Saving Lives with Data: How Blood Supply Chain Optimization Reduces Shortages by 7%

Andreas Handojo[1](✉), Tanti Octavia[2], and Gabriela Consuelo Heriyanto[1]

[1] Informatics Department, Petra Christian University, Surabaya, Indonesia
handojo@petra.ac.id

[2] Industrial Engineering Department, Petra Christian University, Siwalankerto 121–131, Surabaya, Indonesia

Abstract. This study aims to predict the demand for blood bags considering their expiration date, to help address the uncertainty and potential shortages in the Red Cross's blood stock. The ARIMA method was used to predict the future demand for blood bags, particularly during the COVID-19 pandemic. The simulation results show a 45% reduction in excess stock and a 7% reduction in stock shortages, indicating that the predictive model can effectively optimize the blood supply chain. These findings have significant implications for humanitarian activities, particularly in times of crisis when the demand for blood is high and uncertain, as it enables better planning and management of blood supply, which ultimately saves lives.

Keywords: Blood · Inventory Control · Blood Bag · Red Cross

1 Introduction

Blood serves a variety of vital functions in the human body. One of them is the distribution of essential substances throughout the body. Furthermore, blood aids in the removal of waste substances that the body does not require [1, 2]. Unfortunately, because blood can only be generated by people, it can only be donated in limited numbers. There has never been a product that can replace blood or a chemical process that can create blood. As a result, blood is regarded as a scarce and very expensive commodity. When blood levels in a person's body are lower than they should be, the only way to overcome this is to receive blood from other people through blood transfusions. The blood used for transfusions is obtained through blood donation activities. Blood donation, also known as "donation of blood," is the process of collecting blood from willing donors [2].

The Blood Transfusion Unit (UTD), which is part of the Indonesian Red Cross (PMI), organizes blood donation events [3, 4]. UTD PMI tests and processes the blood collected. Complete blood, or Whole Blood (WB) is blood received via blood donation activities. The other components of blood processing are Washed Red Cells (WRC), Packed Red Cells (PRC), Platelet Concentrate (TC), Apheresis, Plasma, Buffy Coat (BC), and so on. The blood components are then kept under strict conditions. Each component of blood has its own expiration date [1]. If stored blood has passed its expiration date, it

T. T. Y. Alabdullah et al. (Eds.): ICIGR 2022, ASSEHR 750, pp. 487–494, 2023.
https://doi.org/10.2991/978-2-38476-052-7_53

is ruined and must be discarded. As a result, in order to prevent squandering resources, UTD PMI should avoid keeping surplus blood bags. Meanwhile, a shortage of blood flow may force the therapy operation to be canceled. Of course, this can imperil the lives of people who require blood transfusions. As a result, both excess and scarcity of blood supply must be avoided.

When creating demand projections, it is necessary to account for degradation variables. This is due to the fact that most blood components have a shelf life of 5 to 35 days. If a blood component has reached its expiration date, it can no longer be utilized for blood transfusions. This reduces the amount of blood available for utilization. The prediction findings can be more accurate in estimating blood needs if this degradation component is considered.

Many prediction approaches may be used to forecast blood demands. Several approaches, such as the Weighted Moving Average method, are frequently utilized in studies to anticipate PMI blood requirements [6]. This strategy outperforms the Simple Moving Average method. This is due to the fact that the computations are straightforward, and the weight numbers may be modified accordingly. However, if you utilize this strategy, determining the appropriate weight will be tough, necessitating a lot of trial and error. The Single Exponential Smoothing approach is another popular one. This method was employed in research by [7]. This strategy is simple to learn and apply, and it is useful for short-term forecasting. However, this method cannot accurately predict data that is trending over time.

In this research, the ARIMA forecasting approach was used to estimate blood components to predict blood needs. This research develops a forecasting system to project demand while also considering the degradation of blood components, which occurs between 5 and 35 days. This is done to see whether the degradation factor can improve the accuracy of forecasting demand for blood components. Implementation is done by developing a blood bag inventory control application.

2 Literature Review

Several research on forecasting blood demand have been performed. There have been various forecasting methodologies used. For example, in a study to estimate blood demand for WB and RBC blood products, demographic mapping was used to predict future trends in blood demand [8]. This research aims to use statistics on the requirement for blood per 1.000 persons (in 2008) to forecast future demand based on population growth. The study's drawback is that modeling the population will be extremely challenging given the possibilities of population relocation, disease outbreaks, food shortages, couples refusing to have children, and so on.

Nasyika et al. (2019) [9] developed a system for predicting the number of requests for blood bags at UTD PMI Jombang Regency, Indonesia, using the least square regression line method. Lestari et al. [10] have also developed research for forecasting the demand for blood bags using historical information on blood bag requests, such as utilizing the moving average, the weighted moving average, and the exponential smoothing approach. This research can demonstrate that the moving average, weighted moving average, exponential smoothing, and exponential smoothing methods can predict the demand for blood with a low error rate. The limitation of this technique is that it cannot handle trending or seasonal data, because the data must be steady or constant, yet data on blood requirement is frequently ambiguous and depends on the situation and conditions.

