkan nilai Alpha

0,40

Masukkan nilai Beta

0,06

Pilih Tanggal Akhir Prediksi

2025/08/20

Lakukan Prediksi

Gambar 4 Tampilan Prediksi

4.5 History Display

The history feature functions to display a collection of archived stock predictions that have been saved in the system. The information displayed includes the prediction execution time, the range of data periods used, the parameter values α and β , the MAPE value along with its classification, and the end limit of the prediction period. Besides displaying previous result details, this feature also helps users perform evaluation comparisons between predictions without having to repeat the calculation process. The display is designed to be simple yet informative, so users can access and understand the prediction history results more easily.

Daftar Riwayat
☒ Tampilkan semua

	id_prediksi	tanggal_prediksi	periode_data	alpha	beta	mape	keterangan_mape	tanggal_akhir_prec
0	27f1c944	2025-08-20	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-20
1	c65a9ba3	2025-08-20	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-20
2	ceadee45	2025-08-18	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-18
3	9d7e8dd0	2025-08-17	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-17
4	9cab259c	2025-08-15	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-01
5	aba3f889	2025-08-10	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-10
6	ae1d59dc	2025-08-10	2019-01-02 - 2025-05-22	0.4	0.06	20.32	Kemampuan Peramalan Layak/Memadai	2025-08-10
7	e5e141f2	2025-08-10	2019-01-02 - 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-10

Detail Riwayat

Pilih ID Prediksi

27f1c944

Detail Riwayat
Deploy

Pilih ID Prediksi

27f1c944

Ringkasan entri:

	id_prediksi	tanggal_prediksi	periode_data	alpha	beta	mape	keterangan_mape	tanggal_akhir_prediksi
0	27f1c944	2025-08-20	2019-01-02 – 2025-05-22	0.4	0.06	4.46	Kemampuan Peramalan Sangat Baik	2025-08-20

Tabel hasil lengkap (gabungan training, aktual, dan prediksi tambahan).

	Tanggal	Price	Forecast	Error	Periode
0	2019-01-02	2550	None	None	None
1	2019-01-03	2530	None	None	None
2	2019-01-04	2580	2510	0.0271	None
3	2019-01-07	2640	2519.68	0.0456	None
4	2019-01-08	2730	2552.376	0.0651	None
5	2019-01-09	2680	2612.257	0.0253	None
6	2019-01-10	2680	2629.811	0.0187	None
7	2019-01-11	2730	2641.549	0.0324	None
0	2019-01-02	2550	None	None	None
1	2019-01-03	2530	None	None	None
2	2019-01-04	2580	2510	0.0271	None
3	2019-01-07	2640	2519.68	0.0456	None
4	2019-01-08	2730	2552.376	0.0651	None
5	2019-01-09	2680	2612.257	0.0253	None
6	2019-01-10	2680	2629.811	0.0187	None
7	2019-01-11	2730	2641.549	0.0324	None
8	2019-01-14	2740	2670.714	0.0253	None
9	2019-01-15	2760	2693.876	0.024	None

Download Detail PDF

Hapus Entri Ini

Gambar 5 Tampilan Riwayat

4.6 System Evaluation

System evaluation was carried out by comparing the actual movement data of BBTN's stock price against the forecasting results generated through the Holt's Linear Exponential Smoothing method. Furthermore, the model's accuracy was calculated using the Mean Absolute Percentage Error (MAPE) to assess the level of closeness between the predictions and the true values.

4.7 Comparison of Actual and Predicted Data

Evaluation was conducted using BBTN stock price data from the period January 2024 to May 2025. This actual data was processed by the prediction system based on the Holt's Linear Exponential Smoothing method, then the forecast results were compared with the actual stock price values. This comparison is presented in a table containing the date, actual price, prediction results, and percentage error as the basis for measuring system accuracy.

No	Tanggal	Price	Forecast	Error	Periode	Keterangan Mape
0	2024-01-02 00:00:00	1265	1233.27	2.51	1	Kemampuan Peramalan Sangat Baik
1	2024-01-03 00:00:00	1255	1233.18	1.74	2	Kemampuan Peramalan Sangat Baik
2	2024-01-04 00:00:00	1295	1233.09	4.78	3	Kemampuan Peramalan Sangat Baik

3	2024-01-05 1295 00:00:00	1233.00	4.79	4	Kemampuan Peramalan Sangat Baik
4	2024-01-08 1285 00:00:00	1232.91	4.05	5	Kemampuan Peramalan Sangat Baik
5	2024-01-09 1330 00:00:00	1232.81	7.31	6	Kemampuan Peramalan Sangat Baik
6	2024-01-10 1335 00:00:00	1232.72	7.66	7	Kemampuan Peramalan Sangat Baik
7	2024-01-11 1360 00:00:00	1232.63	9.37	8	Kemampuan Peramalan Sangat Baik
...		...	...	...	...
323	2025-05-12 1275 00:00:00	1203.56	5.6	324	Kemampuan Peramalan Sangat Baik

Tabel 1 Hasil Prediksi Dengan Data Aktual

Accuracy Calculation With MAPE

Mean Absolute Percentage Error (MAPE) is an evaluation method used to measure the accuracy of prediction results by comparing the average percentage of absolute difference between the actual value and the predicted value. A low MAPE value indicates a high accuracy level, while a large value indicates less accurate predictions. Generally, MAPE <10% is categorized as excellent, 10-20% good, 20-50% fair, and >50% considered poor.

$$MAPE = \frac{100\%}{n} \sum_{t=1}^n \frac{|y_t - F_t|}{y_t}$$

$$MAPE = \frac{100\%}{324} \times (2.51 + 1.74 + \dots + 5.59) = 12.95$$

Thus, the stock price prediction system produces a MAPE value of 12.95% on the test data. This result shows that the Holt's Linear Exponential Smoothing method is quite reliable in providing estimates of BBTN's stock price, although its accuracy is in the good category and there is still a deviation between the actual data and the prediction results. This difference is particularly visible in certain periods with sharper price fluctuations, where the model tends to give more moderate results. Therefore, this system can be used as a tool for short-term trend analysis, but final investment decisions still need to consider other external factors such as macroeconomic conditions and government policies.

5. CONCLUSION AND SUGGESTIONS

Conclusion

Based on the research results, the BBTN stock price prediction system using the Holt's Linear Exponential Smoothing method was able to produce reasonably accurate forecasts. Manual MAPE calculation on the entire data showed a value of 4.46%, while on the test data for the period January

2024 to May 2025, a MAPE value of 12.95% was obtained, which falls into the good category. This proves that the model can be used as a tool for short-term trend analysis, although further development is still needed to make predictions more accurate and comprehensive.

Suggestions

The development of the stock price prediction system based on Holt's Linear Exponential Smoothing can still be improved in the future. One direction for development is adding external variables, such as inflation, interest rates, or government policies, to make the prediction results more comprehensive. Furthermore, comparison with other forecasting methods, such as ARIMA or LSTM, can be conducted to obtain a model with higher accuracy. Integrating the system into web-based or mobile platforms is also an opportunity so users can access prediction features flexibly anytime and anywhere. With these developments, the system is expected to become a more reliable, adaptive, and suitable investment analysis tool for the needs of the modern capital market.

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