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Stochastic Integer Programming Models in the Management of the Blood Supply Chain: A Case Study

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Abstract: This paper presents a problem in the management of the blood supply chain at the blood banks with perishability characteristics, especially for the red blood cells and platelets. Focus of this discussion is to minimize the total cost, shortage and wastage levels of the blood unit. Stochastic integer programming approach is used to solve this problem by assuming the blood group and taking into account the age of the blood. At the end of this study we give a simulation to see the result of applying the method in this issue.

Keywords: Supply Chain Management, Blood Banks, Perishable Items, Stochastic Integer Programming

1. Introduction

Blood, the most important component of the body's transportation systems, is a liquid that carries nutrients and oxygen to all organs of the body. Blood is categorized as a scarce resources because its usage age is limited. From Health Media [15] is known that the red blood cells function to move oxygen to our cells, platelets function to relate to the process of coagulation and white blood cells function to keep the body immune system and defend the body against bacteria or viruses. Plasma is a liquid component substance such as albumin, blood clotting, hormones, various proteins and salts. If there is a shortage blood then the need for nutrients and oxygen is not satisfied and this will lead to death. Blood transfusion is the process of moving blood from a person to a person in need of blood. The blood inventory in Indonesian is currently managed by the Indonesian Red Cross (*PMI*).

PMI is a national society organization in the social field of humanity which has been recognized nationally with the Presidential Decree no. 25 of 1959 from the Indonesian Red Cross [16]. The main task of *PMI* itself is regulated in Government Regulation no. 18/1980 Chapter IV, section 6, paragraph (1): "The management and execution of blood transfusion business is assigned to *PMI* or an institution assigned by the Minister of Health". Blood processing is performed by the Blood Transfusion Unit (*UTD*), one of this is *PMI UTD* City of Pekanbaru.

Blood input that goes into the blood inventory at *PMI UTD* City of Pekanbaru comes from local *UTD* (independent) production and shipped from other *UTDs*. Whereas the blood output is supplied to the Hospital Blood Bank (*BDRS*), Non-*BDRS* and other *UTDs*. *BDRS* function as a facility to make patients easier to get blood without passing *PMI*. While non-*BDRS* have a different function with *BDRS*, Non-*BDRS* is a hospital that does not have blood banks. *BDRS* determines the level of the optimal supply of all blood components based on discrete simulation in the *BDRS* against stochastic demand and the occurrence of damage (wastage) of blood that may occur in the research of Katsaliaki and Brailsford [11].

Pierskalla [13] states that the duty of *BDRS* is as a manager of the blood collection, crossmatching processes, blood supply management and distribution of blood components by ensuring the blood supply chain and the demand for blood is fulfilled. Nagurney et al. [12] analyze the complex supply chain of human blood consisting of collection sites, testing and processing facilities, storage facilities, distribution centers, as well as demand points, age of the blood storage and calculation of the remaining storage life when the blood units are returned to *BDRS*. In this study they also show that one person in every three seconds across the country may want to receive the blood transfusion.

The demand for the blood continues to rise stochastically and has limited number. On the other hand, Belien and Force [1] mention that the majority only 5% from the citizen population having eligible condition to do blood donor. This also raises the lack of the blood supply to fulfill the needs of the patient. According to the World Health Organization (WHO) the minimum blood supply in each country is 2% of the total residents everyday. Arising problems in the blood supply chain increase complexly because of the perishable characteristics of the blood that has a limited usage for use. Especially platelets are highly perishable since they can only be stored up to 5 days with storage temperatures of 22°–24°C and red blood cells up to 35 days with storage temperatures of 2°–6°C on inventory. Therefore, everyday there are always two possibilities, i.e., shortages stock of blood (stock out) or excess stock of blood (over stock) in the inventory. Excess blood stock can also cause blood become damaged (wastage) if it has outdate the age limit of its use.

Belien and Force [1] reports that the several studies have been done to find solutions to the blood supply chain problem. Such as discrete event simulation, Monte Carlo simulation, statistical analysis (linear regression, survival analysis, logistic regression and ANOVA) and in operations research (integer programming, linear programming and stochastic dynamic programming). There are four main actors in the blood supply chain, i.e., donors, blood banks, hospitals and patients. The supply chain of the blood is highly dependent on the number of donors who will donate the blood. Prastacos [14] explained that efforts in blood donors need to be supported by the calculation of the average availability of blood donors and predict the quantity of the blood supply or the blood demand.

