Blood Bags Demand Forecasting using ARIMA

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Abstract. Blood is an irreplaceable thing in the human body. If a person lacks blood then a blood transfusion is needed from someone else. The Red Cross is an organization that handles the need for blood bags for the purposes of blood transfusions. The amount of demand for blood bags varies greatly each month so it is necessary to predict how many blood bags are needed. In this study, the demand for blood bags was forecasted using the ARIMA method. Forecasting was carried out on Whole Blood (WD) and Platelet Concentrate (TC) blood components considering the large difference in expiration time between WD with an expiration of 35 days and TC with an expiration of 5 days. Demand data is taken from January 2018 to September 2021 at the Indonesian Red Cross Surabaya. The forecasting results obtained show that the ARIMA model (0,1,3) for WD and the ARIMA model (1,1,3) for TC has the lowest RMSE error rate. From plotting the forecasting data against real data, it can be seen that the model made is adequate to be used as a forecast of blood bag demand.

INTRODUCTION

Blood has various uses that are very important for the human body, such as distributing important substances throughout the body, distributing oxygen, and also helping to get rid of waste substances that are not needed by the body [1]. Blood can only be produced by humans. Until now, there is still no product that can replace blood or chemical process that can produce blood and blood can only be donated in limited quantities within a certain period (2 months). Thus, blood was considered a rare and very valuable commodity. When a person experiences a condition where his body lacks blood, then the only way to overcome this is to receive blood from other people through blood transfusions. The blood used for transfusion is obtained through blood donation from other people [2]. Blood donation is the process of taking blood from donors who voluntarily donate blood. Blood donation activities are organized by the Blood Transfusion Unit (UTD) which is part of the Indonesian Red Cross (PMI) [2][3]. Accordance with national blood needs, every year, PMI targets up to 4.5 million blood bags to fulfill the World Health Organization (WHO) standard, which is minimum 2% of the population [4]. Unfortunately, Indonesia is only able to obtain 4.1 million blood bags/year [5].

The blood obtained is called Whole Blood (WB). WB can also be processed into several different blood components such as Washed Red Cells (WRC), Packed Red Cells (PRC), Platelet Concentrate (TC), Apheresis, Fresh Frozen Plasma (FFP), Plasma, Buffy Coat (BC), and Cryoprecipitate. (AHF). The processed products are then stored in blood bags and stored in accordance with existing regulations. The blood bags are then ready to be distributed to those in need.

From time to time, the need for blood bags varies greatly, therefore it is necessary to forecast the demand for blood bags. This is very important considering that a shortage of supplies can cause someone's death. On the other hand, there is a problem with storing too many blood bags, considering that blood has a limited storage time. Expiration of blood components varies widely, for example whole blood can be stored within 35 days, while some other products can only be stored within 5 days [2]. Expired blood products become biological waste that must be

destroyed. Of course, the processing and destruction of this blood product costs a lot of money. Therefore, it is very important to predict the demand for blood products.

This study tries to predict the demand for blood bags so that PMI can estimate the amount of each blood product that must be produced in a certain period of time. The process of forecasting the need for blood bags will be carried out using the ARIMA method. As a test, in this study forecasting was carried out on the types of Whole Blood (WB) and Platelet Concentrate (TC) products. The choice of WB and TC is because the expiration time of these two products is very different, where the expiration time of WB is 35 days while the expiration time of TC is 5 days. As a test case, the data was obtained from PMI Surabaya, Indonesia with a data period of 2018 to 2021.

LITERATURE REVIEW

Several studies have been conducted in predicting blood demand, there are several forecasting methods that have been used. For example, study to predict blood demand using demographic mapping to predict trends in blood demand for WB and RBC blood products [7]. This study tries to use data on the need for blood per 1000 people (in 2008) to predict the increase in demand based on the increase in population in the future. The weakness of this study is that it will be very difficult to model the population given the possibility of population displacement, possible outbreaks, food shortages, and the possibility of couples not wanting to have children, etc.

