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Research Article [OPEN ACCESS]

Prediction of Whole Blood Stock Using Single Exponential Smoothing: A Case Study at the Indonesian Red Cross, Semarang

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ABSTRACT

The Indonesian Red Cross, as a provider of public health services in the city of Semarang, experienced a shortage of whole blood supply in 2023 due to high demand. In response to this issue, an effective prediction system is needed. This research aims to apply the single exponential smoothing method to predict blood needs at the Indonesian Red Cross in Semarang. The study uses data from 2022 to April 2024 as historical data to forecast blood requirements. The research findings indicate a continuous increase in the demand for whole blood availability. This study provides a foundation for developing a better prediction system with more complex data patterns.

Keyword: Prediction system, single exponential smoothing, whole blood type

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1. INTRODUCTION

The advancement of science and technology has significantly impacted various aspects of human life, including the workplace and organizational management (Aprianto, 2021). One of the tangible benefits of this progress is the acceleration of information flow, enabling company management to make decisions swiftly and accurately (Prabudi & Hasibuan, 2019). This technology has also played a crucial role in humanitarian organizations such as the Indonesian Red Cross, which conducts blood donation drives as one of its primary activities to provide public health services (Putra & Hidayati, 2023).

The Indonesian Red Cross in Semarang City, particularly through its Blood Donation Unit, plays a crucial role in managing, storing, and providing blood to hospitals (Mirza, 2019). However, in April 2023, the Indonesian Red Cross in Semarang City experienced a depletion of whole blood supplies due to high demand, especially for surgical procedures (Utomo, 2023). This issue of blood supply depletion is not only occurring in Semarang but is also a common challenge faced by Indonesian Red Cross units in various cities due to unpredictable fluctuations in demand (Sumari et al., 2021).

Based on initial observations, the Indonesian Red Cross in Semarang City has attempted to address blood stock depletion through various solutions and policies, such as conducting regular blood donation drives, expanding collaboration networks with various institutions to increase the number of donors, and organizing community education programs on the importance of blood donation. However, unpredictable fluctuations in demand often render these efforts insufficient. Therefore, a system that can predict blood stock levels is needed to anticipate the needs of the Indonesian Red Cross Blood Donation Unit in Semarang City. This predictive system can help the Indonesian Red Cross plan blood procurement more effectively, ensuring that shortages do not occur when needed (Budipriyanto et al., 2021).

Previous research has been conducted to develop blood stock prediction systems using complex forecasting methods such as double exponential smoothing, triple exponential smoothing, and partial least square (Batarius & Sinlae, 2024; Hatta & Fitri, 2020; Rani et al., 2023). Double exponential smoothing and triple exponential smoothing are considered more complex because they involve two or three parameters to handle trends and seasonality, requiring more complicated calculations and more data compared to single exponential smoothing, which uses only one parameter (Arifin, 2021). In this study, single exponential smoothing was chosen for its simplicity and ease of implementation, making it suitable for short-term forecasting and random fluctuations (Nugraha, 2022).

This study aims to develop a system that uses single exponential smoothing forecasting to predict whole blood stock levels. The system provides blood stock predictions based on historical data series, helping institutions ensure sufficient blood availability to meet fluctuating demand. Consequently, this research not only contributes to the literature on blood stock forecasting methods but also offers a practical solution that can be implemented by the Indonesian Red Cross in Semarang City to support its operations.

2. MATERIALS AND METHODS

This study uses a statistical approach to address the problem of forecasting whole blood stock at the Indonesian Red Cross in Semarang City, employing the single exponential smoothing method. The research data consists of periodic data on the use of whole blood from 2022 to April 2024. This data is collected monthly, providing a value for each month's observation to be analyzed. The data is obtained through observation and interviews with responsible parties and is updated monthly to ensure the forecast results remain current. This approach ensures the forecasting model is always updated with the latest data, thereby enhancing the accuracy of the predictions (Bela & Bhakti, 2022). Data collection methods in this study include field studies, namely observation and interviews.

1. This research was conducted by visiting the research site directly to obtain primary data from the responsible parties.
2. The study also involved direct question-and-answer sessions with relevant parties to reinforce the data obtained from the observations.

The steps involved in conducting this research are illustrated in Figure 1.

Figure 1. Research Stages

1. Problem Identification
    a) Conducting a needs analysis for blood stock at the Indonesian Red Cross, Semarang.
    b) Evaluating the existing issues in managing blood stock, particularly whole blood type.
    c) Clearly formulating the research problem, which is forecasting the amount of blood stock using the single exponential smoothing method.
2. Literature Review
    a) Reviewing journal articles, and other reference sources related to blood stock forecasting and the single exponential smoothing method.
    b) Understanding the theoretical framework underlying the forecasting method.
    c) Identifying theoretical gaps in the literature to strengthen the research foundation.
3. Data Collection
    a) Designing data collection instruments, including formats for recording blood bag usage.
    b) Determining the target population, which is the data on whole blood bag usage for 2022 through April 2024.
    c) Collecting raw data through observation and interviews with responsible parties.