Haijema et al. [7] use a dynamic stochastic programming model and a simulation model at the blood banks in the Netherlands for production and the management platelets of the blood supply with the assumption of the production cost factor of platelets. Hemmelmayr et al. [8] develop the integer programming models to decide which hospitals a vendor (through the vehicles from the blood centers) should visit each day given that the routes are fixed for each region. Ghandforoush and Sen [5] they formulate a nonlinear integer programming model to determine the minimum cost of platelets production schedule for the regional blood center. The initial formulation carries a non-convex objective function that is difficult to solve and would not guarantee convergence to optimality. As both the objective function and constraints of the revised formulation include quadratic terms, a two-step transformation linear 0-1 integer alternative is the proposed to guarantee the optimality.

Gunpinar and Centeno [6] use stochastic integer programming model to reduce wastages and shortages of the blood in the hospital with the assumption of the blood age, blood demand for two types of patients: Type-1 patients is the only patient who needs new blood in blood transfusion while patients Type-2 is a patient who needs old blood or new blood within blood transfusion as well as using a crossmatching transfusion ratio for one blood bank and one hospital. In addition, the deterministic model is included in the model and the blood used is the blood that is quickly damaged such as red blood cells and platelets in general without considering the blood group. There are 3 model formulations in their research, among others are the stochastic integer programming model, stochastic integer programming model with two patient types and deterministic integer programming model with crossmatch-to-transfusion (C/T) ratio and crossmatch release period.

Based on the background of the issues described and the importance management of the blood supply chain it needs to do research on the management of the blood supply chain for the better supply and stock management. Therefore, in this study the authors attemp to develop stochastic integer programming model in the management of the blood supply chain In Gunpinar and Centeno [6]. In this proposed method the assumtion of blood groups for a blood bank is added and the other related assumption are taken into account to reduce the occurrence (wastage) and shortages of blood. In this article, authors only discuss the first formulation model of stochastic integer programming of Gunpinar and Centeno [6] by taking into account the blood group with the data obtained from *PMI UTD* City of Pekanbaru for the year 2017. For the calculations we use LINGO 16 and Microsoft Excel 2010 program applications with four demand scenarios for the year 2017.

In section 2, the authors present the model development for solving the problem of blood supply chain in *PMI UTD* City of Pekanbaru. Then, section 3 presents the computational results of the application of the proposed model development and the section 4 presents conclusion.

2. Proposed Methods

In this section the authors develop the models of Gunpinar and Centeno [6] by considering the blood group. This constraint assures that the demand for blood in the hospital more efficient and can prevent the occurrence of risks and errors in the delivery and blood transfusion into patients with certain types of blood groups. It also makes the distribution of blood demand from *PMI UTD* City of Pekanbaru to the hospital easier. With this blood group assumtion it is more ensure the safety of blood transfusion and minimize errors in blood transfusions in patients.

Blood groups used in this blood supply chain model is a blood group substance such as: A, B, O and AB without crossmatching because the blood being delivered by *PMI UTD* City of Pekanbaru is the blood that has been determined directly by hospitals to transfus in to patients and the process of crossmatching has been done by hospital blood bank (*BDRS*).

BDRS takes the blood to *PMI UTD* City of Pekanbaru in accordance with type and blood groups requests required by the patient and the *UTD PMI* Pekanbaru city never receives a return of the blood from *BDRS*. Below, it is given the assumptions of the stochastic integer programming model and notations of the development of stochastic integer programming models in the management of blood supply chain that has been developed in accordance with notation in Gunpinar and Centeno [6] and those used in blood supply chain models.

1. The following assumptions are made in accordance with the model of Gunpinar and Centeno [6] and used by authors in development of stochastic integer programming model in the management of blood supply chain:
   a. The capacity of the blood center is limited.
   b. Lead times for the blood supply are zero. In other words, the hospital orders for the blood products are fulfilled in no time.
   c. The age of the blood units received from the blood center is known and the varies over time.
   d. The lifetime of the platelets is limited to five days including two days of testing.
   e. The lifetime of the red blood cells is limited to thirty five days including two days of testing.
   f. General blood issuing policy for the hospital is FIFO where the oldest units on inventory are issued first when the blood units are requested by physicians for the patient needs.
   g. If the demand is not satisfied due to the unavailability of the blood units, a shortage cost is incurred.
   h. If the blood unit expires, a wastage cost is incurred associated with discarding the blood units.
2. The following notations are used for development of stochastic integer programming model in the management of the blood supply chain for a blood bank and a hospital consisting of the addition of assumptions blood group, the indices used in the model, the parameters used in the model as well as decision variables used in model developed by authors in the blood management.
   a. The addition of blood group assumptions in notation follows:

$$f_n = \text{Blood group } n,$$

where n denotes the number of the blood group starting with $n = 1$ to $n = 4$ and is given by