Another study [7] employed a single exponential smoothing approach to account for random, trend, and seasonal effects on data.However, if the data utilized is not steady, prediction with this approach is poor. Because the single exponential smoothing method's equation lacks a smoothing mechanism for the influence of trends, it cannot transform non-stationary data into stationary data.

To address the shortcomings of the forecasting approach used in this research, the forecasting method will employ the auto-regressive integrated moving average (ARIMA) method. The ARIMA approach combines three methods: AR (autoregressive), MA (moving average), and ARMA (autoregressive and moving average). This approach is flexible enough to examine data in the form of random, trending, seasonal, or cyclical patterns. Because this method is a combination method, it is expected to have a high level of accuracy. This forecasting approach has already been done in previous research [11].

3 Results and Discussion

In this research, a blood bag inventory control application was developed by implementing a blood bag demand forecasting system using ARIMA and taking expiration factors into account. The blood bags produced are recorded in the system along with their expiration date. This record is necessary to know how many bags of blood are needed (Fig. 1). The system also provides blood bag inventory search data along with expiration information for each blood bag. This is to facilitate the search for blood bags that have an expiration date in the near future, so they can be used immediately (Fig. 2).

Requests for blood bags from the hospital, individual parties (with a doctor's recommendation), or UTD PMI in other areas are made via telephone, and the officer must record and enter the request data manually. This application provides a system for recording requests for blood bags so that they can easily be entered into the inventory control system to check for their availability (Fig. 3).

The inventory control process for the availability of blood bags uses some primary data, such as:

1. Demand prediction data obtained by the ARIMA method, which has been carried out in previous research [9], yields monthly data divided equally into 4 weeks.
2. The initial stock data (beginning inventory) of blood bags that was recorded at the beginning of the week.
3. Requests for blood bags (from the hospital and UTD PMI partners) are recorded at the beginning of the week.
4. Estimates of production results generated in that week
5. Data on the number of expired blood bags that will occur that week.

Based on these data, the total number of blood bags needed for that week is calculated. This is used to give PMI an idea of the need for or excess stock of blood bags that occurred

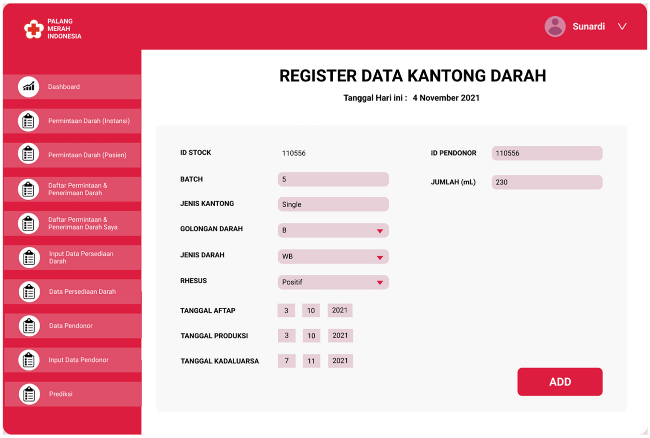

Fig. 1. Blood bags registered

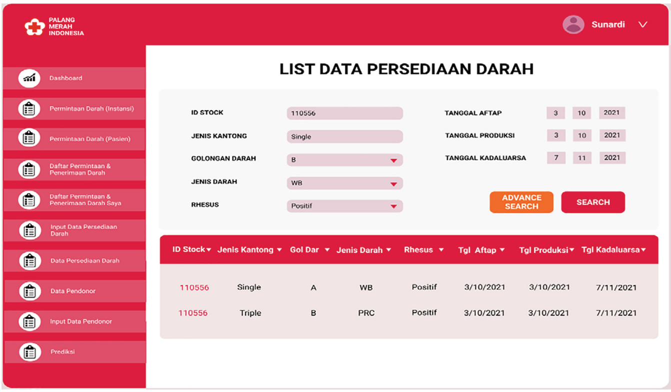

Fig. 2. Blood bags view list

that week. PMI can take anticipatory actions, such as if the need for blood bag stock is high, it can carry out promotions or blood donation activities more intensely that week. If the need for blood bag stocks is low or even exceeds the need, donor activities can be further reduced so that blood bag stocks are not excessive, which causes the number of blood bags to be destroyed to increase.

As the days of the week go by, the blood donation activities will continue so that in the middle of the week (around Thursday or Friday), the total number of blood bags that have been donated will be collected. This amount will reduce the need for blood bags that week. If the stock is in excess (marked with a parenthesis symbol), then it will go into the next week's period. If the stock is lacking, PMI can broadcast to active donors or through families who request blood bags.