Research has also been developed by predicting the need for blood bags based on historical data on blood bag requests, such as using moving average, weighted moving average, exponential smoothing, and exponential smoothing method by Lestari et al. [8]. This study can prove that the moving average, weighted moving average, exponential smoothing, and exponential smoothing method can predict the need for blood with a low error rate using 6 periods. However, the weakness of this methods is that the forecasting cannot handle trending or seasonal data, where the data must be stable or constant. Whereas the data on the need for blood is often uncertain and depends on the situation and conditions.

Another study uses the SES (Single Exponential Smoothing) method [9], where this method has been able to consider random, trend, and seasonal effects on the data. However, prediction with this method is not good if the data used is not stationary. This is because the equation used in the SES method does not have a smoothing procedure for the effect of trends so that it cannot convert non-stationary data into stationary data.

To overcome the weakness of the forecasting method that has been carried out in this study, in this study, the forecasting method made will use the Auto Regressive Integrated Moving Average (ARIMA) method. The ARIMA method is a combination of three methods, namely the AR (Autoregressive), MA (Moving Average), and ARMA (Autoregressive and Moving Average) method. This method is able to analyze data in the form of random, trend, seasonal, or cyclical so that the flexibility is high. It is expected that the level of accuracy of this method is quite high because this method is a combined method.

IMPLEMENTATION

The blood donation process begins with the donor filling out a blood donor registration form along with a medical history. After filling out, the donor submits the form to the donor administration officer. The process is followed by weighing and a simple health check by a doctor. Donors who have passed the initial examination will proceed to the examination of hemoglobin (Hb) and blood group. Donors who meet the requirements to donate will have their blood drawn by officers in about 10 minutes. Donors will get a blood donor Membership Card which serves to assist the recording of donor blood donor activities. To avoid the side effects of blood donation that can cause anemia, donors are recommended to donate their blood again after 2 months for male donors with a maximum of 6 times a year and 2.5 months for female donors with a maximum of 6 times a year.

After taking the blood, the staff immediately placed a bag of whole blood or Whole Blood into a box. When the box is filled with blood bags, the box is brought by the staff to the Screening Test Laboratory. In this laboratory, staff will conduct an examination of the blood obtained. The examination process begins with a blood filter test performed on all blood with an individual testing system without a pooling system. This is done to avoid false negatives. The examination process in this blood screening test aims to ensure that there are no blood-borne infections, such as Hepatitis B (HBsAg), Hepatitis C (Anti-HCV), HIV (Anti-HIV) and Syphilis (TP-Antibodies). Furthermore, the laboratory staff will reconfirm the blood type using an automatic device. This is to ensure the

blood type in the blood obtained is correct. Then the staff will conduct an antibody screening examination on the blood obtained to eliminate minor cross-tests.

Whole Blood (WB), which has gone through a series of examination processes, is then processed into blood components. The components are Washed Red Cells (WRC), Packed Red Cells (PRC), Platelet Concentrate (TC), Apheresis, Fresh Frozen Plasma (FFP), Plasma, Buffy Coat (BC), and Cryoprecipitate (AHF). These blood components have a function to provide alternative treatments to clinical parties in treating patients. This is because blood transfusion using blood components gives a more positive response than using Whole Blood. To ensure the quality of blood products, UTD PMI Surabaya conducts quality tests of blood products which are carried out randomly for each blood component product and are carried out regularly every month. This examination also includes examination for bacterial contamination. In addition, UTD PMI Surabaya also has a product release team that is responsible for evaluating the result for each blood product. This is done to ensure that the distributed blood products meet specifications, are of high quality, informative, and safe.

Based on blood's components, UTD PMI Surabaya has monthly demand, stock, and expired blood for whole blood and platelet concentrate from January 2018 to September 2021 as seen on Table 1.

