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Determination Strategy for Controlling Bloodstock Components Packed Red Cell Using Monte Carlo Simulation

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Abstract. Blood supply is an important part that is very influential on health because almost all blood types are necessary for medical activities. This condition makes blood management very important, but improper blood management can cause a waste that results in huge final costs and causes losses for both the customer and the blood supplier. In this case, Monte Carlo simulation can be used to develop several policies that can optimize blood inventory levels and minimize inventory costs at Indonesian Red Cross XYZ. In this simulation, input data required are blood donor supply and Packed Red cells (PRC) demand data, this data will be used to determine the shortage and expired rate. From simulation will be obtained shortage rate of 33 blood bags and an expired rate of 75 blood bags with inventory cost Rp. 36,226,964. Monte Carlo simulation will make new policy rules with increasing the supply of whole blood (WB) which will be used as a component of the PRC and reducing the supply level. From these simulation results, the best policy will gain and applied at PMI XYZ to optimize inventory cost.

Keyword: Simulation, Optimization, Packed Red Cell, Cost, Blood Inventory

Abstrak. *Suplai darah merupakan bagian penting yang sangat berpengaruh terhadap kesehatan karena hampir semua golongan darah diperlukan untuk kegiatan medis. Kondisi ini membuat pengelolaan darah menjadi sangat penting, namun pengelolaan darah yang tidak tepat dapat menyebabkan pemborosan yang mengakibatkan biaya penyimpanan yang sangat besar dan menimbulkan kerugian baik bagi pelanggan maupun pemasok darah. Dalam hal ini, simulasi Monte Carlo dapat digunakan untuk mengembangkan beberapa kebijakan yang dapat mengoptimalkan tingkat persediaan dan meminimalkan biaya persediaan di Palang Merah Indonesia XYZ. Pada simulasi ini, data input yang dibutuhkan adalah data suplai donor darah dan data kebutuhan Packed Red cell (PRC), data ini akan digunakan untuk menentukan tingkat kekurangan dan kadaluarsa. Dari simulasi Monte Carlo didapatkan tingkat kekurangan Sebanyak 33 kantong darah dan tingkat kadaluarsa 75 kantong darah dengan biaya persediaan Rp. 36.226.964. Simulasi Monte Carlo akan membuat kebijakan baru dengan skenario peningkatan suplai whole blood (WB) yang akan digunakan sebagai komponen PRC dan menurunkan level suplai. Dari hasil simulasi akan membentuk sebuah kebijakan yang lebih bagus untuk diterapkan pada PMI XYZ yang digunakan untuk mengoptimalkan biaya penyimpanan.*

Kata Kunci: Simulasi,Optimisasi, Sel Darah Merah, Biaya, Persediaan Darah.

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1. Introduction

Indonesian Red Cross is a national association engaged in the social and humanitarian field. Social health service is one of their programs that organizes blood donation, blood supply, and blood distribution. [1]. Therefore, Indonesian Red Cross has an important role in forecasting the demand and supply of blood, as well as determining the level of blood supply. The main goal of Indonesian Red Cross is to fulfill blood demand efficiently both in terms of cost or time in an environment filled with uncertainty [2] . In its management, the main thing that needs to be considered by Indonesian Red Cross is an efficient supply with good management of blood, it is expected to reduce deaths due to bleeding and other cases [3].

International Red Cross records that the blood supply is divided into several components, namely whole blood (WB), Packed Red Cells (PRC) or red blood cells, liquid plasma, and others [4]. However, in this study we will focus on PRC which usually lasts for 5 days while all blood has a legal age of about 30 days and if it is past that age the blood must be discarded due to contamination and can be said expired so that it can cause losses to Red Cross Organization [5].

Nowadays The main problems that occur in the Indonesian Red Cross are Improper blood management it will create wastage because of the blood characteristics that are not durable and can be damaged easily, so if the blood inventory is in a big number of amount and not be used until the expiration date, then the blood will be broken and it will give a financial loss to Indonesian Red Cross [1].

Problems In Indonesian Red Cross XYZ are complex because it cannot be solved only by mathematical or analytical methods. After all, the demand and supply of blood are uncertain (stochastic) and occur repeatedly it making the amount of blood supply cannot be determined [6]. To solve problems that are difficult using analytical or mathematical methods, the simulation method can be used as an alternative solution [7]

Based on the explanation above, this study will consider the problems in Indonesian Red Cross XYZ related to costs, blood supply, and storage time which will be simulated using Monte Carlo in Microsoft Excel software. In the Indonesian Red Cross XYZ does not have a policy related to blood storage, especially the PRC component. The Monte Carlo simulation model created will be the research output used to determine the right policy in controlling PRC blood component inventory with an indication of the total inventory cost having a minimum budget but not causing a large shortage of demand and expired.

