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Implementation of Triple Exponential Smoothing in Predicting Blood Stock Inventory

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Abstract
Blood availability is an important component for the Indonesian Red Cross (PMI) Blood Donor Unit (UDD) in maintaining blood supplies so that blood is not wasted and there is no shortage. This study aims to test the effectiveness of using the Triple Exponential Smoothing (TES) method in predicting blood stock inventory at UDD PMI. Triple Exponential Smoothing is a forecasting method that considers seasonal patterns in data, which is relevant in predicting blood demand based on historical data. This study began by collecting historical blood stock data from January 2019 to December 2023. Next, the data was analyzed to identify seasonal patterns and trends. This method is applied to the four main blood types (A, B, AB, and O) by calculating the accuracy value using Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE). The results show that the TES method can accurately predict blood availability and demand, with a low MAPE value of 2.15% for blood type A. For blood type B, the MAPE value is 1.38%, blood type O is 1.03%, and blood type AB is 2.42%. This research is expected to significantly contribute to more effective and efficient bloodstock management at PMI and become an academic reference for future blood stock forecasting studies.
Keywords: Triple Exponential Smoothing; Blood Type; Mean Absolute Percentage Error; Mean Absolute Error; Prediction

Introduction
The Indonesian Red Cross (PMI) is a social organization responsible for providing blood through the Blood Donor Unit (UDD). This activity is crucial because the available blood stock must always meet the community's needs [1]. The challenge often faced is managing blood supplies to avoid detrimental shortages or excesses. Blood shortages can seriously impact life safety, while overstocking can cause waste, as blood has a limited validity period [2]. Therefore, an accurate prediction system is required to manage blood stocks more effectively.

Data mining is a popular field of study used by experts to develop prediction models. Predictions are expected to help reduce risks in blood supplies, which are considered important, by looking at historical data to predict future data [3]. The prediction method used in this study is Triple Exponential Smoothing (TES).

TES has been widely used to forecast data with seasonal patterns, making it suitable for predicting blood supplies that fluctuate according to certain periods. TES combines smoothing, trend, and seasonal components, unlike other methods, to produce more accurate predictions [4]. With high accuracy, TES is expected to assist PMI in planning blood stocks as needed, improving efficiency, and reducing potential blood shortages or wastage.

This study aims to test the effectiveness of TES in predicting blood supplies at PMI using monthly data covering several types of blood types. The indicators used to measure the level of accuracy are Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE) so that it can be seen to what extent TES can provide accurate predictions for each type of blood group. This research is expected to contribute academically to understanding the effectiveness of prediction methods.

Literature Review

1. Forecasting

Forecasting is the process of examining previous circumstances to predict what will happen in the future. It is necessary because social life is highly uncertain and difficult to predict [5]. In other words, forecasting aims to produce a forecast that can minimize the prediction error, which is usually measured using metrics such as mean square error, mean absolute error, and so on [6].

A forecasting method is a way to quantitatively estimate what will happen in the future based on relevant information from the past. In other words, forecasting methods are objective [7]. In addition, this method provides a sequence of work and problem-solving in the forecasting process so that the rationale and resolution of a problem can be used in forecasting activities with the same approach.

2. Blood Type

Blood is a pale yellow liquid connective tissue composed of plasma, a suspension of red blood cells or erythrocytes, white blood cells or leukocytes, and platelets. One of the main functions of blood is to transport oxygen needed by cells throughout the body. Blood also contains nutrients, metabolic waste, and various immune system building blocks designed to protect the body from various diseases [8].

Blood type is a form of categorization of a person's blood based on the presence or absence of antigenic substances derived from the surface of the red blood cell membrane due to differences in carbohydrate and protein types. Antibodies and the type of antigenic substances present in human blood determine a person's blood type [9].

3. Triple Exponential Smoothing

The Triple Exponential Smoothing method is used to forecast a seasonal data pattern. To get the forecasting value, this method uses three parameters, namely alpha (α), beta (β), and gamma (γ) [10]. The following equation can be used to determine the formula of the Triple Exponential Smoothing method.

$$S_t = \alpha\left(\frac{X_t}{l_{t-L}}\right) + (1-\alpha)(S_{t-1} + T_{t-1}) \quad (1)$$

$$T_t = \beta(S_t - S_{t-1}) + (1-\beta)T_{t-1} \quad (2)$$

$$L_t = \gamma\left(\frac{X_t}{S_t}\right) + (1-\gamma)l_{t-L} \quad (3)$$

$$F_{t+m} = (S_t + T_t m)l_{t-L+m} \quad (4)$$

Description:

S_t = Level component at time -t
X_t = Observation at time -t
α, β, γ = Exponential parameter with values between 0-1
$F_{(t+m)}$ = Forecast for m time steps into the future
m = Future Period
T_t = Trend component at time -t
L_t = Seasonality component at time -t

4. Mean Absolute Percentage Error (MAPE)

Mean absolute percentage error (MAPE) is one of the many methods used in evaluation to measure the accuracy and precision of prediction results, and it is very often used. MAPE is a proportionality measure used to calculate the absolute error of each period divided by the actual observations in that period, and then the average is calculated. The following is the formula for obtaining the MAPE value [11].

$$MAPE = \frac{1}{n}\sum_{i-1}^{n}\left|\frac{y_i - y_i'}{y_i}\right| \times 100 \quad (5)$$

Description:

n = Amount of Data
y_i' = Forecast value
y_i = Actual value

The MAPE value has criteria that indicate that the accuracy value is getting lower if the MAPE value is getting bigger. The following is a table of MAPE value criteria.

Table 1. MAPE Value Criteria

MAPE Value	Criteria
<10%	Accurate
10%-20%	Good
20%-50%	Fair
>50%	Inaccurate

Materials & Methods

1. Data Collection

This study uses historical monthly blood stock data from the Indonesian Red Cross (PMI) Blood Donor Unit (UDD) in Panyabungan City, Mandailing Natal Regency, North Sumatra, from January 2019 to December 2023. The data collected includes the blood stocks of the four main blood types: A, B, AB, and O.

Table 2. Actual Blood Type Data

Period	Blood Type A	Blood Type B	Blood Type 0	Blood Type AB
Jan-19	32	17	38	1
Feb-19	8	39	30	9
Mar-19	21	33	62	6
...	...	...	...	...
...	...	...	...	...
...	...	...	...	...
Dec-21	24	41	39	9
Jan-22	50	45	66	12
...	...	...	...	...
...	...	...	...	...
Jul-22	31	43	57	6
Aug-22	20	42	67	7
...	...	...	...	...
Nov-23	36	39	57	10
Dec-23	27	28	48	12

2. Research Method

This research method can be shown in Figure 1 below.

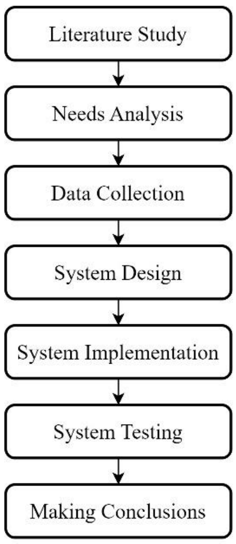

Figure 1. Research Method

The following is an explanation of this research method.

a. Literature Study
Literature study is a method for collecting and analyzing information from various written sources. The purpose is to build a theoretical basis, understand previous findings, formulate questions, and increase credibility in research.

b. Needs Analysis
Requirements analysis is the process of identifying and defining the needs of a system or project. The goal is to ensure that the designed solution can efficiently meet the expectations of the stakeholders and users.

c. Data Collection
Data collection is a structured process of obtaining information needed in a research or project. It involves planning objectives and methods, selecting collection techniques such as interviews or surveys, collecting data systematically, verifying the accuracy of the data, and storing the data securely.

d. System Design
This system design aims to create solutions that meet the needs identified during the needs analysis. At this stage, researchers use context diagrams, DFDs, and ERDs to facilitate the system's development process.

e. System Implementation
System implementation is the stage where the design is converted into an operational system. This stage includes component integration, program coding, and system testing.

f. System Testing
System testing is the process of evaluating a system to ensure that all functions work according to specifications. The goal is to find and fix bugs and ensure the system is stable and ready to use.

g. Making Conclusions
Drawing conclusions is the final step, which summarizes the main findings concisely. The aim is to convey the key points of the analysis and answer the research questions.

3. System Scheme

The following is a scheme of the blood stock prediction system using the three-fold exponential smoothing method.

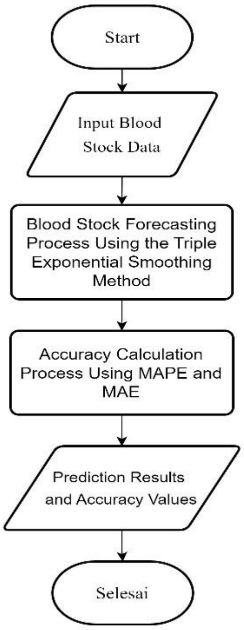

Figure 2. System Scheme

The following is an explanation of the system schema flow process.

a. Data Collection
The first step in this research system scheme is data collection, where the data to be predicted is obtained from the Indonesian Red Cross Blood Donor Unit. The data taken is in the form of monthly data regarding the stock of blood types A, B, O, and AB.

b. Prediction of Triple Exponential Smoothing (TES)
After data collection is carried out, the TES method will proceed with the calculation process. The prediction flow using TES is shown below.

