



Performance of Moving Average and Exponential Smoothing Methods in Forecasting Demand for Blood Components

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Abstract: The development of population growth in Indonesia affects the need for blood which must be stored as a supply. Blood supply management in Indonesia is managed by PMI (Indonesian Red Cross). PMI is a national association in Indonesia that operates in the fields of social humanity. The Importance of blood needs makes PMI maintain blood supplies. UTD PMI Denpasar City experienced an excess of blood supplies so blood that had passed its expiration date was destroyed. Therefore, this research can provide information and recommendations to UTD PMI Denpasar City in controlling the supply of blood components. The methods used in this forecasting are the Moving Average and Exponential Smoothing methods with the data studied being the number of requests for blood components from January 2021 to April 2023. In the analysis to get the right forecasting method, the smallest MAPE value was obtained for the respective forecast demand. each. each blood component is Exponential Smoothing with an alpha of 0.9, including Packed Red Cell getting a MAPE value of 1.34%, Fresh Frozen Plasma getting a MAPE value of 6.70%, and Trombocyte Concentrat obtained a MAPE value of 7.28%.

Keywords: Forecasting, Blood components, Mean Absolute Percentage Error (MAPE). Exponential Smoothing, Moving Average.

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Introduction

The volume of blood in an adult human body is about 3.6 liters (women) and 4.5 liters (men). The blood contains blood cells and a fluid called blood plasma that contains various nutrients and other substances. About 55% of blood is a fluid or plasma component, the remaining 45% is a component of blood cells. Blood is a body fluid that is vital for human life, it carries oxygen and nutrients to all cells in the body and transports the products of cell metabolism. Blood is in an arterial or venous blood vessel, and is part of the human body's organ system that plays an important role in human survival [1], [2].

Blood is one of the categories of products that are perishable or have a short lifetime, so it requires special handling in the process of storage, distribution and inventory management [3], [4]. Blood components are obtained from voluntary blood donors. There are several types of blood components given during blood transfusion, namely: Whole Blood (WB) which is used for transfusion without further processing. WB is the raw material for processing into other blood components, Packed Red Cell (PRC) obtained from WB by removing most of the plasma volume from whole blood. PRC may contain large amounts of leukocytes and platelets depending on the centrifugation method. Liquid Plasma (LP) is a

yellow liquid blood component obtained from WB which is useful for increasing plasma volume and increasing stable clotting factors (Clotting factors II, VII, X, and XI). Thrombocyte Concentrate (TRC) is obtained from WB which is stored in a sterile blood bag system with an integrated transfer bag, containing platelets suspended in plasma. Fresh Frozen Plasma (FFP) obtained from WB collected into a sterile blood bag system with an integrated transfer bag. FFP is separated after rapid spin centrifugation from WB or platelet rich plasma and is rapidly frozen to its core which preserves the function of labile coagulation factors. Anti Hemophilic Factor (AHF) is a blood component that contains the cryoglobulin fraction of plasma. Obtained from FFP of WB origin that is further processed and concentrated [5].

Along with the development of population growth in Indonesia, this development will affect the need for blood that must be stored as supplies. Based on the World Health Organization standard, the minimum blood requirement in a country is 2% of the population [6]. According to data from the Central Statistics Agency (BPS), the population of Indonesia in mid-2022 is 275,770,000 people, so ideally 5,515,400 blood bags are needed. The management of blood supplies in Indonesia is currently managed by PMI (Indonesian Red Cross). PMI is a national association organization in Indonesia engaged in the social humanitarian field which is

recognized in accordance with Presidential Decree No. 25 of 1950 and Presidential Decree No. 246 of 1963.

Blood transfusion services are carried out by the Blood Transfusion Unit. The Blood Transfusion Unit (UTD) is a health service facility that organizes blood donation, blood supply, and blood distribution. UTD Denpasar has the responsibility to fulfill the availability of blood in the Denpasar area. The availability of blood is highly dependent on the willingness and awareness of the community to donate blood voluntarily and regularly. In addition, blood and blood components are medicinal materials that can save lives, therefore UTD must fulfill this responsibility by providing quality products and providing the best service [7]. Therefore, a system that is capable of forecasting blood supplies at UTD Denpasar is needed.

Forecasting is the process of estimating some future needs which include needs in terms of quantity, quality, time and location needed in order to meet the demand for goods or services. Forecasting activity is a business function that tries to estimate the demand and use of products so that those products can be made in the right quantity. In this research, a forecasting method has been developed using the Moving Average method and the Exponential Smoothing method at UTD Denpasar. This method was chosen because in previous studies this method showed good performance for forecasting blood supplies.[1], [2], [8].

Through this research, the best performance results of the Moving Average and Exponential Smoothing methods will be obtained in forecasting the demand for blood components. The developed model is expected to produce forecasting of blood component demand, so that UTD Denpasar can control the entry and exit of blood.

Method

1) Business Understanding

The first stage carried out in blood demand forecasting research is a process of understanding the data or problem to be solved. At this stage, the problem raised is the difficulty of determining the demand for blood in the following month which results in many expired blood stocks. The purpose of this research is to find out the best forecasting method for blood component demand.