2. Related Work

Previous studies were used to obtain information related to the research topic chosen by the researcher. Previous studies that discussed optimizing blood supplies and minimizing blood supply costs have been carried out to solve a problem that exists in the Indonesian Red Cross and other blood suppliers. Conducted research dealing with emergency blood supply with a supply chain stochastic model (having an uncertain parameter value/unstable/probabilistic degree of certainty) and multiple-objective (having various criteria involves more than one function to achieve an optimization). This research was conducted for efficiency to minimize cost and effectiveness by minimizing delivery time of blood supply in emergency condition with a hybrid approach combining the constraint and LaGrange relaxation methods which were developed to model an uncertain demand [8]

Blood products themselves are easily damaged and have a limited age in a certain period (Perishable). This condition will affect inventory problems and blood distribution time for patients. Inventory problems also appear in the supply of blood products which is uncertain because the number of donors who come to donate blood cannot be determined. In addition to inventory problems, there is often a shortage of supplies because the bloodstock is not eligible for the demand so that problems regarding storage costs will also arise. From these problems researcher designed a supply system for platelets with two shelf-life periods labeled "old" units and "young" units [9]. Meanwhile, consider a discrete-time inventory system with a level of protection for the platelet ordering problem [10].

States that optimization is often used in blood supply management problems. This optimization was made using a mathematical programming approach that focuses on the problem of storage locations and strategic decision-making [11]. Proposed a dynamic programming approach for platelet production [12]. Proposed integer programming and variable search techniques to evaluate the change from a vendor-managed inventory system to a new system for the Austrian Red Cross [13].

3. Methodology

3.1. Data Collection

Research was conducted in Indonesian Red Cross XYZ In this research the required data collection will be divided into two types of data:

A. Primary Data

Primary data is collected from the research location. Primary data collection in this study was carried out by two methods observation and Interviews to obtain the required data related to build a simulation model.

B. Secondary Data

Secondary data is indirect data or supporting data such as literature study for collecting data through references (previous research, books, journals related to the research conducted) and Indonesian Red Cross XYZ data bank like information of company profiles, blood characteristics data, a blood production processes. Data collected from Indonesian Red Cross XYZ used to build simulation models are blood demand data for PRC component type O, Donor data of PRC component type O, storage costs data, orders data, expired data, and shortages data.