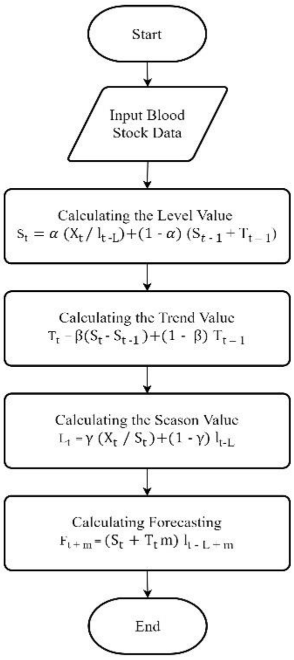

Figure 3. TES Flow

c. Calculation of MAPE and MAE
After performing calculations using TES, proceed with evaluation or calculation of accuracy. In this research, the calculation of accuracy uses MAPE and MAE, and later, this model can help in testing the accuracy of predicting blood stock inventory.

d. Prediction Results
The last step in this research system scheme is the result of predicting blood stock inventory with the TES method,

which is also in the form of accuracy values calculated to derive conclusions from the algorithm used.

Results and Discussion

The results and discussion will explain the application of the Triple Exponential Smoothing method in predicting blood stock inventory. The data used is monthly historical data from January 2019 to December 2023. This TES method will produce output in the form of prediction results, error values, and predictions for the future.

1. Manual Calculation of Triple Exponential Smoothing (TES)

At this stage, we will manually explain how to calculate predictions using the TES algorithm. The step to finding the TES algorithm calculation is to find the level value, trend value, season value, and prediction value. Below is a calculation table using the TES algorithm.

Table 3. Manual Calculation of TES

Period	Blood Type O	Level (St)	Trend (T)	Season	Prediction
Jan-23	81			1.02	
Feb-23	74			0.93	
Mar-23	87			1.10	
Apr-23	75	79.25	0.04	0.95	
May-23	69	74.58	-0.43	0.97	81.04
Jun-23	101	87.76	0.93	1.04	69.24
Jul-23	88	85.28	0.59	1.06	97.36
Aug-23	61	77.30	-0.27	0.87	81.26
Sep-23	63	72.10	-0.76	0.92	75.01
Oct-23	70	69.67	-0.93	1.02	74.36
Nov-23	57	62.66	-1.54	0.99	73.2
Dec-23	48	58.80	-1.77	0.84	53.04

The first step to finding the initial level value in April is to use the average formula from January 2023 to April 2023. The values of each parameter are assumed to be $\alpha = 0.4$, $\beta = 0.1$, $\gamma = 0.5$. The calculation result for the initial level value is 79.25. For calculating the next level value, the following formula is used:

$$S_t = \alpha\left(\frac{X_t}{l_{t-L}}\right) + (1-\alpha)(S_{t-1} + T_{t-1})$$
$$S_t = 0.4\left(\frac{69}{1.02}\right) + (1-0.4)(79.25 + (-0.04))$$
$$S_t = 74.58$$

If the level value is known, then find the trend value. To find the initial trend value in April 2023, perform trend initialization. The data used for trend initialization is data from January 2023 to April 2023. The following is a table of initial trend initialization calculations.

Table 4. Trend Initialization

Jan-Apr	May-Aug	X	Y
81	69	X = 69 – 81 = -12	Y = -12/12 = -1
74	101	X = 101 – 74 = 27	Y = 27/12 = 2.25
87	88	X = 88 – 87 = 1	Y = 1/12 = 0.08
75	61	X = 61 – 75 = -14	Y = -14/12 = -1.17
	Mean		0.04

Once the initial trend value is known, find the next trend value. The following is the calculation formula for finding the next trend value.

$$T_t = \beta(S_t - S_{t-1}) + (1-\beta)T_{t-1}$$
$$T_t = 0.1(74.58 - 79.25) + (1-0.1)\,(-0.04)$$
$$T_t = -0.43$$

If the level and trend values are known, the next step is finding the season value. The calculation formula for finding the initial season value in January 2023 - April 2023 uses each actual data point divided by the initial level value. Use the following calculation formula to find the season value for May onwards.