2) Data Understanding

At this stage, the process of collecting data from the research site is carried out. After that, the process of understanding the data used and identifying data patterns is carried out.

3) Data Preparation

In this third stage is the stage of data preparation that will be used in the next stage, what is done at this stage is to determine the stationarity of existing data with autocorrelation. Autocorrelation is the correlation between a lag variable and the period of the lag itself. Autocorrelation is needed to determine the pattern of data formed. The method that will be carried out for analyzing this data pattern is to test the stationarity of the data. To conduct a stationarity test in this study will be done by looking at the ACF (autocorrelation coefficient) and PACF (Partial Autocorrelation Function) and Lag values. After conducting stationarity of the data, the next modeling process is carried out. In this process, the calculation of each method used is carried out

4) Modeling

Moving Average Method

The Moving Average method is a forecasting method based on stationary patterned historical data by calculating the average of actual data observations in a row according to the desired moving period, Moving Average is suitable for use if the data does not contain trend and seasonal components [8], [9]. The average value is used as a basis for forecasting in the coming period [10]-[12]. In this study, the Moving Average Method of 2 months to 12 months is used. The method equation is as follows.

$$F_t(n) = \frac{A_t + A_{t-1} + \dots + A_{t-n}}{n} \quad (1)$$

Description,

$F_t(n)$ = Forecasting value of the tth period with Moving Average n periods

A = Forecasting value in the tth period

Exponential Smoothing Method

The Exponential Smoothing method is a procedure that repeats calculations continuously using the latest data. Each data is given a weight, where the weight used is symbolized by α . In the context of Exponential Smoothing or other forecasting methods, α (alpha) is a smoothing parameter that controls how much weight is given to historical data versus actual data. The value of α can be set according to the desired level of smoothing: In this study, the Exponential Smoothing Method is used using a smoothing interval of 0.1 to 0.9 [13]-[16]. Finding the forecast value can be done using:

$$F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1}) \quad (2)$$

Description,

F_t = New forecasting

F_{t-1} = Prior forecasting

α = Alpha value ($0 \leq \alpha \leq 1$)

A = Actual value

Evaluation

After obtaining the results of the calculation of each method, it is continued with the smallest forecasting error test in order to find out which method will be used for future forecasting. The forecasting error test used is Mean Absolute Percentage Error (MAPE). Mean Absolute Percentage Error is a measurement of error in forecasting by calculating the average absolute difference between actual data and forecasting results in each period divided by the actual data in that period. Then average the absolute percentage error. MAPE was chosen for accuracy testing because it can provide relatively accurate results [17]-[20]. MAPE as an indicator of how much error in forecasting compared to actual values can be calculated with the following equation:

$$MAPE = \frac{1}{n} \sum_{t=1}^n \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right| \times 100\% \quad (3)$$

Description:

Y_i = Original data value in the i-th sector at time t

$\hat{Y}_i$ = Predicted value of the i-th sector at time t

n = Number of periods/observations

In determining the ability of a forecasting model, there is a MAPE range that can be used as a reference. The range of MAPE capability measures can be seen in Table 1.

Table 1. MAPE Value Range

Range	Description
<10%	Highly Accurate Forecasting
10%-20%	Accurate Forecasting
20%-50%	Fairly Accurate Forecasting
>50%	Inaccurate Forecasting

Results and Discussion

In this study, a forecast has been carried out using the Moving Average and Exponential Smoothing methods to forecast the demand for blood components. The data used in this study are blood component demand data from January 2021 to April 2023. Blood component demand data can be seen in Table 2.

Table 2: Blood Component Demand Data

Month	Packed Red Cell	Fresh Frozen Plasma	Thrombocy Concentrate
31/01/21	242	9	15
28/02/21	228	5	18
31/03/21	263	6	28
30/04/21	222	15	14
31/05/21	436	3	5
30/06/21	376	3	5
31/07/21	227	0	10
31/08/21	260	3	15
30/09/21	282	10	4
31/10/21	311	11	0
30/11/21	345	5	0
31/12/21	356	3	0
31/01/22	361	12	2
28/02/22	252	0	9
31/03/22	399	3	80
30/04/22	380	6	55
31/05/22	377	6	30
30/06/22	419	9	26
31/07/22	382	5	23
31/08/22	347	0	0
30/09/22	384	9	0
31/10/22	438	16	0
30/11/22	388	9	0
31/12/22	387	11	6
31/01/23	427	10	15
28/02/23	391	0	24
31/03/23	400	5	10
30/04/23	364	3	19

Moving Average Method Forecasting

Forecasting the demand for blood components using the Moving Average method with a movement value of 2 months to 12 months. The results of the calculation of demand forecasting for each blood component are presented in Tables 3, 4 and 5.

