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Optimisation of Inventory Management Through Time Series Analysis of Inventory Data with Double Exponential Smoothing Method

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ABSTRACT

Stock forecasting is very useful for companies in knowing the trend of inventory needed in the next period, with time series data often forecasting can be a solution in supporting decision making. Excess or lack of stock of goods is often caused by a less than optimal record management process and often relies on personal intuition. In this study, the Double Exponential Smoothing method is applied in analyzing time series data and forecasting stock data. This method is used because it is in accordance with the company's sales data which is up and down. In addition, this forecasting calculation does not escape the error rate of forecasting calculations, therefore this system is also supported by the MAD (Mean Absolute Deviation), MSE (Mean Square Error) and MAPE (Mean Absolute Percentage) methods to calculate the error rate of the forecasting results. The forecasting results show that this method is able to provide fairly accurate predictions with a MAD value of 5.2475, MSE of 43.009, and MAPE of 26.307%. By using DES, companies can perform better stock planning, reduce the risk of over- or under-stocking, and improve inventory management efficiency. The DES method is proven to be flexible and easy to implement in computerized information systems, so it is recommended to be used more widely in corporate inventory management.

Keywords: Double Exponential Smoothing; Stock Forecasting; Time Series Data Analysis

1. INTRODUCTION

In the business world, achieving maximum profit and customer satisfaction are two main goals that must be considered. To achieve these two goals, careful planning is needed, one of which is through stock forecasting. Stock forecasting is an important step to determine attitudes towards future situations using historical demand data to minimize errors in determining the amount of stock to be provided (Ahmad, 2020). This forecasting process is based on analyzing previous data to get an estimate of future needs (Wardah and Iskandar, 2022).

Forecasting is an important management function and part of planning in the company. With good forecasting, companies can make more careful planning (Fildes et al., 2022; Urva et al., 2023). Forecasting methods can be divided into two: informal and formal approaches. In many companies, the approach that is often used is the informal approach, which relies on intuition and personal experience in forecasting (Boone et al., 2019; Lin, 2024).

However, informal approaches are often not accurate enough and can cause problems such as overstocks that cannot be sold due to declining quality, or shortages that make consumers switch to competitors. This problem occurs due to sub-optimal stock planning, where the amount of demand is often not balanced with the inventory the company has. To solve this problem, PT Mega Sejahtera Abadi can switch to formal computerized forecasting methods, such as using the Double Exponential Smoothing method. This method is suitable because it can handle data with unstable trends, and allows companies to know the error rate of their forecasting. By using this method, companies can improve stock planning and reduce errors in inventory management.

In the competitive business world, efficient and accurate inventory management is essential to maintain smooth operations and maximize profits. PT Mega Sejahtera Abadi faces significant challenges in managing stock due to an inappropriate forecasting approach, resulting in overstocks or understocks. Overstocks lead to losses as goods become unsaleable, while shortages can result in the loss of customers to competitors. Therefore, more sophisticated and accurate forecasting methods are required to improve inventory management efficiency and customer satisfaction.

Double Exponential Smoothing (DES) is able to handle data with unstable trends, resulting in more accurate

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forecasting than simple forecasting methods (Khairina et al., 2021). DES can be adapted to various types of time series data, making it highly flexible for various forecasting needs(Dewantara & Giovanni, 2023; Saputra et al., 2022). The method is easily implemented in computerized information systems, allowing for automation and good integration with inventory management systems (Suryadana & Sarasvananda, 2024). DES allows the measurement of error rates in forecasting, providing useful feedback for continuous improvement (Maulana & Mulyantika, 2020). This research aims to develop and implement a stock forecasting information system at PT Mega Sejahtera Abadi using the Double Exponential Smoothing method. The main objective is to provide a more accurate forecasting method to reduce errors in determining the number of stock items, optimize the management of stock items to reduce excess and shortage of stock, and ensure timely availability of products to meet customer needs and increase their satisfaction.