TABLE 1. Demand of Whole Blood

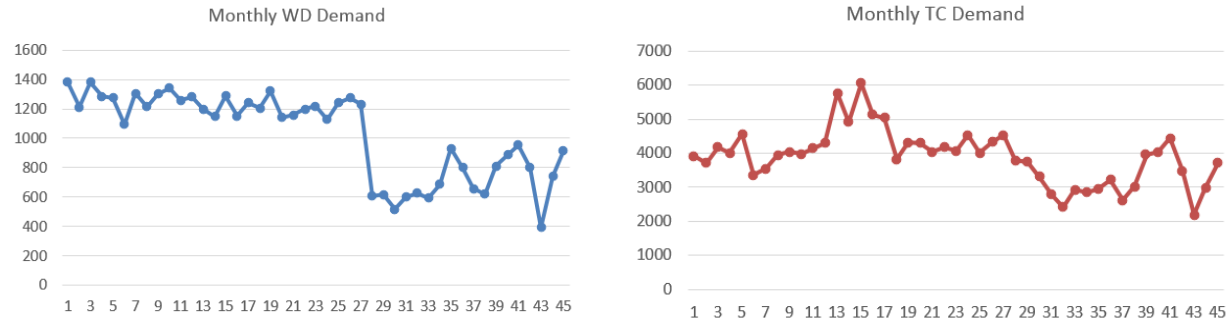
	Blood Types	2018	2019	2020	Jan- Sept 2021
Whole Blood (WB)	Demand	15336	14410	9732	6779
	Expired	38	222	4	5
	Stock	2099	1515	1246	339
Platelet Concentrate (TC)	Demand	47705	56164	40876	30447
	Expired	35913	27774	20786	6808
	Stock	8435	7146	4638	6541

From the Table 1, the blood stock of WB every year is about 5-14% of the blood demand with a very low amount of expired blood. One of the factors that support the small amount of expired blood is the lifespan of WB blood which is quite long, around 35 days. On the other hand, the demand for TC every month is about 3 to 5 times more than the demand for WB. The blood stock provided by PMI's UTD is also much larger at 10-21% of the total blood demand. The important thing to analyses more deeply is the amount of expired TC which is quite large, around 20-75% of the total TC demand. One of the causes of the high number of expiry date of TC is its relatively short life span of 5 days. In Fig. 1, it can be seen for both WD and TC blood demand, blood type O has the highest percentage of requests, followed by blood types B, A, and AB respectively.

(a) WB Demand based on Blood Type (b) TC Demand based on Blood Type

FIGURE 1. Demand based on Blood Type

In this study, demand data is taken from January 2018 to September 2021. Past demand from WD and TC is plotted to see the trend of data patterns. In the Fig.2, it appears that the demand for WD and TC began to decline in the 28th and 29th period (April and May 2020), respectively. If we look back at the condition of society in the April 2020 period, the Covid pandemic in Indonesia began to occur. As for TC, the highest demand occurred in the 15th period (March 2019).



(a) Monthly WD Demand (b) Monthly TC Demand

FIGURE 2. Blood Bags Demand

We will predict the demand data that we have plotted using ARIMA (p,d,q). ARIMA solution is done using Python. Several ARIMA models are created and compared based on the AIC value. The ARIMA model for WD and TC can be seen in Tables 2 and 3. The Table 2 shows that the ARIMA models of WD there are several models that provide low AIC values. That several models then compared based on the RSME value. The RSME value for the ARIMA model (0,1,3) gives the smallest forecast error value compared to all forecasting models predictions. As for TC (can be seen in Table 3), the ARIMA model of TC there are several models that provide low AIC values. That several models then compared based on the RSME value. The RSME value for the ARIMA model (1,1,3) gives the smallest forecast error value compared to all forecasting models predictions. This model is used to predict blood demand for both WD and TC.