Table 3. 2-month to 12-month Moving Average Forecasting Results on Packed Red Cell

Month	Inquiry	MA 2	MA 3	MA 4	MA 5	MA 6	MA 7	MA 8	MA 9	MA 10	MA 11	MA 12
31/01/2021	242	0	0	0	0	0	0	0	0	0	0	0
28/02/2021	228	235	0	0	0	0	0	0	0	0	0	0
31/03/2021	263	245,5	244,33	0	0	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...
31/03/2023	400	395,5	406	401,25	398,6	405,17	402,14	395,25	393,78	396,3	394,55	393,33
30/04/2023	364	382	385	395,5	393,8	392,83	399,29	397,38	391,78	390,8	393,36	392

Table 4. 2-month to 12-month Moving Average Forecasting Results on Fresh Frozen Plasma

Month	Inquiry	MA 2	MA 3	MA 4	MA 5	MA 6	MA 7	MA 8	MA 9	MA 10	MA 11	MA 12
31/01/2021	9	0	0	0	0	0	0	0	0	0	0	0
28/02/2021	5	7	0	0	0	0	0	0	0	0	0	0
31/03/2021	6	5,5	6,67	0	0	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...
31/03/2023	5	2,5	5	6,5	7	8,5	8,57	7,5	7,22	7,4	7,27	7,17
30/04/2023	3	4	2,67	4,5	5,8	6,33	7,71	7,88	7	6,8	7	6,92

Table 5. 2-month to 12-month Moving Average Forecasting Results on Thrombocyte Concentrate

Month	Inquiry	MA 2	MA 3	MA 4	MA 5	MA 6	MA 7	MA 8	MA 9	MA 10	MA 11	MA 12
31/01/2021	15	0	0	0	0	0	0	0	0	0	0	0
28/02/2021	18	16,5	0	0	0	0	0	0	0	0	0	0
31/03/2021	28	23	20,33	0	0	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...
31/03/2023	10	17	16,33	13,75	11	9,17	7,86	6,88	8,67	10,4	12,18	15,75
30/04/2023	19	14,5	17,67	17	14,8	12,33	10,57	9,25	8,22	9,7	11,18	12,75

Figure 2 to Figure 6 is a comparison chart of the Moving Average forecasting results with the actual data of Packed Red Cell blood demand.

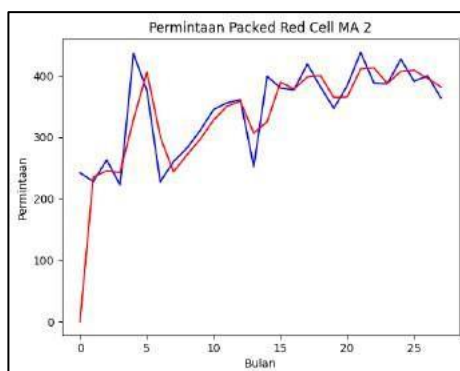


Figure 2. PRC Moving Average 2

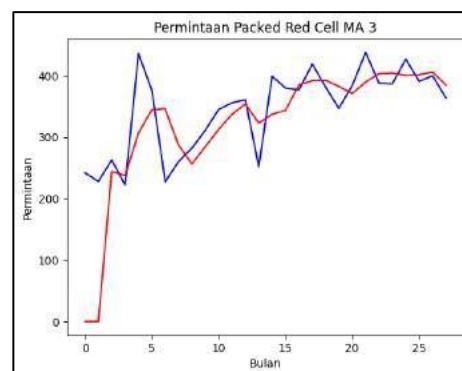


Figure 3. PRC Moving Average 3

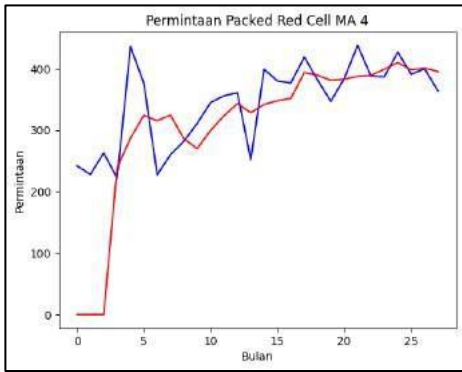


Figure 4. PRC Moving Average 4

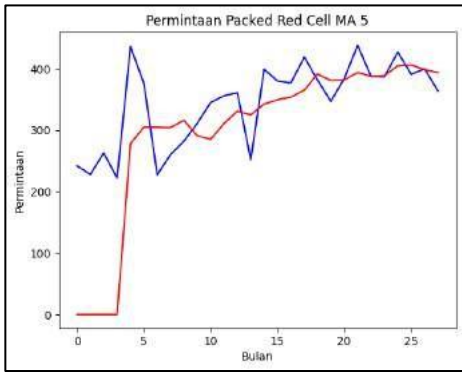
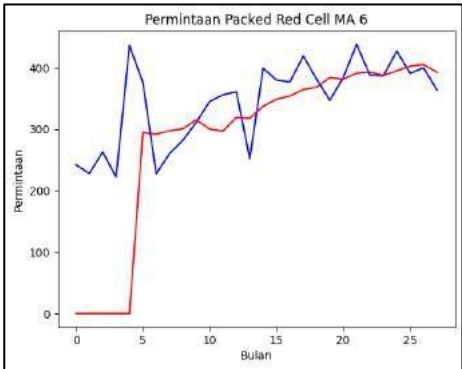


Figure 5. PRC Moving Average 5



PRC Moving Average 6

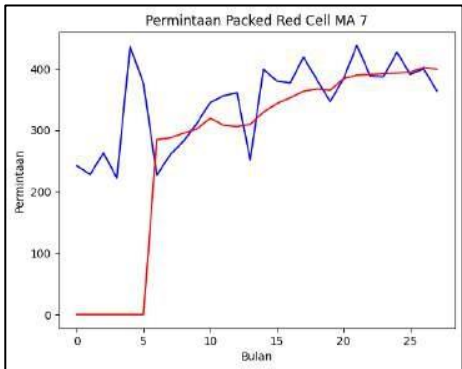


Figure 7. PRC Moving Average 7

Figure 8-11 is a comparison chart of the Moving Average forecasting results with the actual data of Fresh Frozen Plasma blood demand.