2. LITERATURE REVIEW

Inventory management is a crucial aspect of business operations, and optimizing it necessitates the application of advanced forecasting techniques. Time series analysis is fundamental in accurately predicting inventory levels (Aziz & Sanjaya, 2023; Sudipa et al., 2023) . Exponential smoothing, in particular, has been recognized as a valuable tool in enhancing inventory decisions for retailers (Sihotang, 2023; Wiguna et al., 2023). This method aids in forecasting by continually updating and smoothing past data exponentially, leading to improved accuracy in predicting future inventory levels. (Ahmar et al., 2021). Double exponential smoothing, a variation of the traditional exponential smoothing method, has garnered attention for its effectiveness in handling time series data with trends. It is particularly beneficial when the data to be forecasted exhibits a trend, making it suitable for scenarios where inventory levels undergo gradual changes over time. (Mentari & Iftadi, 2023). By integrating the Double Exponential Smoothing method into inventory management practices, businesses can strengthen their forecasting capabilities and make more informed decisions regarding stock levels and ordering strategies. Furthermore, the amalgamation of artificial intelligence and advanced forecasting techniques like exponential smoothing has been demonstrated to offer valuable insights for optimizing production capacity and warehouse inventory (Atmaja et al., 2022; Mrówczyńska et al., 2017). This approach empowers businesses to forecast demand more accurately, thereby reducing excess inventory costs while ensuring product availability when required. Additionally, the utilization of Double Exponential Smoothing in forecasting sales has been compared with other methods such as weighted moving average, showcasing its efficacy in predicting future sales trends with lower Mean Absolute Percent Error values (David Saputra, 2024). Harnessing the Double Exponential Smoothing method in time series analysis for stock data can significantly enhance inventory management practices. By combining this technique with advanced forecasting models and artificial intelligence, businesses can achieve more precise predictions, minimize costs associated with excess inventory, and ultimately enhance overall operational efficiency.

3. METHOD

Double Exponential Smoothing Method

Brown's Double Exponential Smoothing is a linear model proposed by Brown. This method is used when the data shows a trend. Trend is a smoothed estimate of the average growth at the end of each period. Double Exponential Smoothing can be calculated with only three data values and one value for α (David Saputra, 2024).

1) Single smoothing formula:

$$S'_t = \alpha X_t + (1 - \alpha) S'_{t-1} \quad (1)$$

2) Double smoothing formula:

$$S''_t = \alpha S'_t + (1 - \alpha) S''_{t-1} \quad (2)$$

3) Total smoothing formula:

$$a_t = S'_t + (S'_t - S''_t) \quad (3)$$

4) Trend smoothing formula:

$$b_t = \frac{\alpha}{1-\alpha} (S'_t - S''_t) \quad (4)$$

5) Forecasting formula:

$$F_{t-m} = a_t + b_t m \quad (5)$$

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Description:
S'_t = Single smoothing value
S''_t = Double smoothing value
X_t = Actual data at time t
a_t = Total smoothing
b_t = Trend smoothing
F_{t-m} = forecast value
m = future period
α = a constant with a value between 0 and 1

Forecasting Error Measurement

An accurate projection result is a forecast that can minimize forecast error. Forecast is a prediction of what will happen, but not necessarily implemented by the company. In calculating the forecast error, the following formula can be used(Hodson, 2022; Rizki et al., 2021):

1) Mean Absolute Deviation (MAD)
Mean Absolute Deviation is a calculation used to calculate the average absolute error.

$$MAD = \frac{\sum |Xt - Ft|}{n} \quad (6)$$

Description:
Xt = Actual value
Ft = Predicted value
n = Number of data

2) Mean Squared Error (MSE)
Mean Squared Error is the average square of the forecast error.