3.2. Research Flow

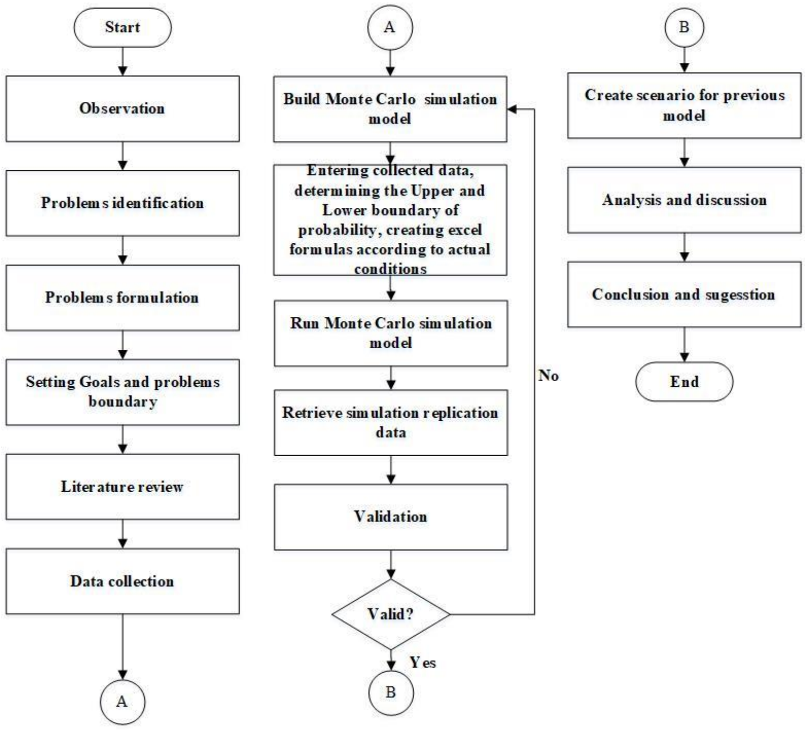

Figure 1 Research Flow Diagram

The first step in this research is doing some observation to understand the real condition refer to blood inventory system and obtain an information as a basis for this research. The next step will be to identify problems inside the research location to optimize blood supply. The identification problem doing by direct observation and interviews at Indonesian Red Cross XYZ office. After that, the thing that must be done is formulate the problem, determine the research objectives and determine the boundaries of problems. This is because the researcher not possible to examine all the problems that exist in real system. In this boundary problem, assumptions may occur in the system simulation. With the boundary of the problem, researchers can focus on the object that will be studied. The next step is to review the literature by conducting a study to find references with previous studies correlating previous research. Then, Data collection for both primary and secondary data. The next step is to manage the data, either manually or using an application so much information can be obtained. Data management consist of simulation, validation, scenario modeling, and scenario comparison to determine the right policy in minimizing inventory costs. After that, analysis and discussion were sent out to describe how the actual model changes from the first scenario, second scenario, and third scenario based on the results of total inventory costs. The final step is to describe conclusions and make decisions based on the analysis that has been done previously.

3.3. Total Cost Inventory Function Index

$$\sum_{t=1}^{30} Q_{st} . C_s + \sum_{t=1}^{30} Q_{et}. C_E + \sum_{t=1}^{30} I_t. C_h + \sum_{t=1}^{30} P_t. C_p \quad (1)$$

Equation (1) is a function to minimize the total inventory cost. This total cost is influenced by the rateof blood supply variable, the blood inventory rate, shortage rate and also expired rate. Index listed below:

- t = simulation period index
- p = incoming blood index
- h = inventory index
- s = shortage index
- E = expired index Parameters
- Cp= ordering cost
- Ch= holding cost
- Cs= shortage cost
- CE= expired cost
- Qst = rate of blood shortage in t period
- Q_{et} = rate of expired blood in t period
- Q_{st} = rate of blood Shortage in t period
- Q_{et} = rate of expired blood in t period

4. Result and Discussion

The following table and matrix are result of Monte Carlo simulation using Microsoft excel for 30 days (30 replications) which is used to determine the policies that will be taken to optimize inventory and minimize inventory costs that occur at Indonesian Red Cross XYZ.

Table 1 Result of Monte Carlo Simulation

Day	Stock	Random	Supply	Random	Demand	Final Stock	Shortage	Expired
1	0	97	26	39	0	26	0	0
2	26	25	0	62	0	26	0	0
3	26	76	7	96	16	17	0	0
4	17	0	0	58	0	17	0	0
5	17	63	3	0	0	20	0	10
6	20	88	14	98	19	14	0	0
7	14	21	0	58	0	14	0	0
8	14	31	0	71	0	14	0	0
9	14	83	10	90	10	14	0	0
10	14	19	0	75	3	8	0	1
11	8	5	0	25	0	7	0	0
12	7	20	0	55	0	7	0	0
13	7	71	5	4	0	12	0	7
14	12	68	4	48	0	9	0	0
15	9	39	0	3	0	9	0	0
16	9	11	0	55	0	9	0	0
17	9	74	5	95	15	0	1	0
18	0	63	3	68	0	3	0	0
19	3	16	0	45	0	3	0	0
20	3	63	3	45	0	6	0	0
21	6	41	0	9	0	6	0	0
22	6	2	0	73	1	4	0	2

Day	Stock	Random	Supply	Random	Demand	Final Stock	Shortage	Expired
23	4	55	2	75	3	2	0	0
24	2	36	0	82	6	0	4	0
25	0	83	10	39	0	10	0	0
26	10	77	7	85	8	9	0	0
27	9	65	3	26	0	12	0	0
28	12	89	14	88	9	15	0	0
29	15	17	0	58	0	15	0	0
30	15	81	9	40	0	24	0	0
Mean			4		3	11	0,167	1
Total			**125**		**90**	**332**	**5**	**20**