$$L_t = \gamma\left(\frac{X_t}{S_t}\right) + (1-\gamma)l_{t-L}$$
$$L_t = 0.5\left(\frac{69}{74.58}\right) + (1-0.5)\ 1.02$$
$$L_t = 0.97$$

If the level, trend, and season values are known, then the last step is calculating the prediction. The following is the formula for calculating predictions for May and beyond.

$$F_{t+m} = (S_t + T_t m)l_{t-L+m}$$
$$F_{t+m} = (79.25 + 1 * 0.04)\ 1.02$$

$F_{t+m} = 81.04$

2. Prediction Results

The TES method was used to predict monthly blood stocks for the four main blood types (A, B, AB, and O) from January 2019 to December 2023. This study evaluates Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE) to determine the accuracy of the prediction results using the Triple Exponential Smoothing (TES) algorithm. The following is a table of prediction evaluation results using the TES algorithm.

Table 5. Prediction Result

No	Blood Type	MAPE	MAE
1	Blood type A	2.15%	14.63
2	Blood type B	1.38%	17.17
3	Blood Type O	1.03%	21.43
4	Blood Type AB	2.42%	5.55

Based on the prediction results table above, the Triple Exponential Smoothing (TES) algorithm shows satisfactory accuracy for each blood type. Prediction calculations for blood type A using parameter values alpha 0.2, beta 0.4, and gamma 0.2 resulted in a MAPE accuracy value of 2.15% and an MAE of 14.63. In blood group B, they use alpha 0.7, beta 0.2, and gamma 0.3 parameter values, resulting in a MAPE accuracy value of 1.38% and an MAE of 17.17. In blood type O, a parameter value of alpha 0.4, beta 0.2, and gamma 0.3 resulted in a MAPE accuracy value of 1.03% and an MAE of 21.43. In blood type AB, they use alpha 0.1, beta 0.1, and gamma 0.6 parameter values, resulting in a MAPE accuracy value of 2.42% and an MAE of 5.55.

The accuracy value using TES shows that this algorithm can predict blood stock inventory. The accuracy evaluation results show that the TES method can provide accurate predictions with low MAPE and MAE values. The MAPE value of less than 10% indicates a high level of prediction accuracy, so TES is considered effective for maintaining a balance between blood supply and demand.

3. System Implementation

The prediction system designed in this research is implemented as follows.

a. Login Page

The login page is the initial display of this prediction system. On this page, the user enters the username and password data that has been registered to be able to access the prediction system.

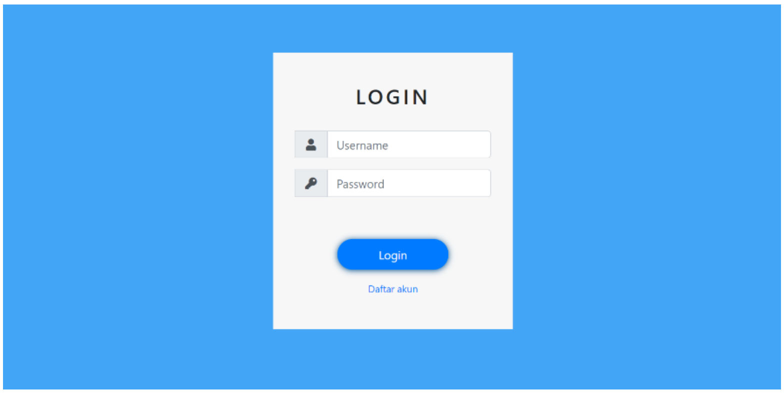

Figure 4. Login Page

b. Dashboard Page

The home page of this prediction system is the main page. This page explains the Triple Exponential Smoothing prediction algorithm.

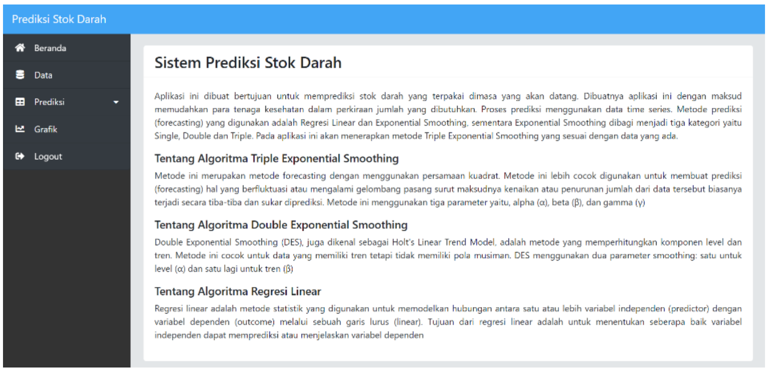

Figure 5. Dashboard Page

c. Blood Type Data Page
This blood type data page is useful for storing data from each blood type group. On this page, the user can input and manage blood type data.