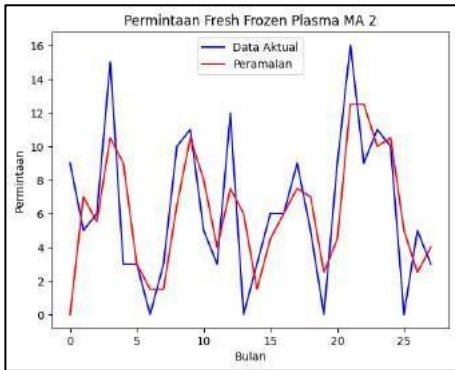
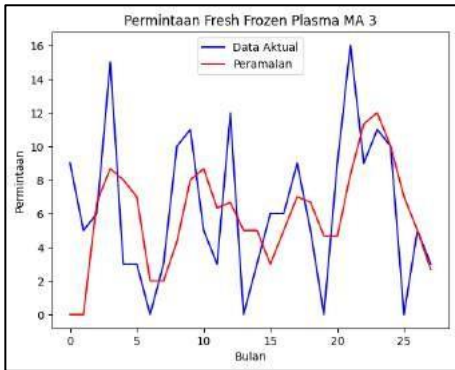
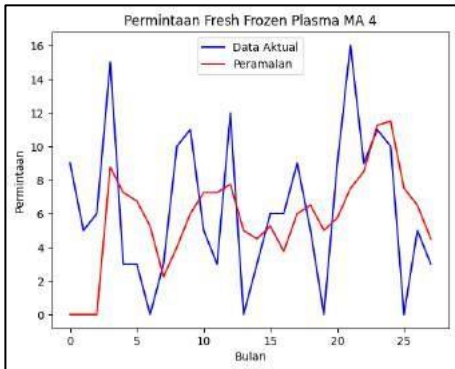


