Blood Collection Strategy: A Lesson Learned from Indonesian Blood Supply Chain

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Abstract. Blood collection management consists of complex processes that impact the blood outdated rate. This research intends to build an effective collection strategy for the blood bank so expiration rates could be reduced. According to the observed system complexity, a suitable method in this research is discrete event simulation. Three scenarios are used in this research is the strategy of PMI in collecting the blood supply, which is a Mobile Unit Model (MUM) strategy. With the 95\% minimum target of order fulfilment rate, this research is succeeded in decreasing expiration rates by 4\%, by changing the supply rate of MUM, from 40 hours of time between arrivals to be 44 hours.

1. Introduction
Blood is body fluid that has specific function to distribute oxygen, nutrition, and the remains of metabolism. For specific reasons, such as accident, postpartum haemorrhage, and specific disease will cause a person in the urgency of accessing others’ assistance to fulfill his requirement for blood. Generally, the process of blood’s intake from the donor could be performed with the conventional model (whole blood) and apheresis model (specific component).

Blood that is given by donors in Indonesia is mostly in the form of whole-blood (blood that has complete components). Following donation, whole-blood may be processed to be several components like Packed Red Cell (PRC), Platelet (TC), Fresh Frozen Plasma, and others. There is also blood donation process that only aims to get a specific blood component, like the use of apheresis method for Platelet (TC) composition transfusion.

A blood bank is an independent organization that has the authority to manage whole-blood donation and its distribution for humanitarian needs. Whole-blood supply can be grouped by the blood types and rhesus. According to the type, whole-blood can be grouped to A, B, AB, and O. When grouped by rhesus, whole-blood can be grouped into R(+) and R(-). The organization in Indonesia that is legally authorized to collect blood from donors is Indonesian Red Cross (PMI). One important indicator of blood bank performances is the accuracy in determining the blood supply. The exact determination of supplies numbers will affect the expected service level achievement and blood’s outdated rate, so collecting management is a critical point that requires careful consideration.

Blood Collecting Management is a complex process. The complexity is caused by several factors, those are: 1. The blood supply source of UDD PMI is an independent supplier with its own uncertainty and stochastic pattern. 2. The demands for blood to the blood bank also has its own uncertainty and stochastic
pattern. 3. Blood is a perishable product because it has a short shelf life. The decision uncertainty from blood bank in managing blood collection will lead to the excessive or lack of supplies.

The problem that is often faced by a blood bank is the high shortage rate and the high expiration rate of certain types of blood component. This anomaly is experienced by a blood bank when determining the inaccuracy target and supply strategy that also involves donors. This research aims to build a blood collection strategy for a blood bank by determining the blood supply composition so that shortage rate and expiration rate can be suppressed.

2. Literature Review

Blood collection management is one of the main echelons in blood supply chain that has a great impact on the blood supply chain management performance [1]. Blood collection problem is prevalent and must be solved in order to sustain blood availability [2] because such a problem may cause shortage and high expiration rates.

Managing the rate of expired blood products in a blood bank is one of the challenges in blood management in Indonesia [3]. This is caused by the high rate of supply fluctuation from donors and the uncertain blood demands. Good coordination between parties is needed to create an effective method of blood collection. The parties include those responsible for forecasting the amount of supply, those who manage blood, those distribute blood, and those who need the blood [4]. The effectiveness of blood collection procedure can be determined from the decision accuracy that can fulfil blood demands in the right time with right amount [5]. Factors that affect the performance of blood collection are the resources and the collection strategy effectiveness [6] and [7].

Early research on blood collecting strategy is done by [8], which built a forecasting model for the blood supply planning by using Markov model. The rationale of using the method is from the stochastics condition of the involved entities in the blood collection system. [9] created the blood supply planning procedure in a natural disaster condition by using a simulation. The simulation approach was also used by [10] to adjust the rate of blood supply to the apheresis donor system without considering the variation of blood age needed by hospitals. This research will present the management of blood collecting by considering supply and demand fluctuate. The current research’s novelty is that the blood supply from donors is still in the form of whole-blood and the demands are allowed blood age preference. By considering the system complexity that involved in this research, hence simulation model approach will be employed as tools in accomplishing the existing problems.