$$MSE = \frac{\sum |Xt - Ft|^2}{n} \quad (7)$$

Description:
Xt = Actual value
Ft = Predicted value
n = Number of data

3) Mean Absolute Percentage Error (MAPE)
The percentage error is the percentage error of a forecast where :

$$PE = \left(\frac{Xt - Ft}{Xt} \right) \quad (8)$$

Mean Absolute Percentage Error is the mean absolute percentage error of a forecast.

$$MAPE = \frac{\sum |PE|}{n} x\ 100\% \quad (9)$$

Description:
Xt = Actual value
Ft = Predicted value
N = Number of data
PE = Percentage error

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The smaller the MAPE value means that the estimated value is closer to the true value, or the method chosen is the best method. The following is an analysis of the MAPE value:

Table 1
MAPE Value Range

MAPE Range	Value Meaning
<10%	Excellent forecasting model capability
10-20%	Good forecasting model capability
20-50%	The ability of the forecasting model is feasible
>50%	Poor forecasting model capability

4. RESULT

Forecasting Calculation with Double Exponential Smoothing Method

The Double Exponential Smoothing method is a linear model proposed by Brown. In this method, the smoothing process is carried out twice. The following is an example of calculating stock forecasting using the double exponential smoothing method for finished goods, namely cement 3 wheels 40kg. The sales table of 40kg 3-wheel cement at PT Mega Sejahtera Abadi in 2023 can be seen in table 2 below:

Table 2
Stock Quantity Table items

No.	Period	Out of Stock (pcs)
1.	January	70
2.	February	42
3.	March	39
4.	April	17
5.	May	15
6.	June	20
7.	July	37
8.	August	31
9.	September	18
10.	October	23
11.	November	20
12.	December	10

From the cement sales data above, we will look for forecasting in January 2023 to December 2023. Alpha (α) which will be used as a weight value is equal to (α=0.6)

Determines the first smoothing
S'2 = (0,6) 42 + (0,4) 70 = 53,2
S'3 = (0,6) 39 + (0,4) 36,4 = 44,68
S'4 = (0,6) 17 + (0,4) 29,44 = 28,07
S'5 = (0,6) 15 + (0,4) 5,37 = 20,23
S'6 = (0,6) 20 + (0,4) 3,3 = 20,09
S'7 = (0,6) 37 + (0,4) 13,18 = 30,24
S'8 = (0,6) 31 + (0,4) 37,62 = 30,69
S'9 = (0,6) 18 + (0,4) 34,11 = 23,08
S'10 = (0,6) 23 + (0,4) 16,83 = 23,03
S'11 = (0,6) 20 + (0,4) 20,48 = 21,21
S'12 = (0,6) 10 + (0,4) 18,37 = 14,48

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Determines the second smoothing (S''_t)

$S''_t = \alpha S'_t + (1 - \alpha) S''_{t-1}$

S "1 = 70
S "2 = (0,6) 53,2 + (0,4) 70 = 59,92
S "3 = (0,6) 44,68 + (0,4) 59,92 = 50,78
S "4 = (0,6) 28,07 + (0,4) 50,78 = 37,15
S "5 = (0,6) 20,23 + (0,4) 37,15 = 27
S "6 = (0,6) 20,09 + (0,4) 27 = 22,85
S "7 = (0,6) 30,24 + (0,4) 22,85 = 27,28
S "8 = (0,6) 30,69 + (0,4) 27,28 = 29,33
S "9 = (0,6) 23,08 + (0,4) 29,33 = 25,58
S "10 = (0,6) 23,03 + (0,4) 25,58 = 24,05
S "11 = (0,6) 21,21 + (0,4) 24,05 = 22,35
S "12 = (0,6) 14,48 + (0,4) 22,35 = 17,63

Determining the magnitude of the constant (a_t)