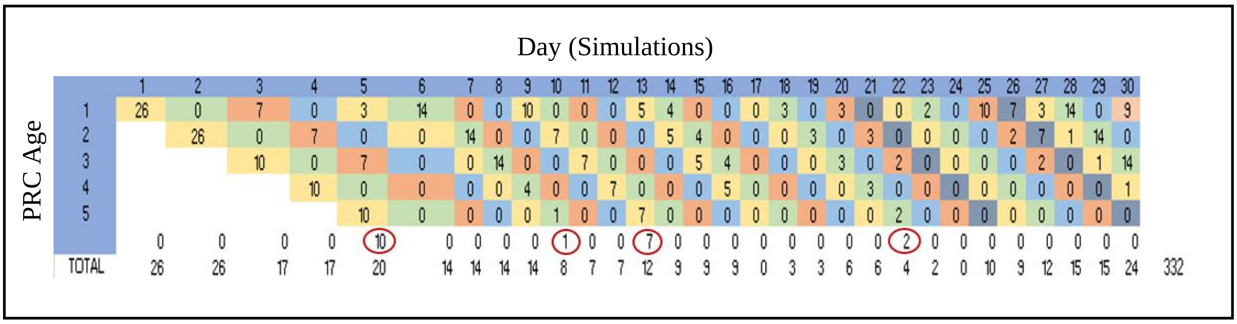

Figure 2 Matrix for stock of PRC blood components expired in 5 days

A. *Validation Test*

The validation test used in this research are variance comparation test and mean comparation test. Variance comparison test makes sure that the assumption of each populations has the same variance. According to the calculation, the result of the F-value is 1,5 for accepted blood supply and 0,53 for blood demand. Since the range of acceptance is between 0.476 and 2.101, then the H_0 is accepted or the simulation result is in line with the real system.

Mean Comparison Test used to compare the performance between the real system with the simulation model. Because the data is from two populations, so the test used is the double-sided test. The t-value from the mean comparison test in the demand of PRC O blood is 1, and the t-value in the supply of O blood is -0.94. Since the range of acceptance is between -2.048 and 2.048, so the result is H_0 is accepted, which means that the simulation data is in line with the real system data.

B. *The Development of Scenarios*

From the Monte Carlo simulation that proven valid, several scenarios were made to gain the optimum total inventory cost. The model with scenario 1 will be given a policy with converting whole blood components that are less or equal than 25 days into PRC components, this transformation is done because WB blood components can be changed to PRC at any time with a short time to suffice customer demand when a shortage occurs. The addition of WB for making the PRC component can only be done as many as 21 bags in a 1 period. The purpose of this scenario is to minimize shortages with the shortage average by replication occurs every day as many as 0.633 or approximately 1 bag of blood per day.

Scenario 2 will develop a policy by adding WB to reduce the shortage and supply level of the PRC component. Supply level for the daily supply of blood products based on the replication of the real model, the average daily supply is 4 bags and the demand is 3 bags. To approach the level of demand, the supply level was reduced by 88% so the inventory would not accumulate excessively become expired products.

C. Total Inventory Cost Comparation

The results of replication which amounted to 30 times with 1 initial model and 2 scenarios that have different policies, the results obtained are comparisons of expired and shortage rates for packed red cell components, while the comparison data is as follows:

- Green: Initial Model (based on real system) - Blue: Scenario 1 – Yellow: Scenario 2