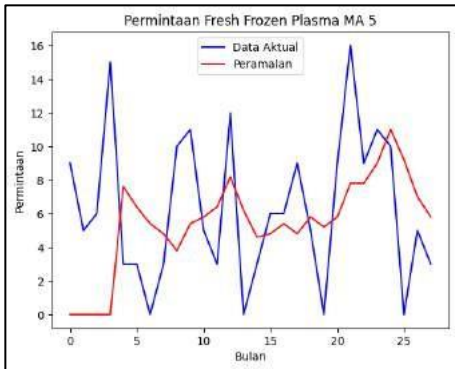
Figure 8. FFP Moving Average 2



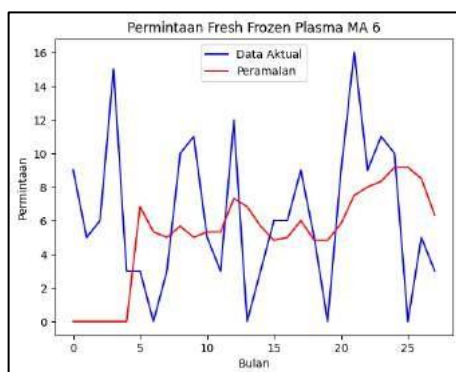
FFP Moving Average 3



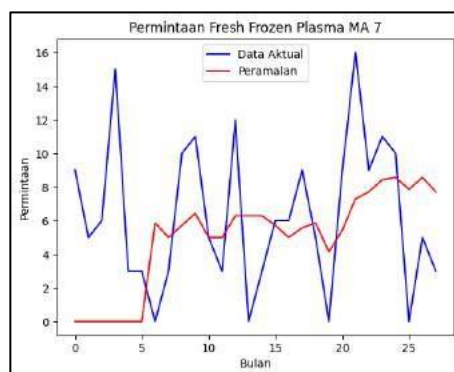
FFP Moving Average 4



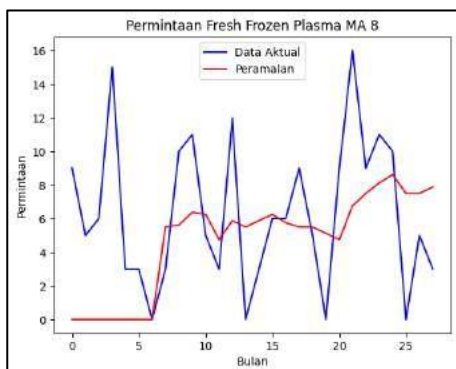
FFP Moving Average 5



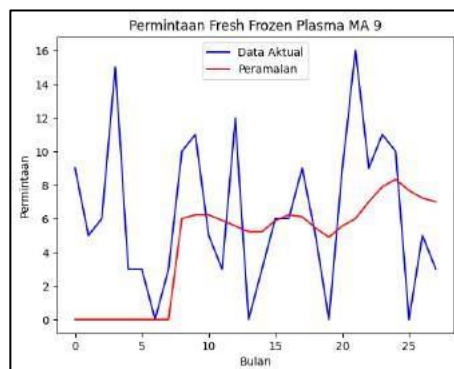
FFP Moving Average 6



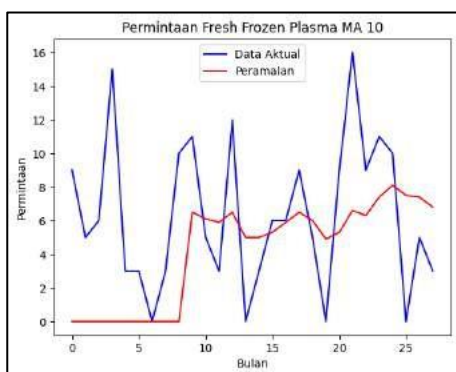
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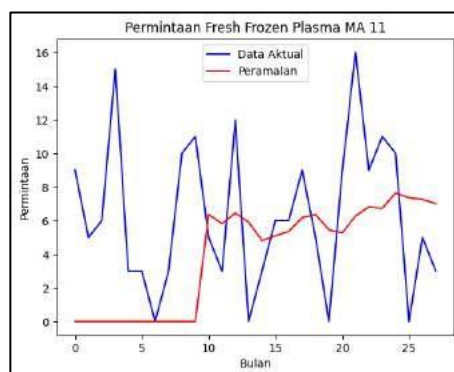
FFP Moving Average 8



FFP Moving Average 9

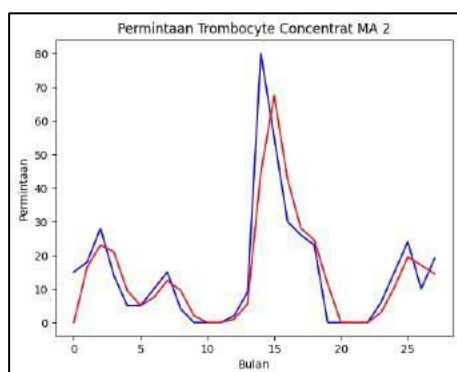


FFP Moving Average 10

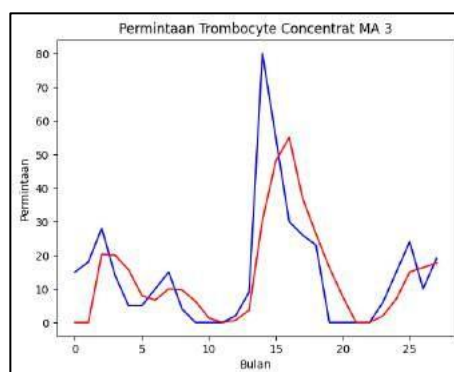


FFP Moving Average 11

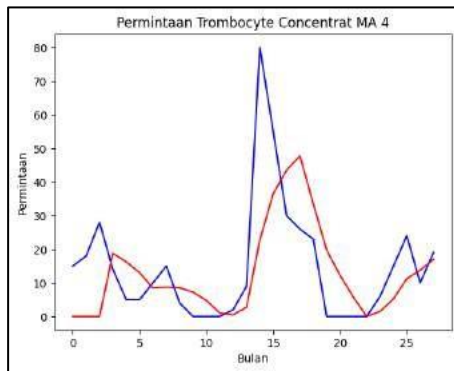
Figure 12-15 is a comparison chart of the results of Moving Average forecasting with actual data on demand for Trombocyte Concentrate



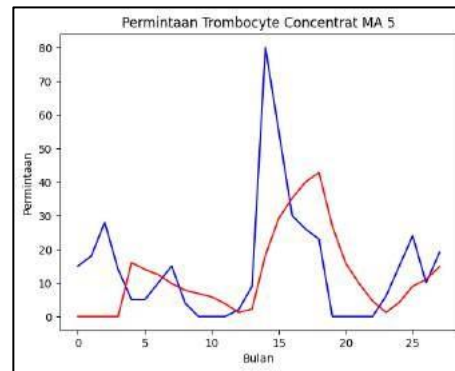
TRC Moving Average 2



TRC Moving Average 3



TRC Moving Average 4



TRC Moving Average 5

MAPE testing of the results of Moving Average forecasting 2 months to 12 months on each of the blood components that have been presented can be seen in table 6. below.