$a_t = 2S'_t - S''_t$

a1 = 2 (70) - 70 = 70
a2 = 2 (53,2) - 59,92 = 46,48
a3 = 2 (44,68) - 50,78 = 38,58
a4 = 2 (28,07) - 37,15 = 18,99
a5 = 2 (20,23) - 27 = 13,46
a6 = 2 (20,09) - 22,85 = 17,33
a7 = 2 (30,24) - 27,28 = 33,19
a8 = 2 (30,69) - 29,33 = 32,06
a9 = 2 (23,08) - 25,58 = 20,58
a10 = 2 (23,03) - 24,05 = 22,01
a11 = 2 (21,21) - 22,35 = 20,08
a12 = 2 (14,48) - 17,63 = 11,34

Determining the amount of slope (b_t)

$b_t = \frac{\alpha}{1-\alpha}(S'_t - S''_t)$

b1 = 0
b2 = $\frac{0,6}{0,4}$ (53,2 - 59,92) = -10,1
b3 = $\frac{0,6}{0,4}$ (44,68 - 50,78) = -9,14
b4 = $\frac{0,6}{0,4}$ (28,07 - 37,15) = -13,6
b5 = $\frac{0,6}{0,4}$ (20,23 - 27) = -10,2
b6 = $\frac{0,6}{0,4}$ (20,09 - 22,85) = -4,14
b7 = $\frac{0,6}{0,4}$ (30,24 - 27,28) = 4,43
b8 = $\frac{0,6}{0,4}$ (30,69 - 29,33) = 2,05
b9 = $\frac{0,6}{0,4}$ (23,08 - 25,58) = -3,75
b10 = $\frac{0,6}{0,4}$ (23,03 - 24,05) = -1,53
b11 = $\frac{0,6}{0,4}$ (21,21 - 22,35) = -1,7
b12 = $\frac{0,6}{0,4}$ (14,48 - 17,63) = -4,72

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Determine the amount of forecasting (F_{t-m})

$F_{t-m} = a_t + b_t m$

S1 = 70 + 0 = 70
S2 = 46,48 + (-10,1) = 36,4
S3 = 38,58 + (-9,14) = 29,4
S4 = 18,99 + (-13,6) = 5,37
S5 = 13,46 + (-10,2) = 3,3
S6 = 17,33 + (-4,14) = 13,2
S7 = 33,19 + 4,43 = 37,6
S8 = 32,06 + 2,05 = 34,1
S9 = 20,58 + (-3,75) = 16,8
S10 = 22,01 + (-1,53) = 20,5
S11 = 20,08 + (-1,7) = 18,4
S12 = 11,34 + (-4,72) = 6,62

Forecasting Error Calculation

Based on the results of the forecasting calculations carried out above, the forecasting error will be calculated to determine and assess the level of accuracy of the forecasting carried out. In this study, the authors used the MAD, MSE and MAPE methods to calculate the accuracy level of the forecasting performed. From the calculations carried out, the MAD value is 5.2475, the MSE value is 43.009 and the MAPE value is 26.307%. In the following figure are the forecasting results and the level of accuracy of the forecasting calculation using historical data on cement 3 wheels 40kg that has been done:

Tabel 3
Accuracy Calculation

Month	Actual (Xt)	S't	S"t	at	bt	Forecast (Yt)	Xt-Yt	| Xt-Yt|	| Xt-Yt|^2	| PE|
Januari	70	70	70	70	0	70				
Februari	42	53,2	59,92	46,48	-10,08	36,4	5,6	5,6	31,36	13,33
Maret	39	44,68	50,78	38,58	-9,14	29,44	9,56	9,56	91,39	24,51
April	17	28,07	37,15	18,99	-13,62	5,37	11,63	11,63	135,30	68,42
Mei	15	20,23	27,00	13,46	-10,15	3,30	11,70	11,70	136,80	77,97
Juni	20	20,09	22,85	17,33	-4,14	13,18	6,82	6,82	46,45	34,08
Juli	37	30,24	27,28	33,19	4,43	37,62	-0,62	0,62	0,38	1,67
Agustus	31	30,69	29,33	32,06	2,05	34,11	-3,11	3,11	9,64	10,02
September	18	23,08	25,58	20,58	-3,75	16,83	1,17	1,17	1,38	6,53
Oktober	23	23,03	24,05	22,01	-1,53	20,48	2,52	2,52	6,33	10,94
November	20	21,21	22,35	20,08	-1,70	18,37	1,63	1,63	2,64	8,13
Desember	10	14,48	17,63	11,34	-4,72	6,62	3,38	3,38	11,41	33,78