4. Data Analysis
   a) Processing and cleaning raw data to ensure data quality and completeness.
   b) Analyzing data using the single exponential smoothing method. This analysis includes: Determining the optimal smoothing factor (α), Applying the single exponential smoothing formula to forecast the blood stock for the next period, Updating the forecasting model monthly with the latest actual data to improve accuracy.
5. Data Interpretation
   a) Interpreting the forecasting results from the single exponential smoothing analysis.
   b) Comparing the forecast results with actual data to evaluate the model's accuracy.
   c) Drawing conclusions from the analysis results and evaluating their implications for blood stock management at the Indonesian Red Cross, Semarang.
   d) Developing recommendations based on research findings to enhance the efficiency of blood stock management.

2.1 Single Exponential Smoothing Method

Among various forecasting methods, the single exponential smoothing method utilizes simple historical data and assumes that this historical data is fluctuating or non-stationary (Komariah et al., 2022). Single exponential smoothing is a straightforward forecasting method suitable for short- and medium-term forecasting. Each data point is assigned a weight denoted by the symbol α (Al Haris, 2020; Hudaningsih et al., 2020). The value of α is freely determined within the range $0 < \alpha < 1$ and serves to reduce the forecast error (Hartono et al., 2023). In this study, an α value of 0.1 is used.

2.2 Mean Absolute Error

Mean absolute error (MAE) serves as a method to measure the accuracy of a forecasting model. The MAE value represents the average absolute error between the forecasted results and the actual data (Nurani et al., 2023). It is commonly used to assess the accuracy of forecasts in the single exponential smoothing method (Suryanto & Muqtadir, 2019).

2.3 Mean Absolute Percentage Error

Mean absolute percentage error (MAPE) serves as a metric to measure relative error. The forecast error relative to actual demand over a specific period can reduce the accuracy of the forecast results (Fajrul et al., 2022). MAPE can be used alongside MAE to measure forecast accuracy, assessing how well the single exponential smoothing model predicts blood stock (Salsabila, 2020). The difference between these metrics lies in their calculation: MAE measures the average of the absolute differences between forecasted and actual values, while MAPE measures relative error as a percentage. The criteria for evaluating MAPE are presented in Table 1.

Table 1. The criteria for evaluating MAPE

MAPE Range	Accuracy Level
< 10%	Highly accurate forecast
10% - 20%	Good forecast
20% - 50%	Reasonable forecast
> 50%	Inaccurate forecast

3. RESULTS AND DISCUSSION

Table 2 shows the time series data for whole blood. This data encompasses the use of blood bags at the Indonesian Red Cross, Semarang, from 2022 through April 2024.

Table 2. The number of whole blood bag usages from 2022 to april 2024

Period	whole blood (A)			whole blood (B)			whole blood (O)			whole blood (AB)		
	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024
January	6	9	12	10	7	12	14	12	16	7	10	13
February	12	14	17	16	11	17	17	16	13	8	13	12
March	1	12	9	6	9	13	9	15	9	8	6	11
April	13	13	7	12	9	6	22	10	9	8	4	4
May	14	14		15	13		13	10		8	5	
June	13	12		12	11		10	7		7	7	
July	14	9		12	13		11	11		10	12	
August	11	13		22	14		14	11		10	10	
September	21	15		20	8		16	7		12	12	
October	19	11		16	17		12	20		5	11	
November	15	15		13	18		14	13		11	3	
December	18	10		16	12		17	15		11	11	

Next, the calculation of single exponential smoothing to forecast whole blood inventory is as follows:

1. Forecast of whole blood inventory (type A)
   This calculation involves inputting historical data of whole blood type A with a value of α = 0.1. (Table 3).

Table 3. Forecast of type A inventory

Period (t)	Yt	Ft	Error	MSE	MAPE
January-2022	6	6,000	0,000	0,000	0,000
February-2022	12	6,000	6,000	36,000	0,500
March-2022	1	6,600	-5,600	31,360	5,600
April-2022	13	6,040	6,960	48,442	0,535
May-2022	14	6,736	7,264	52,766	0,519
June-2022	13	7,462	5,538	30,665	0,426
July-2022	14	8,016	5,984	35,806	0,427
August-2022	11	8,615	2,385	5,690	0,217
September-2022	21	8,853	12,147	147,547	0,578
...	...	...	...	...	...
March-2024	9	12,677	-3,677	13,520	0,409
April-2024	7	12,309	-5,309	28,188	0,758
May-2024		**11,778**	57,783	648,750	13,317%
Average			2,14013	24,0278	0,493%

According to the calculations, it was determined that the forecasted inventory of whole blood type A for May 2024 is 11.778, with a total error over 28 months amounting to 57.783. The average calculation resulted in an MSE value of 24.0278 and a MAPE value of 0.493%.