Table 1 shows the results of blood bag inventory control processing carried out on whole blood (WB) components (35-day expiration) and platelet concentrate (TC) (5-day expiration). The prediction of the need for whole blood for that month is 1.200

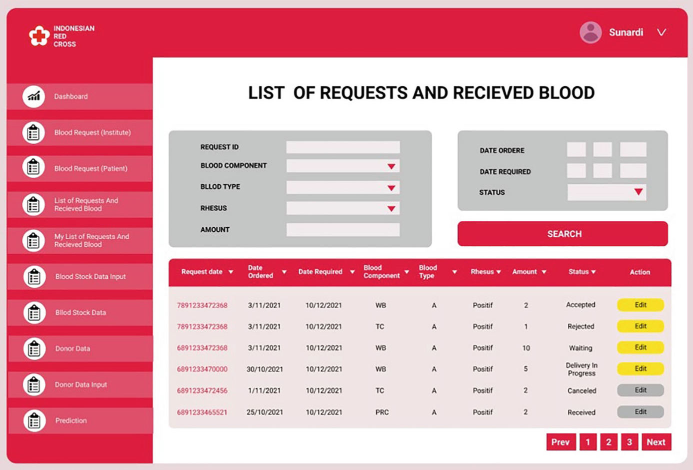

Fig. 3. Blood bags request and received data

bags. This need is divided equally into four weeks, so that each demand is 300 bags. A request for blood bags is filled with previously obtained requests for blood bags from hospitals and partners (via official letters or e-mails). WB has fewer expired blood bags compared to TC, considering the WB expiration time is the highest compared to other blood components.

In the table, it can be seen that the estimated shortage of WB blood bags did not occur; instead, there were an excess of 25 bags. This excess stock will be included as beginning inventory data in the following week's period. The same thing happened to TC blood bags; in the first week, the stock was estimated to be over 110 bags. So, PMI can anticipate this by reducing the production process to WB and TC components. Blood obtained from donors can be diverted to meet the needs of other blood components. This is different from the estimated data on the excessive or shortage of blood bags for the TC component in the third week, where the stock actually fell short by 35 bags. So, PMI can produce more TC components or hold more intensive blood donation activities that week.

With this inventory control data for blood bags, PMI can organize blood donation activities more efficiently so that the amount of blood available can meet needs and not be excessive, which of course causes an increase in costs for processing and destroying blood bags. The limitation of this study is that the numbers included in the calculations are not actual donor data; this is in view of maintaining the confidentiality of donor data. The absence of orderly and near-real-time recording of the blood processing process will make it difficult to process real needs. According to the simulation process, the results of this study succeeded in reducing excess stock by 45% and stock shortage by 7%.

Table 1. Inventory control of blood bags

Blood Component		Week 1	Week 2	Week 3	Week 3
Whole Blood (WB)	Predicted Demand	300	300	300	300
	Beginning Inventory	75	25	5	20
	Blood Bags Request	70	50	65	50
	Production	110	200	180	190
	Expired	40	90	30	45
	Blood Bags Needed	225	215	210	185
	Total Blood Donation (middle of the week)	250	220	230	211
	Excessive/Shortage	25	5	20	26
Platelet Concentrate (TC)	Predicted Demand	200	200	200	200
	Beginning Inventory	210	110	75	(35)
	Blood Bags Request	170	155	180	145
	Production	250	200	180	200
	Expired	280	180	160	160
	Blood Bags Needed	190	225	285	340
	Total Blood Donation (middle of the week)	300	300	250	290
	Excessive/Shortage	110	75	(35)	(50)

4 Conclusion

Blood is an important requirement for the human body; a lack of it can cause illness and even lead to death. Therefore, it takes blood donors from other humans. The blood donation process is carried out by the Red Cross (PMI) by carrying out blood donation activities, processing blood into the required blood components, storing, and distributing blood bags upon request. If a stock of blood bags has passed its expiration date, the bags must be destroyed. These processes, of course, will cost a lot. Therefore, in this research, it was carried out to provide inventory control information on the availability of blood bags, which can provide information about the need for blood bags by considering expiration issues so that blood bag supplies are not lacking or excessive.

This study presents the calculation of the need for blood bags by considering the demand prediction factor (using the ARIMA method), the initial stock, the demand for blood bags, the amount of blood component production, and the total number of blood donors received each week. The information collected in this research is expected to help PMI anticipate the need for or excess of blood bags. Future research development can be carried out by creating a new formulation that is able to accommodate obsolete problems. Development can also be done by adding the ability to segment donors (active or inactive), predict blood bags with a method that can accommodate the specificity of each blood component, and predict donors who can donate their blood.

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

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