3. Problem Review

The problem that is going to be solved in this research is policy planning in a blood bank to determine the blood supply rate from donors. Blood supply model in a blood bank consists of two main schemes, which are Mobile Unit Model (MUM) and Fixed Location Model (FLM). The application of MUM is donor activity by sending blood bank’s employees to a place where the donors are gathered. Meanwhile, in FLM, donors are the ones who visit the blood bank collection. The model is illustrated in Figure 1.

![Diagram](image_url)

**Figure 1.** The illustration of Indonesia blood supply chain system

According to Fig. 1, the demands of blood come from two customer groups, which are Hospital Blood Bank (BDRS) and Non-Hospital Blood Bank (NBDRS). The differences in the demands from each
group is the blood age. BDRS needs much shorter blood type than the NBDRS. The demand from BDRS has the maximum of 7 days WB and PRC age, while the maximum age of the demands from NBDRS is 35 days.

4. The Modelling Approach
The method in this research is the discrete simulation method to determine the amount of whole-blood that is targeted from MUM donors. The consideration of using simulation in BSCM is because of its capability in modelling a complex system (Edgar Alfonso et al., 2012). The model considers the blood products queue in the inventory system before distributing them to the customers, so following [11] the appropriate model simulation is the discrete event simulation.

4.1. System Components
System components identification aims to understand the changes in the system, from the input arrival until the distribution of output. [12] and [13] stated that the elements or important components that should be taken into account to build a simulation model are entities, resources, activities, controls, and queues in the system.

An entity is the object observed in the system. An entity has dynamic characteristics because it can experience displacement, transformation, status change, and can affect and be affected by other entities in the system. The entity that is involved in this research is Whole Blood (WB), Packed Red Cell (PRC), and Platelet (TC) to all blood types (A, B, AB, O) and Rhesus (+, -).

Control Variable or decision variable is a sequence of procedures or acts to arrange how the simulation activities run. In this research, the control variable is the procedure in scheduling of blood collection from the donors in the MUM model.

4.2. Simulation Flowchart
Flow chart diagram was used as a tool to simplify the real system. This will help make it easier to build models in computer simulation. The flow chart diagram shown in figure 2.

![Simulation flow chart diagram in blood supply chain](image-url)
Research stages as illustrated in Figure. 2, could be explained as follows:

1. Donor Analysis
   The activities that covered at this stage is examining the donor behaviour (Mobile Unit Model & Fixed Location Model), so it could be identified the statistic distribution started from donor’s time between arrival and donor’s entity per arrival. The portion of donor’s blood type will be identified also at this stage.

2. Demand Analysis
   The activities that covered at this stage is observing the behaviour of blood’s demand from hospital, therefore, it could be identified statistic distribution time between arrival of demand and entity per arrival of demand. It is also could be notified the proportion of blood’s component type requested and the age of blood that tolerated by the consumers.

3. The Measurement of Shortage Rate
   The activities that covered at this stage is performing blood’s supply analysis that will be reduced with the upcoming demand. Shortage will be experienced if the demand from consumers cannot be accomplished. In this research, assumption on back order towards unfulfilled demand will be excluded.

4. The measurement of Expired Rate
   The activities that performed at this stage is identifying the undistributed numbers of blood’s component that reach its tolerated limitation of age.

5. The arrangement of collecting strategy scenario
   At this stage, alternative of actions will be carried out in managing the supplies, hence, blood supply will fulfil its minimal value of shortage and outdated.

5. Result and Discussions

5.1. Current State Model
   The current state model is built to test if the proposed model represents the current system effectively. In the current state, the researchers input some stochastic values from the system based on observation data collected in a year period in one of the blood banks in Indonesia. The uncertainty variable in the current state model is presented in Table 1.

| No | Variable Name                  | Expression                  |
|----|--------------------------------|-----------------------------|
| 1  | Time Between Arrival MUM       | 0.5 + EXPO(1.21)            |
| 2  | Entities Per Arrival MUM       | ANINT(NORM(37, 17.7))      |
| 3  | Time Between Arrival FLM       | Constant, Value: 1          |
| 4  | Entities Per Arrival FLM       | ANINT(NORM(7.88, 3.95))    |
| 5  | Time Between Arrival BDRS’s Demand | 0.5 + EXPO(0.84)        |
| 6  | Entities Per Arrival BDRS’s Demand | ANINT(0.5 + ERLA(8.75, 2)) |
| 7  | Time Between Arrival NBDRS’s Demand | 0.5 + EXPO(0.51)        |
| 8  | Entities Per Arrival NBDRS’s Demand | ANINT(NORM(6.06, 3.02))   |

EXPO in the column of expression at Table 1 refers to exponential distribution. While the word of NORM refers to normal distribution, while ERLA refers to erlang distribution. ANINT means the value of entities that is assumed in the integer number. For example, time between arrival MUM has expression 0.5 + EXPO (1.21) it means that Time between arrival at MUM has exponential distribution with mean 1.21 days.