Table 6. Error Accuracy Testing Results

Forecasting Methods	MAPE Value		
	PRC	FFP	TRC
MA 2	11%	39%	40%
MA 3	17%	51%	63%
MA 4	20%	55%	74%
MA 5	24%	59%	76%
MA 6	26%	58%	69%
MA 7	28%	59%	69%
MA 8	31%	60%	74%
MA 9	35%	59%	81%
MA 10	39%	62%	81%
MA 11	42%	66%	87%
MA 12	MA 12	46%	71%

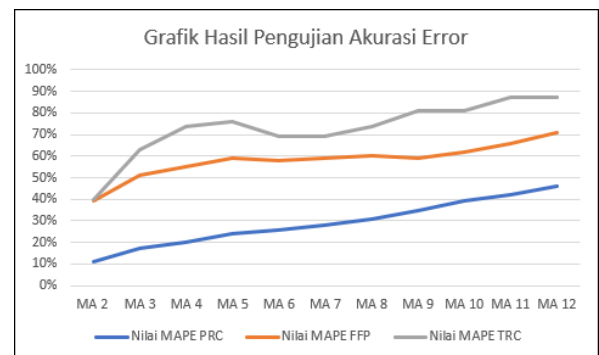


Figure 16. Graph of Moving Average Error Accuracy Testing Results

Based on Table 6 and Figure 16, it can be seen that the 2-month Moving Average which has the smallest error value for each blood component, namely Packed Red Cell (PRC), has a MAPE value of 11%. Fresh Frozen Plasma (FFP) obtained a MAPE value of 39%, and Thrombocyte Concentrate (TRC) obtained a MAPE value of 40%.

Exponential Smoothing Method Forecasting

Forecasting the demand for blood components using the exponential smoothing method with a smoothing value of $\alpha = 0.1$ to $\alpha = 0.9$. The results of the calculation of demand forecasting for each blood component are presented in Tables 7, 8 and 9.

Table 7. Forecasting Results of Exponential Smoothing 0.1 to 0.9 on Packed Red Cell

Month	Inquiry	ES 0.1	ES 0.2	ES 0.3	ES 0.4	ES 0.5	ES 0.6	ES 0.7	ES 0.8	ES 0.9
31/01/2021	242	242	242	242	242	242	242	242	242	242
28/02/2021	228	240,6	239,2	237,8	236,4	235	233,6	232,2	230,8	229,4
31/03/2021	263	242,84	243,96	245,36	247,04	249	251,24	253,76	256,56	259,64
...	...	...	...	...	...	...	...	...	...	...
31/03/2023	400	369,15	393,03	398,64	400,02	400,15	399,88	399,54	399,33	399,42
30/04/2023	364	368,64	387,22	388,25	385,61	382,08	378,35	374,66	371,07	367,54

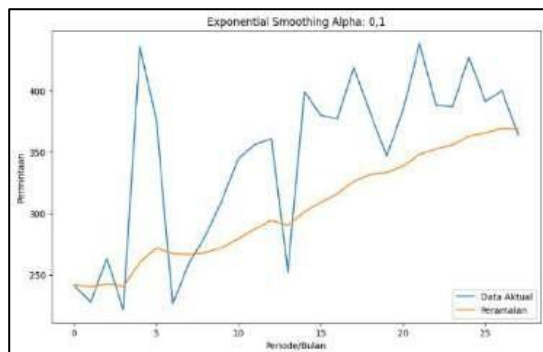
Table 8. Forecasting Results of Exponential Smoothing 0.1 to 0.9 on Fresh Frozen Plasma

Month	Inquiry	ES 0.1	ES 0.2	ES 0.3	ES 0.4	ES 0.5	ES 0.6	ES 0.7	ES 0.8	ES 0.9
31/01/2021	9	9	9	9	9	9	9	9	9	9
28/02/2021	5	8,6	8,2	7,8	7,4	7	6,6	6,2	5,8	5,4
31/03/2021	6	8,34	7,76	7,26	6,84	6,5	6,24	6,06	5,96	5,94
...	...	...	...	...	...	...	...	...	...	...
31/03/2023	5	6,84	6,66	6,22	5,62	5,06	4,65	4,42	4,41	4,6
30/04/2023	3	6,45	5,93	5,25	4,57	4,03	3,66	3,43	3,28	3,16

Exponential Smoothing Forecasting Results 0.1 to 0.9 on Thrombocyte Concentrate

Month	Inquiry	ES 0.1	ES 0.2	ES 0.3	ES 0.4	ES 0.5	ES 0.6	ES 0.7	ES 0.8	ES 0.9
31/01/2021	15	15	15	15	15	15	15	15	15	15
28/02/2021	18	15,3	15,6	15,9	16,2	16,5	16,8	17,1	17,4	17,7
31/03/2021	28	16,57	18,08	19,53	20,92	22,25	23,52	24,73	25,88	26,97
...	...	...	...	...	...	...	...	...	...	...
31/03/2023	10	14,05	12,85	12,53	12,93	13,36	13,45	13,1	12,36	11,3
30/04/2023	19	14,54	14,08	14,47	15,36	16,18	16,78	17,23	17,67	18,23

Figure 17-20 is a comparison chart of the Exponential Smoothing forecasting results with the actual data of Packed Red Cell blood demand.