TABLE 2. AIC Value for each ARIMA Models of WD

ARIMA Model	AIC	RMSE
(1,1,0)	579,217	163,1823
(2,1,0)	580,221	161,3356
(3,1,0)	577,563	152,8191
(0,1,1)	578,509	161,8587
(0,1,2)	578,082	157,3447
(0,1,3)	576,088	149,3406
(1,1,1)	575,017	151,1494
(2,1,1)	576,930	151,0041
(3,1,1)	579,563	152,8187
(1,1,2)	576,937	151,0216
(2,1,2)	579,018	151,1510
(3,1,2)	580,936	151,0152
(1,1,3)	578,088	149,3411
(2,1,3)	580,949	151,0418
(3,1,3)	582,939	151,0155
(1,2,0)	588,691	212,8677
(2,2,0)	588,856	208,4327
(3,2,0)	582,136	188,2317
(0,2,1)	571,860	174,6600
(0,2,2)	572,734	172,2020
(0,2,3)	573,201	169,0096
(1,2,1)	573,094	173,0400
(2,2,1)	574,449	171,7911
(3,2,1)	572,419	155,1875
(1,2,2)	575,871	174,6867

TABLE 3. AIC Value for each ARIMA Models of TC

ARIMA Model	AIC	RMSE
(1,1,0)	692,703	592,1483
(2,1,0)	694,702	592,1434
(3,1,0)	694,559	577,0783
(0,1,1)	692,525	590,8286
(0,1,2)	694,339	589,3980
(0,1,3)	693,125	566,8747
(1,1,1)	691,430	570,1141
(2,1,1)	692,856	566,0249
(3,1,1)	694,010	560,1916
(1,1,2)	693,021	567,2204
(2,1,2)	695,432	570,1287
(3,1,2)	696,856	566,0267
(1,1,3)	693,830	558,7313
(1,2,0)	697,562	749,8415
(2,2,0)	697,651	732,8585
(3,2,0)	696,369	703,9171
(0,2,1)	684,944	648,3672
(0,2,2)	684,279	625,5896
(0,2,3)	686,246	625,4445
(1,2,1)	684,277	625,5132
(2,2,1)	686,250	625,3186
(3,2,1)	686,488	612,5511
(1,2,2)	688,945	648,3808
(2,2,2)	688,277	625,5160
(3,2,2)	690,252	625,3302

The data is then processed using the ARIMA model (0,1,3) for WD and the (1,1,3) model for TC. The forecasting results obtained are then compared with the real demand data. The difference between the real demand and the forecast results is then calculated the magnitude of the error using RMSE. In addition, the data obtained is plotted on a graph so that the differences can be analyzed. It can be seen that the error in TC is very high. This is understandable given the higher demand for TC with a high amount of stock expiring as well (TC expiration is only 5 days). From the plot results on the graph, it can be seen that both forecasting on WB (Fig. 3) and on TC (Fig. 4) data from forecasting using ARIMA is sufficient to provide a sufficient number of demand for blood bags.