To prove that the built model has represented the current system, a statistical test by using T-student test was conducted. Hypothesis at this test is H₀: There is no difference between simulation model with current system. H₁: There is a difference between simulation model with current system. On the 95% level of confidence with error rate tolerance of 5%, the result of t Stat is 0.97476 and the value
of t Critical two-tail is 2.178813 so the $H_0$ was not to reject. This means that the built model has represented the current system.

5.2. Scenario Design
The focus of this research is to build a scenario of the most precise number blood supply that to be targeted by a blood bank per month. The supply source uses one of the two models, which are mobile unit and fixed location. In the scenario planning, an intervention is made in the mobile unit supply. This is because the MUM behaviour is more controllable by the blood bank and it is assumed that the FL behaviour will be stable during the simulation period.

The scenario of the supply design is based on the blood bank strategy in controlling the supply from MU. In Scenario 1, the blood bank used an offensive strategy by a marketing campaign to increase the supply from MU. In Scenario 2 and 3, the blood bank party negotiated to delay the supply rate from MU. The difference in the scenarios is shown from the level of TBA. In the existing condition, the average time between arrival is 41.04 hours or 1.71 days. The scenario detail is shown in Table 2.

| Supply Source | Scenario 1 | Scenario 2 | Scenario 3 |
|---------------|------------|------------|------------|
| MUM           | 0.8 x TBA MU Existing | 1.1 x TBA MU Existing | 1.5 x TBA MU Existing |

The simulation was done in 90 days. The average and variance of the expired items in accumulation is presented in Table 3.

| Groups         | Sum | Average | Variance | Order fulfilment |
|----------------|-----|---------|----------|------------------|
| EXISTING       | 181 | 181     | 28276.89 | 0.96             |
| SCENARIO 1     | 413 | 413.7   | 36082.23 | 0.96             |
| SCENARIO 2     | 113 | 113.2   | 10056.18 | 0.95             |
| SCENARIO 3     | 148 | 14.8    | 187.2889 | 0.90             |

From the ANOVA test within the scenarios, the obtained F value is $F (15.436) > F_{crit} (2.866)$, which indicates the difference of outdated rate caused by the current condition, scenario 1, scenario 2, and scenario 3.

The blood bank requires that the tolerated number of order fulfilment is minimum of 95% from total demands. Table 4 describes the levels of shortages and order fulfilment rate from the current condition and proposed scenarios.

| Groups         | Sum  | Average | Variance | Order fulfilment |
|----------------|------|---------|----------|------------------|
| EXISTING       | 593  | 59.3    | 347.5667 | 0.96             |
| SCENARIO 1     | 547  | 54.7    | 225.1222 | 0.96             |
| SCENARIO 2     | 728  | 72.8    | 318.8444 | 0.95             |
| SCENARIO 3     | 1353 | 135.3   | 10803.12 | 0.90             |

Referring to the low expiration rate, the third scenario is the best scenario. However, if it is based on the number of fulfilment rate that is tolerated by the blood bank, scenario 3 cannot meet the specified standards.
6. Conclusion and Recommendation

The blood collection strategy gives impacts on the number of expired blood bags in the blood bank inventory system. The effort to decrease an outdated rate should consider the shortage caused by inventory reduction. In the order fulfillment target of 95%, the best scenario to reduce expiration is scenario 2 that lessens the expiration rate by 4% (the average of outdated rate on current system is 181 blood bags, while on the result of proposed scenario 2, the average of outdated rate decreases to 113 blood bags). To implement the scenario 2, the blood bank should regulate the campaign intensity in executing the donor activity for mobile unit model. So, activity of MUM is recommended as every 45,1 hours or 1,88 days.

This research’s limitation is that it only involves supply arrangement from MUM. Recommendation for further research is to decrease the expiration rate by is considering the production composition from the blood bank, the inventory target policies, and the inventory cost calculation in ordering and storing products.

7. References

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