PRC Exponential Smoothing 0.1

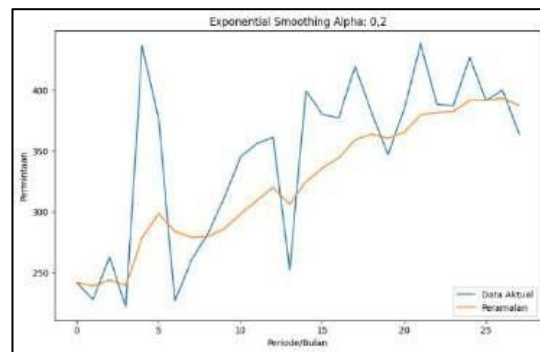
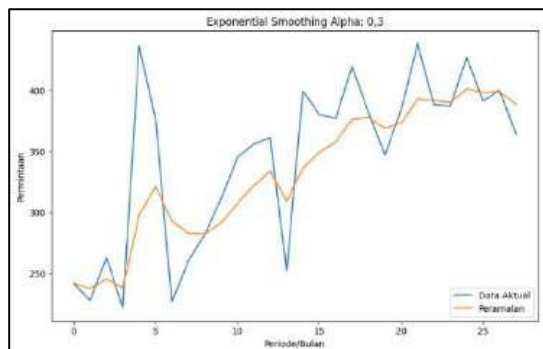


Figure 18. PRC Exponential Smoothing 0.2



PRC Exponential Smoothing 0.3

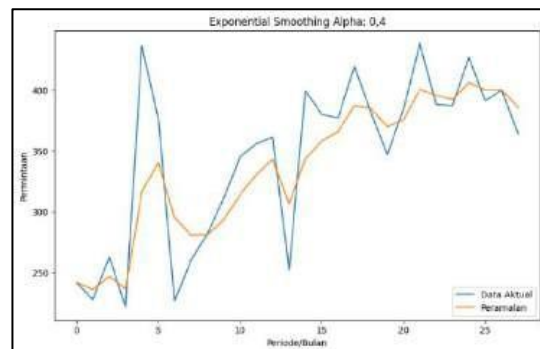


Figure 20. PRC Exponential Smoothing 0.4

Figure 21-24 is a comparison chart of the Exponential Smoothing forecasting results with the actual data of Fresh Frozen Plasma blood demand.

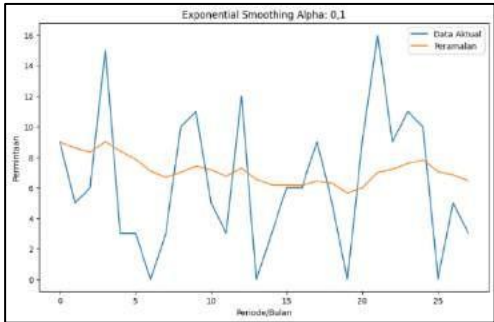


Figure 21. FFP Exponential Smoothing 0.1

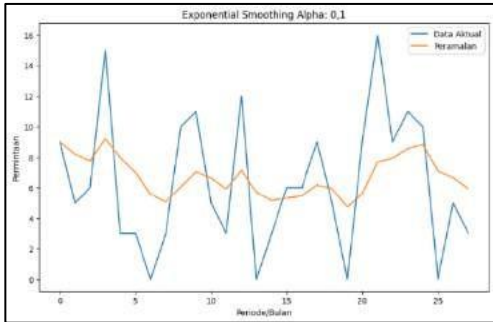


Figure 22. FFP Exponential Smoothing 0.2

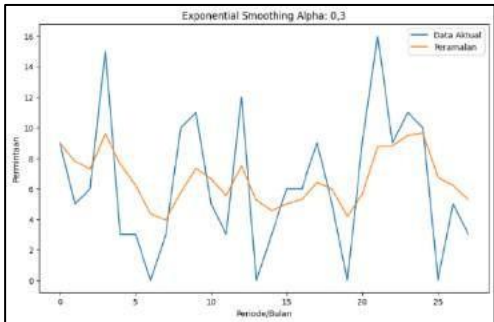


Figure 23. FFP Exponential Smoothing 0.3

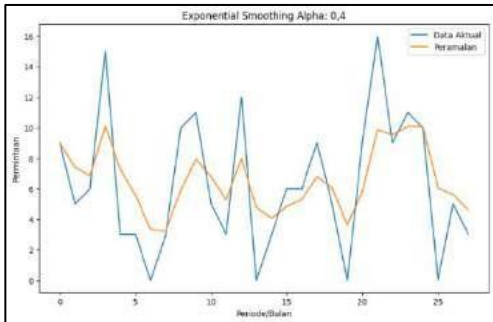


Figure 24. FFP Exponential Smoothing 0.4

Figure 25-28 is a comparison chart of the Exponential Smoothing forecasting results with the actual blood demand data for Trombocyte Concentrate.