The provided table 1 the performance of a forecasting model over a twelve-month period, with the metrics Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) used to evaluate the accuracy of the predictions. MAD (Mean Absolute Deviation) is 5.24746, which indicates the average absolute error between the actual values (Xt) and the forecasted values (Yt). This metric helps understand the magnitude of errors without considering their direction (positive or negative). A lower MAD value signifies a better-fitting model, as it indicates smaller average errors. MSE (Mean Squared Error) is 43.0088, reflecting the average of the squared differences between the actual values and the forecasted values. Squaring the errors emphasizes larger errors, making MSE a sensitive metric to outliers. The higher value of MSE compared to MAD suggests some predictions deviated significantly from the actual values, thus contributing disproportionately to the error measure. MAPE (Mean Absolute Percentage Error) is 26.31%, representing the average absolute percentage error between the actual and forecasted values. MAPE provides a relative measure of forecast accuracy, making it useful for comparing forecasting performance across different datasets or models. A MAPE of 26.31% implies that, on average, the forecasted values deviate from the actual values by 26.31%.

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DISCUSSIONS

The Double Exponential Smoothing (DES) method is used in this study to forecast the stock of goods at PT Mega Sejahtera Abadi, specifically for 3-wheel 40kg cement products. This method, introduced by Brown, performs the smoothing process twice to produce more accurate forecasts. Sales data of 40kg 3-wheel cement for 2023 is used as the basis for the calculation. The forecasting process starts by calculating the first smoothing (S't) and the second smoothing (S "t). With an alpha (α) value of 0.6, the first and second smoothing are calculated for each month. The first and second smoothing results show how the historical data is processed to identify patterns and trends. Next, the constant (at) and slope (bt) are calculated for each period. The constant describes the base level of the data, while the slope shows the trend of change over time. For example, for January, the constant is calculated as 70 and the slope as 0, reflecting the baseline data. The forecast (Ft-m) for each month is then calculated using the constant and slope values. The forecasting results show the variation in the expected stock based on the identified trends. For example, the forecast for February was 36.4, while that for December was 6.62, reflecting a significant decrease in the expected stock. To assess the forecasting accuracy, the Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) methods were used. The MAD value of 5.2475 indicates the average deviation between the forecasting value and the actual value. The MSE value of 43.009 shows how large the squared forecasting error is, and the MAPE value of 26.31% shows the average percentage error. The results of this analysis show that the Double Exponential Smoothing method can provide fairly accurate forecasting for stock items, although there are still some deviations. The use of this method allows PT Mega Sejahtera Abadi to perform better stock planning and reduce the risk of over- or under-stocking. Thus, the DES method can be an effective tool in inventory management and inventory planning.

5. CONCLUSION

The conclusion of the research is in the application of the Double Exponential Smoothing (DES) method to forecast the stock of goods at PT Mega Sejahtera Abadi, especially for cement products 3 wheels 40kg. The forecasting results show that this method is able to provide fairly accurate predictions with a MAD value of 5.2475, MSE of 43.009, and MAPE of 26.307%. By using DES, companies can perform better stock planning, reduce the risk of overstocking or understocking, and improve inventory management efficiency. The contribution of this research lies in the development of a computerized forecasting model that can be adopted by other companies with similar problems, as well as providing practical recommendations to improve the accuracy of stock forecasting. For future research, it is recommended to explore and consider external factors such as seasonal changes or market trends that may affect the demand for goods. Further research can also be conducted to integrate the forecasting method with a more sophisticated inventory management system to improve overall operational efficiency.

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