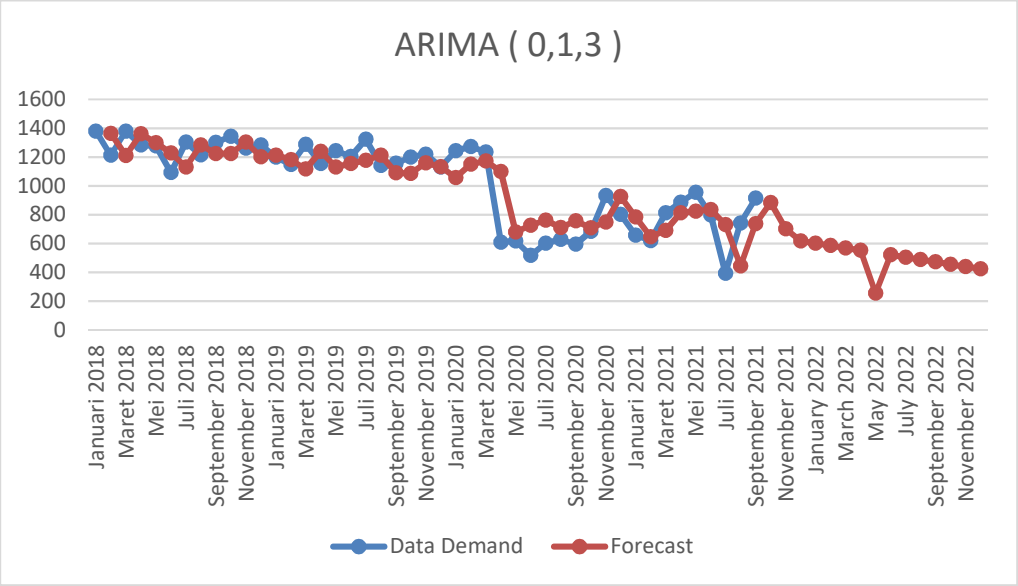


FIGURE 3. Plotting Data of ARIMA (0,1,3) Model for WD Prediction

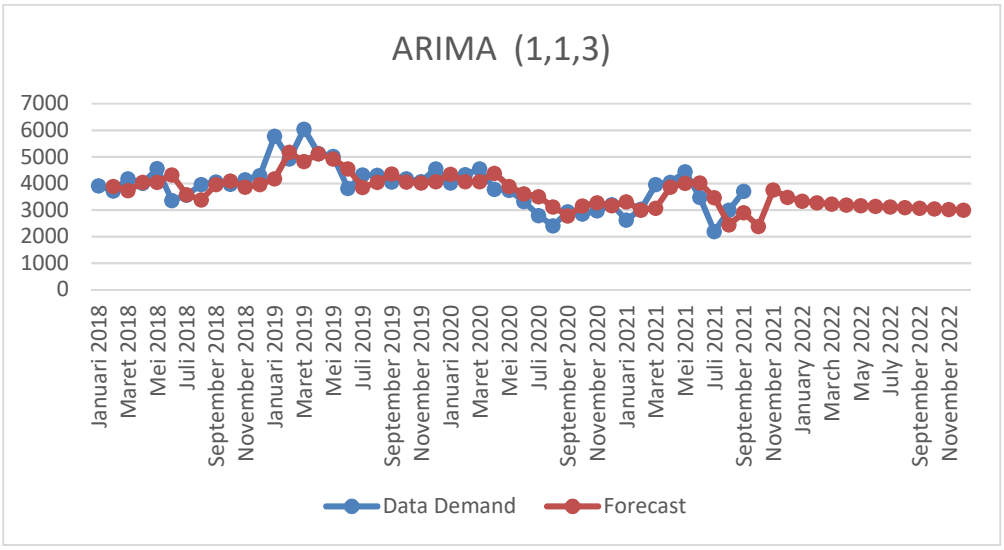


FIGURE 4. Plotting Data of ARIMA (1,1,3) Model for TC Prediction

CONCLUSION

The stock of blood bags at UTD PMI is not a stock of goods in general, considering that the supply of blood bags is closely related to a person's life. On the other hand, the types of blood components stored have an expiration date, processing costs and storage costs. So it is necessary to think about how to keep the blood bag in the right amount. In this case, it may be okay to have a slightly excess amount of stock in order to anticipate a sudden surge in demand, but not too much given the high costs involved.

This study tries to map the need for blood bags at UTD PMI Surabaya using the ARIMA method. The types of blood components selected are WD and TC with the consideration that both have very different expiration dates. WD expiration is 35 days while TC expiration is 5 days. From the applied ARIMA model, it can be seen that the ARIMA model (0,1,3) has the lowest RMSE for WD. Meanwhile for TC, ARIMA model (1,1,3) has the lowest RMSE. The ARIMA forecasting results are then plotted on a graph to see the difference between the forecast data and the original data. It can be seen that the ARIMA model chosen is quite capable of providing adequate forecasts. Given that the supply of blood bags is very important for a person's life, it is very important to develop a separate study to calculate how much safety stock is needed. This safety stock must consider the characteristics of each blood component (expiration time, the need for certain seasonal diseases, availability in certain blood groups and rhesus).

ACKNOWLEDGMENTS

This research was supported by Indonesia Directorate Research and Technology of Higher Education and Petra Christian University Supply Chain Research Group. We thank UTD PMI Surabaya staff for valuable data, discussion, and feedback.

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