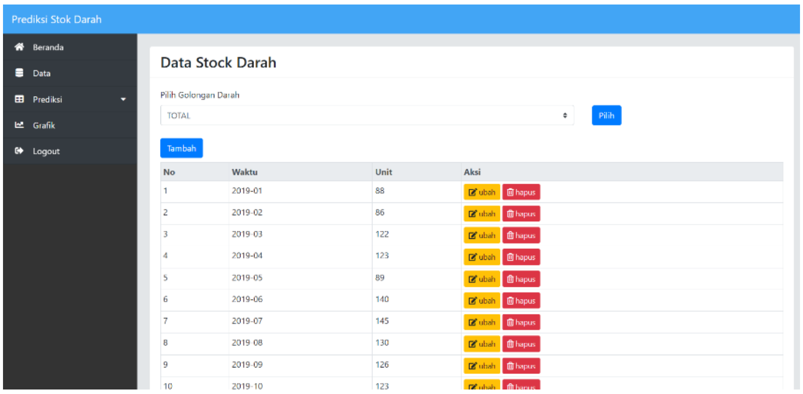

Figure 6. Blood Type Data Page

d. Prediction Page
On this prediction page, users can make predictions and see the results using the Triple Exponential Smoothing (TES) method. They can also save the prediction results to be viewed on the graph page.

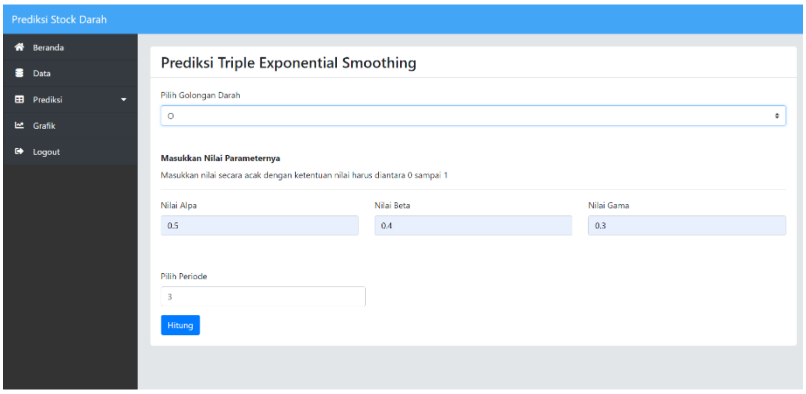

Figure 7. Prediction Page

e. Graphics Page
This page displays a graph of the prediction results that have been saved on the prediction page. This page also displays future predictions.

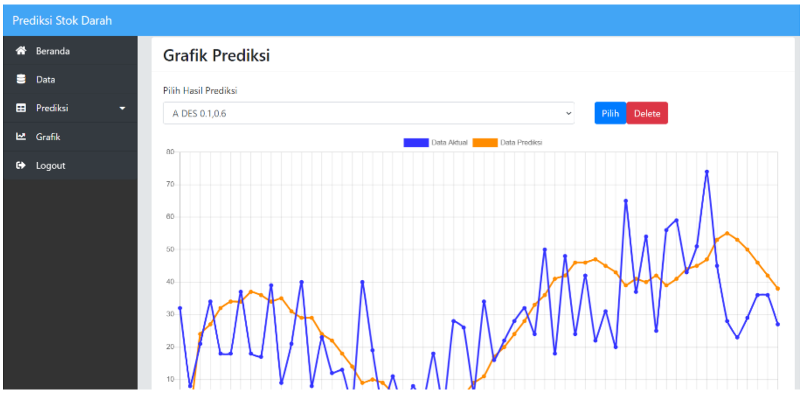

Figure 8. Graphics Page

Conclusions

This study examines the use of the Triple Exponential Smoothing (TES) method to predict blood stocks at the Indonesian Red Cross (PMI) Blood Donor Unit (UDD). This research focuses on the four main blood types (A, B, AB, O) by analyzing monthly stock data from January 2019 to December 2023. Prediction accuracy is measured using Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE). The results show low MAPE values of 2.15% for blood group A, 1.38% for blood group B, 1.03% for blood group O, and 2.42% for blood group AB. This confirms that TES is effective in maintaining the balance of bloodstock and demand, thus reducing the risk of blood shortage or wastage. This research is expected to contribute to more effective bloodstock management at PMI and become a reference for future blood stock prediction studies.

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