2. Forecast of whole blood inventory (type B)
   This calculation involves inputting historical data of whole blood type B with a value of α = 0.1 (Table 4).

Table 4. Forecast of type B inventory

Period (t)	Yt	Ft	Error	MSE	MAPE
January-2022	10	10,000	0,000	0,000	0,000
February-2022	16	10,000	6,000	36,000	0,375
March-2022	6	10,600	-4,600	21,160	0,767
April-2022	12	10,140	1,860	3,460	0,155
May-2022	15	10,326	4,674	21,846	0,312
June-2022	12	10,793	1,207	1,456	0,101
July-2022	12	10,914	1,086	1,179	0,090
August-2022	22	11,023	10,977	120,502	0,499
September-2022	20	12,120	7,880	62,088	0,394
...	...	...	...	...	...
March-2024	13	13,163	-0,163	0,026	0,013
April-2024	6	13,146	-7,146	51,071	1,191
May-2024		**12,432**	24,318	509,204	8,083%
Average			0,90066	18,8594	0,299%

According to the calculations, it was determined that the forecasted inventory of whole blood type B for May 2024 is 12.432, with a total error over 28 months amounting to 24.318. The average calculation resulted in an MSE value of 18.8594 and a MAPE value of 0.299%.

3. Forecast of whole blood inventory (type O)
   This calculation involves inputting historical data of whole blood type O with a value of α = 0.1 (Table 5).

Table 5. Forecast of type O inventory

Period (t)	Yt	Ft	Error	MSE	MAPE
January-2022	14	14,000	0,000	0,000	0,000
February-2022	17	14,000	3,000	9,000	0,176
March-2022	9	14,300	-5,300	28,090	0,589
April-2022	22	13,770	8,230	67,733	0,374
May-2022	13	14,593	-1,593	2,538	0,123
June-2022	10	14,434	-4,434	19,658	0,443
July-2022	11	13,990	-2,990	8,942	0,272
August-2022	14	13,691	0,309	0,095	0,022
September-2022	16	13,722	2,278	5,189	0,142
...	...	...	...	...	...
March-2024	9	13,230	-4,230	17,893	0,470
April-2024	9	12,807	-3,807	14,493	0,423
May-2024		**12,426**	-15,737	385,802	7,351%
Average			-0,5829	14,289	0,272%

According to the calculations, it was determined that the forecasted inventory of whole blood type O for May 2024 is 12.426, with a total error over 28 months amounting to -15.737. The average calculation resulted in an MSE value of 14.289 and a MAPE value of 0.272%.

4. Forecast of whole blood inventory (type AB)
   This calculation involves inputting historical data of whole blood type AB with a value of α = 0.1 (Table 6).

Table 6. Forecast of type AB inventory

Period (t)	Yt	Ft	Error	MSE	MAPE
January-2022	7	7,000	0,000	0,000	0,000
February-2022	8	7,000	1,000	1,000	0,125
March-2022	8	7,100	0,900	0,810	0,113
April-2022	8	7,190	0,810	0,656	0,101
May-2022	8	7,271	0,729	0,531	0,091
June-2022	7	7,344	-0,344	0,118	0,049
July-2022	10	7,310	2,690	7,239	0,269
August-2022	10	7,579	2,421	5,863	0,242
September-2022	12	7,821	4,179	17,467	0,348
...	...	...	...	...	...
March-2024	11	9,404	1,596	2,546	0,145
April-2024	4	9,564	-5,564	30,956	1,391
May-2024		**9,007**	20,075	267,483	10,872%
Average			0,74351	9,90678	0,402%

According to the calculations, it was determined that the forecasted inventory of whole blood type AB for May 2024 is 9.007, with a total error over 28 months amounting to 20.075. The average calculation resulted in an MSE value of 9.90678 and a MAPE value of 0.402%.

3.1 System Implementation

During the implementation phase, the system is designed to facilitate management and utilize the blood stock forecasting feature based on historical data. Several menus are provided, including a login page, a blood type input page, a blood usage data input page, and a forecasting calculation page for the next period. The system implementation can be seen in Figure 2 and Figure 3.