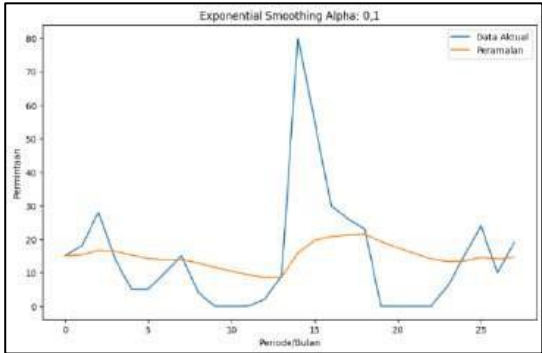


Figure 25. FFP Exponential Smoothing 0.1

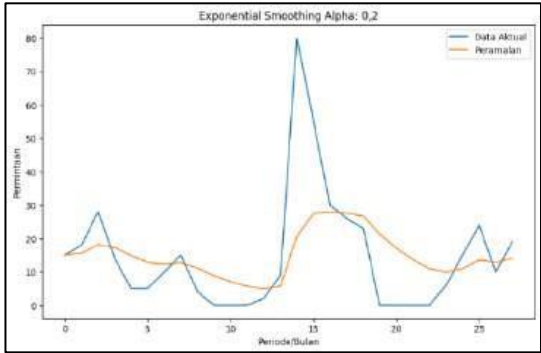


Figure 26. FFP Exponential Smoothing 0.2

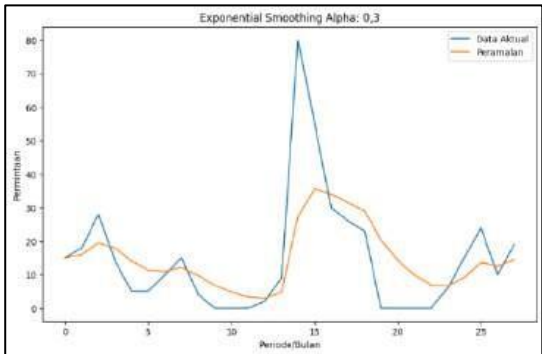


Figure 27. FFP Exponential Smoothing 0.3

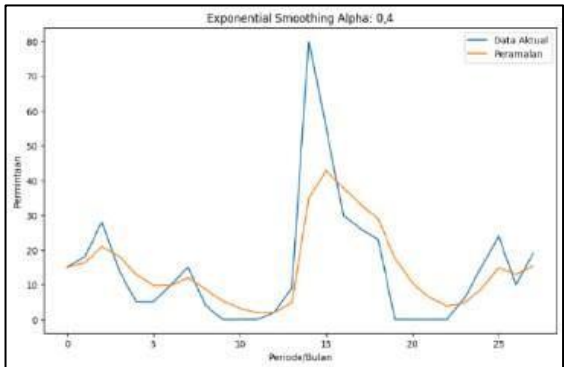


Figure 28. FFP Exponential Smoothing 0.4

MAPE testing of the results of Exponential Smoothing Alpha 0.1 to Alpha 0.9 forecasting on each blood component that has been presented in Tables 7, 8 and 9 above can be seen in table 10. below.

Table 10. Error Accuracy Testing Results

Forecasting Methods	MAPE Value		
	PRC	FFP	TRC
ES 0.1	13%	57%	71%
ES 0.2	10%	48%	55%
ES 0.3	8%	40%	45%
ES 0.4	7%	34%	39%
ES 0.5	6%	28%	35%
ES 0.6	5%	23%	29%
ES 0.7	4%	18%	22%
ES 0.8	3%	13%	15%
ES 0.9	1%	7%	7%

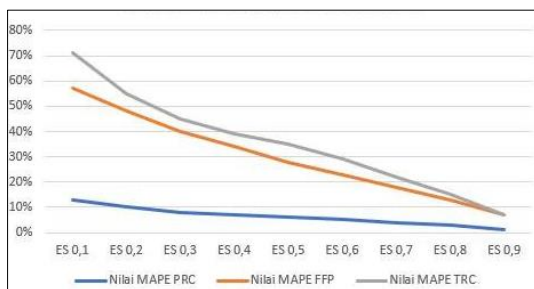


Figure 29. Graph of Exponential Smoothing Error Accuracy Testing Results

Based on Table 10 and Figure 29, it can be seen that Exponential Smoothing 0.9 has the smallest error value for each blood component, namely, Packed Red Cell (PRC) with a MAPE value of 1%, Fresh Frozen Plasma (FFP) with a MAPE value of 7%, and Thrombocyte Concentrate (TRC) with a MAPE value of 7%.

Evaluation

The selected forecasting method for the four blood components is the 0.9 Exponential Smoothing forecasting method with each having the smallest MAPE value. The selection of selected methods for MAPE calculations can be seen in Table 11.

Table 11. Selected Forecasting Methods

No.	Blood Components	Selected Method	MAPE Value
1	Packed Red Cell	Exponential Smoothing 0.9	1%
2	Fresh Frozen Plasma	Exponential Smoothing 0.9	7%
3	Thrombocyte Concentrate	Exponential Smoothing 0.9	7%

Conclusion and Suggestions

Berdasarkan data yang telah dilakukan perhitungan peramalan menggunakan metode Moving Average dan Exponential Smoothing, serta telah dilakukan perhitungan pengujian hasil akurasi terkecil dari metode, maka diperoleh metode yang paling cocok dan akurat untuk memprediksi permintaan masing-masing komponen darah pada periode yang akan datang adalah menggunakan metode Exponential Smoothing Alpha 0,9 dengan perolehan nilai MAPE terkecil dengan perolehan nilai MAPE terkecil Packed Red Cell memperoleh nilai MAPE 1%, Fresh Frozen Plasma memperoleh nilai MAPE 7% dan Trombocyte Concentrat memperoleh nilai MAPE 7%. Saran untuk future research yaitu pada penelitian yang akan datang direkomendasikan untuk memperhitungkan jumlah data yang lebih lengkap tanpa ada data yang berjumlah 0 ataupun tidak memiliki data dan dapat mencoba lebih banyak model uji akurasi kesalahan terkecil.

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