Table 1. *Blood Group for Models.*

Blood group	A	B	O	AB
n	1	2	3	4

   b. Indices used in the development of stochastic integer programming model in the management of blood supply chain for a blood bank and a hospital are as follows:

Table 2. *Indices for Models.*

s	Demand scenario, $s = 1, 2, \dots, S$
i	Age of blood, $i = 1, 2, \dots, I$
t	Time period, $t = 1, 2, \dots, T$

   c. Parameters used in this model are as follows:

Table 3. *Parameters for Models.*

S	Number of scenarios
I	Lifetime of blood product
T	Length of planning
b	Unit shortage cost of blood at the hospital
c	Unit purchasing cost of blood at the hospital
h	Unit holding cost of blood at the hospital
M	Big M (Big Number)
p_s	Probability of scenario s, $\sum_{s=1}^{S} p_s = 1$
w	Unit wastage cost of blood at the hospital
θ_{itf_n}	Proportion of i days old blood group f_n in blood shipments from blood bank in time period t, $0 \le \theta_{itf_n} \le 1$, $\sum_{i=3}^{I} \theta_{itf_n} = 1$
$d_{tf_n}^{s}$	Blood demand group f_n at the hospital in time t (for scenario s)
CAP_{tf_n}	Capacity of the blood bank group f_n distribution to the hospital in time period t

   d. Decision variables are also used in this model are as follows:

Table 4. *Decision Variables for Models.*

$m_{itf_n}^{s}$	Auxiliary variable (safety stock) associated with age class i group f_n in time t for scenario s
$r_{tf_n}^{s}$	Number of blood shortage group f_n at the end of time t for scenario s at the hospital
$u_{tf_n}^{s}$	Number of blood wastage group f_n at the end of time t for scenario s at the hospital
$v_{itf_n}^{s}$	Inventory level of i days old blood group f_n at the end of time t for scenario s at the hospital
x_{tf_n}	Number of blood blood group f_n ordered by the hospital from the blood bank at the beginning of time t
y_{itf_n}	Number of i days old blood blood group f_n received by the hospital at the beginning time t
$z_{itf_n}^{s}$	1 if i days old blood blood group f_n used to satisfy the demand in time period t for scenario s, 0 otherwise

The following describes the purpose function and all the functional constraints that exist with addition of blood group constraints. The purpose function in this case is as follows:

$$\min z = \sum_{n=1}^{4}\sum_{t=1}^{T} c\, x_{tf_n} + p_s \left(\sum_{n=1}^{4}\sum_{s=1}^{S}\sum_{i=3}^{I}\sum_{t=1}^{T} h\, v_{itf_n}^{s} + \sum_{n=1}^{4}\sum_{s=1}^{S}\sum_{t=1}^{T} w\, u_{tf_n}^{s} + \sum_{n=1}^{4}\sum_{s=1}^{S}\sum_{t=1}^{T} b\, r_{tf_n}^{s} \right) \quad (1)$$

The formulations of the constraints with the addition of blood groups are given as follows:

a. The demand of each blood group (f_n) to be achieved at hospital is less than the blood capacity at the blood bank at the same time with time t, with $t = 1, 2, 3, \dots, T$ and $n = \{1, 2, 3, 4\}$. The model is given by

$$\sum_{n=1}^{4} x_{tf_n} \le CAP_{tf_n}, \quad \forall t \quad (2)$$

b. Hospitals never receive any units of blood group (f_n) in one or two days old from the blood bank because two days is the time which is required in testing after blood is collected. The model is as follows:

$$y_{itf_n} = 0,\ i = 1,2,\ldots,\ \forall t,n \quad (3)$$

c. Satisfing the allocation of each blood group (f_n) should be achieved in each age class. The model is given by

$$y_{itf_n} = x_{tf_n}\ \theta_{itf_n},\ i = 3,4,\ldots,\ \forall t,n \quad (4)$$

d. Satisfing the policy rules used by blood bank for each blood group (f_n) is defined by FIFO. The model is as follows:

$$z^s_{itf_n} \ge z^s_{(i-1)tf_n},\ i = 3,4,\ldots,\ \forall s,t,n \quad (5)$$

e. Satisfing the demand for each blood group (f_n) must be reached at the hospital. If the shortage occurs safety stock is use to satisfing the demand. While there is still some residual stock and at least only one class has an inventory amount non-zero. The model is as follows:

$$d^s_{tf_n} = \sum_{i=3}^{I}\left(\left(v^s_{(i-1)(t-1)f_n} + y_{itf_n}\right) z^s_{itf_n} - m^s_{itf_n}\right) + r^s_{tf_n},\ \forall s,t,n \quad (6)$$

f. There is safety stock of each blood group (f_n) that should be achieved as a substitute if there is a shortage of blood from the other stock inventories and does not exceed existing inventories. The model is given by

$$\left(z^s_{itf_n} - z^s_{(i-1)tf_n}\right)\left(v^s_{(i-1)(t-1)f_n} + y_{itf_n}\right) \ge m^s_{itf_n} \quad (7)$$

where

$$i = 3,4,\ldots,I,\ \forall s,t,n$$

g. Blood unit for each blood group (f_n) aged two day is not used to satisfy the demand for blood in the Hospital. In other words, only blood that has an age of more than two days received by the hospital. The model is given by

$$z^s_{2tf_n} = 0,\ \forall s,t,n \quad (8)$$

h. The number of shortage for each blood group (f_n) is not known. The model is given by

$$d^s_{tf_n} - \sum_{i=3}^{I}\left(v^s_{(i-1)(t-1)f_n} + y_{itf_n}\right) \le r^s_{tf_n},\ \forall s,t,n \quad (9)$$

i. Last update of supply period for each blood group (f_n) in each age class can be known in number. The model is given by

$$v^s_{itf_n} = \left(1 - z^s_{itf_n}\right)\left(v^s_{(i-1)(t-1)f_n} + y_{itf_n}\right) + \left(z^s_{itf_n} - z^s_{(i-1)tf_n}\right) m^s_{itf_n} \quad (10)$$

where

$$i = 3,4,\ldots,I,\ \forall s,t,n$$

j. Guarantee that the old blood for each two-day-old blood group (f_n) is never available on inventory. The model is as follows:

$$v^s_{(2)tf_n} = 0,\ \forall s,t,n \quad (11)$$

k. There is no inventory for each blood group (f_n) at the beginning of time period of analysis. The model is given by

$$v^s_{i(0)f_n} = 0,\ \forall s,i,n \quad (12)$$

l. The wastage rate for each blood group (f_n) in the hospital at the end of the period can be analyzed. The model is as follows:

$$u^s_{tf_n} = v^s_{(I)tf_n},\ \forall s,t,n \quad (13)$$

m. The other constraints associated with this model are as follows:

$$x_{tf_n} \in Z^+,\ \forall t,n \quad (14)$$

$$r^s_{tf_n}, u^s_{tf_n} \in Z^+,\ \forall s,t,n \quad (15)$$

$$y_{itf_n} \in Z^+,\ \forall i,t,n \quad (16)$$

$$m^s_{itf_n}, v^s_{itf_n} \in Z^+,\ \forall s,i,t,n \quad (17)$$

$$z^s_{itf_n} \in Z^+,\ \forall s,i,t,n \quad (18)$$

Constraints (14)-(17) are non-negative discrete variables used in the model and constraint (18) is a binary variable. Because the interaction between binary variables and discrete variables in constraints (6), (7) and (10) are nonlinear, then the technique of linearization of Gunpinar and Centeno [6] is used to linearize this three constraints. Below is a tecnique of linearization used with the development stochastic integer programming model in the management of blood supply chain:

$$z^s_{itf_n}\ v^s_{(i-1)(t-1)f_n} = \gamma^s_{itf_n},\ i = 3,4,\ldots,I,\ \forall s,t,n$$

$$\gamma^s_{itf_n} \le z^s_{itf_n}\ M,\ i = 3,4,\ldots,I,\ \forall s,t,n \quad (19)$$

$$\gamma^s_{itf_n} \le v^s_{(i-1)(t-1)f_n},\ i = 3,4,\ldots,I,\ \forall s,t,n \quad (20)$$

$$\gamma^s_{itf_n} \ge M\left(z^s_{itf_n} - 1\right) + v^s_{(i-1)(t-1)f_n} \quad (21)$$

$$i = 3,4,\ldots,I,\ \forall s,t,n$$

$$z^s_{itf_n}\ y_{itf_n} = \alpha^s_{itf_n},\ i = 3,4,\ldots,I,\ \forall s,t,n$$

$$\alpha^s_{itf_n} \le z^s_{itf_n}\ M,\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{22}$$