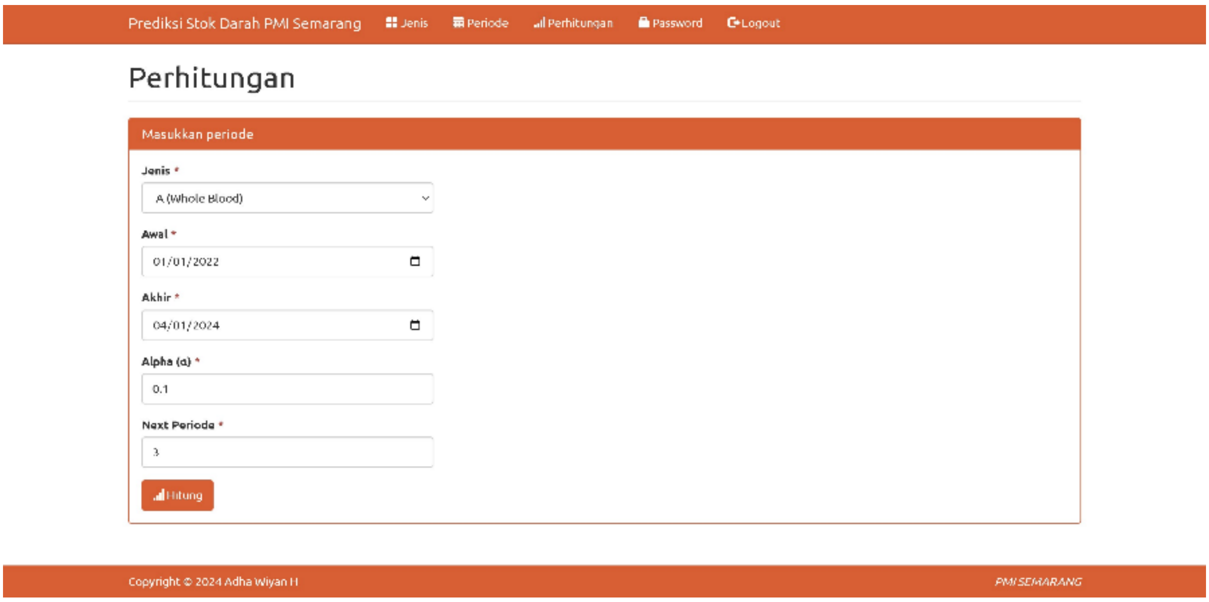

Figure 2. User interface implementation

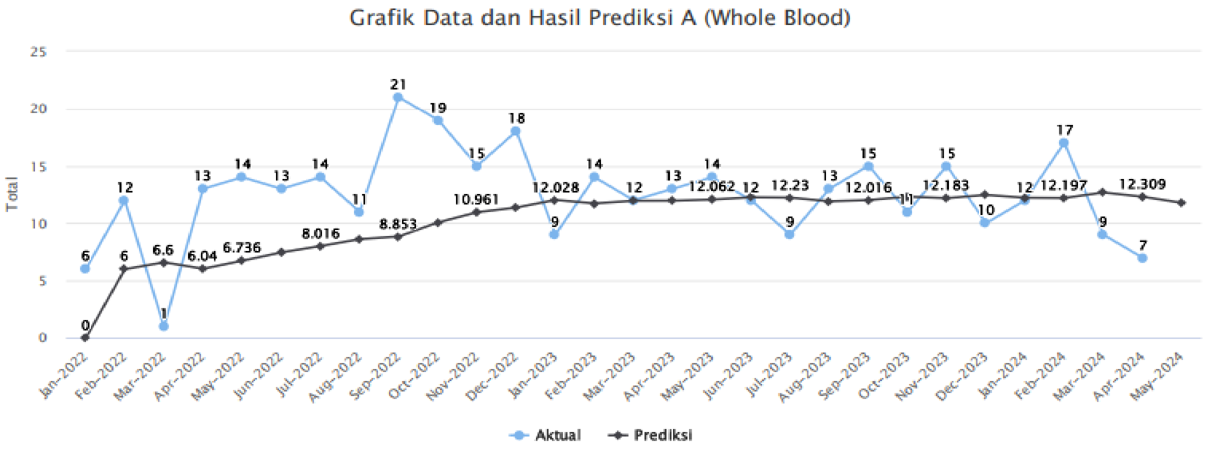

Figure 3. Forecast Graph

4. CONCLUSION

Based on the research findings, the implementation of the single exponential smoothing method to predict whole blood stock at the Indonesian Red Cross, Semarang, indicates a continuous increase in blood demand. The predicted results for May 2024 can guide the Indonesian Red Cross, Semarang, in making better decisions regarding blood inventory planning aligned with demand. With these predictions, the Indonesian Red Cross, Semarang, can take more informed steps to manage its blood stock effectively, optimizing the availability of whole blood for patient needs.

However, this study highlights that the single exponential smoothing method has limitations when applied to fluctuating historical data and complex data patterns. Overall, this research contributes to the management of whole blood stock and forecasting inventory levels at the Indonesian Red Cross, Semarang.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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