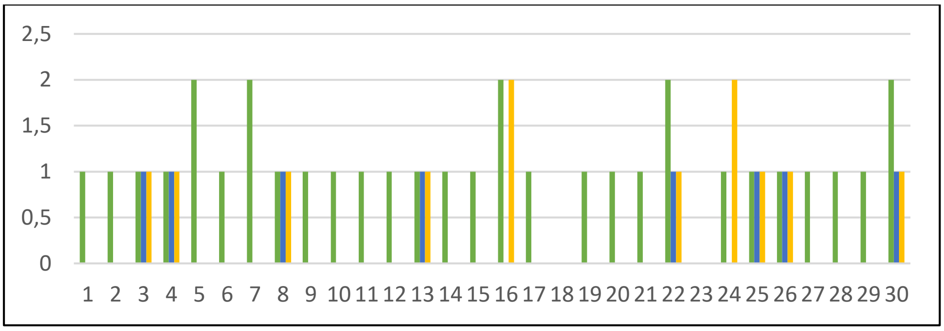

Figure 3 Histogram Comparation of Shortage PRC

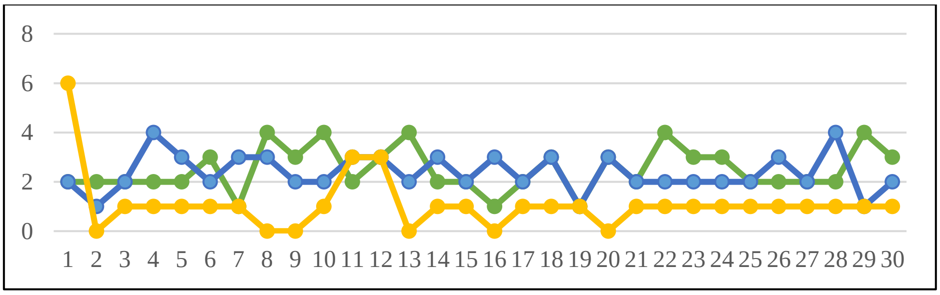

Figure 4 Comparation of Expired PRC components

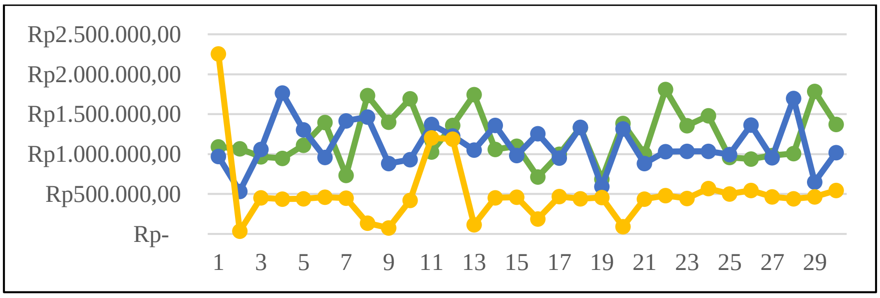

Figure 5 Comparation of Inventory cost PRC components

Table 2 Total Inventory Cost PRC Components

Simulation	*Stock*	*Holding Cost*	*Donors*	*Ordering Cost*
Initial Model	13874	Rp 5.002.96	152	Rp 1.824.000
Scenario 1	13701	Rp 4.940.580	148	Rp 1.776.000
Scenario 2	1966	Rp 708.939	134	Rp 1.608.000

Simulation	*Shortage*	*Shortage Cost*	*Expired*	*Expired Cost*	*Total Inventory Cost*
Initial Model	33	Rp 1.650.000	75	Rp 27.750.000	Rp 36.226.964
Scenario 1	8	Rp 400.000	71	Rp 26.270.000	Rp 33.386.580
Scenario 2	12	Rp 600.000	33	Rp 12.210.000	Rp 19.502.820

This research is expected to know the most optimum scenario to decrease the total inventory cost. Totalinventory cost consists of ordering cost, holding cost, expired cost, and shortage cost. Based on the 30 replications that have been done, the result of the total inventory cost is as in Table 2.

Monte Carlo simulation built based on the current condition of Indonesian Red Cross XYZ. The total cost of inventory spent for a month is Rp. 36,226,964.40 having high expired rates 75 bags and shortage bags of blood with the total average cost for the initial model being Rp. 1,207,565.48. In scenario 1, building a policy of converting whole blood as many as 21 blood bags for 1 period (30 days) has an inventory cost of Rp. 33,386,580.60 with average cost Rp. 1,112,886.02. In scenario 2 by adding a policy of changing WB to PRC to reduce shortages by 21 bags if there is a shortage within a period of 5 days and also reducing supply levels by 88% to avoid a lot of expired products, this scenario has a total inventory cost of Rp. 19,502. 820.60 with an average cost per replication of Rp 650,094.02.

5. Conclusion

To get the appropriate policy in order to optimize the platelet component inventory and minimize total inventory cost in Indonesian Red Cross XYZ simulation Monte Carlo was built with the result below:

1. Initial model: having high expired rates and shortage rates (75 and 33 bags of blood). This causes the blood inventory not optimal because a lot of blood must be removed and large losses with an analysis for the total cost inventory is Rp. 36,226,964.40.

2. Shortage and expired need to be minimized so that blood supply can be optimal, the results of the initial model analysis a policy was built to reduce shortages by converting whole blood

aged 25 days into Packed Red Cells components with a quantity of 21 and succeeded in reducing shortage to 8 bags of blood. with a total cost for the Inventory Cost of Rp. 33,368,580.

3. The expired number is still relatively high at 71 bags or there is no difference between initial model, a further policy was developed by reducing shortages to substitute whole blood and also reducing the supply level for PRC by 88% so that a shortage rate of 12 blood bags and an expired rate of 12 bags were obtained. 33 with a total cost of Rp. 19,502,820.60 for Inventory Cost.

4. Researcher recommendation for Indonesian Red Cross XYZ implement scenario 2 for better optimize inventory of PRC components.

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