$$\alpha^s_{itf_n} \le y_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{23}$$

$$\alpha^s_{itf_n} \ge M\ \left(z^s_{itf_n}-1\right)+\ y_{itf_n}, \tag{24}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$z^s_{itf_n}\ m^s_{itf_n} = \lambda^s_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$\lambda^s_{itf_n} \le z^s_{itf_n}\ M,\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{25}$$

$$\lambda^s_{itf_n} \le m^s_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{26}$$

$$\lambda^s_{itf_n} \ge M\ \left(z^s_{itf_n}-1\right)+\ m^s_{itf_n}, \tag{27}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$z^s_{(i-1)tf_n}\ m^s_{itf_n} = \delta^s_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$\delta^s_{itf_n} \le z^s_{(i-1)tf_n}\ M,\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{28}$$

$$\delta^s_{itf_n} \le m^s_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{29}$$

$$\delta^s_{itf_n} \ge M\ \left(z^s_{(i-1)tf_n}-1\right)+\ m^s_{itf_n}, \tag{30}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$z^s_{(i-1)tf_n}\ y_{itf_n} = \psi^s_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$\psi^s_{itf_n} \le z^s_{(i-1)tf_n}\ M,\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{31}$$

$$\psi^s_{itf_n} \le y_{itf_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{32}$$

$$\psi^s_{itf_n} \ge M\ \left(z^s_{(i-1)tf_n}-1\right)+\ y_{itf_n}, \tag{33}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$z^s_{(i-1)tf_n}\ v^s_{(i-1)(t-1)f_n} = \mu^s_{(i-1)tf_n},\ i=3,4,\ldots,I,\ \forall s,t,n$$

$$\mu^s_{(i-1)tf_n} \le z^s_{(i-1)tf_n}\ M,\ i=3,4,\ldots,I,\ \forall s,t,n \tag{34}$$

$$\mu^s_{(i-1)tf_n} \le v^s_{(i-1)(t-1)f_n},\ i=3,4,\ldots,I,\ \ \forall s,t,n \tag{35}$$

$$\mu^s_{(i-1)tf_n} \ge M\ \left(z^s_{(i-1)tf_n}-1\right)+v^s_{(i-1)(t-1)f_n}, \tag{36}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$\gamma^s_{itf_n},\ \alpha^s_{itf_n},\ \psi^s_{itf_n},\ \mu^s_{(i-1)tf_n} \in Z^+ \tag{37}$$

$$\lambda^s_{itf_n},\ \delta^s_{itf_n} \in Z^+ \tag{38}$$

After the first linearization technique is applied, variables in constraints (6), (7) and (10) are replacedby the following corresponding linearization variables:

$$d^s_{tf_n} = \sum_{i=3}^{I}\left(\gamma^s_{itf_n}+\alpha^s_{itf_n}-m^s_{itf_n}\right)+r^s_{tf_n},\ \ \forall s,t,n \tag{39}$$

$$\gamma^s_{itf_n}+\alpha^s_{itf_n}-\mu^s_{(i-1)tf_n}-\psi^s_{itf_n} \ge m^s_{itf_n} \tag{40}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

$$v^s_{itf_n} = v^s_{(i-1)(t-1)f_n}+y_{itf_n}-\gamma^s_{itf_n}-\alpha^s_{itf_n}+\lambda^s_{itf_n}-\delta^s_{itf_n} \tag{41}$$

$$i=3,4,\ldots,I,\ \ \forall s,t,n$$

3. Computational Results

The results of the computation show that this optimization model can be used in *PMI* especially in *PMI UTD* City of Pekanbaru. For the implementation, the authors provide the blood platelets calculation for the data in February 2017 by assuming four demand scenarios. The four demand scenarios are as follows: in January, February, March and April.

The probability for each scenario are set to 0.2, 0.1, 0.3 and 0.4 with the scenario taken by the cause factor of the demand mainly by hematology, oncology, traumatology and general surgery in year 2017. In current practice, the agregated of the demand modeled is almost Poisson. This assumption are also justified by the results in Haijema et. al [7] and Gunpinar and Centeno [6] research in wich this demand distinction are taken into the account. Here is the simulation computation example, provided by Table 5 presenting the platelets blood production for 14 days in February 2017:

Table 5. *Platelets Blood Production February 2017.*

No	Date	Blood group				No.	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	20*	5	16	1	8	8	6	7	11	3
2	2	26	3	27	1	9	9	5	9	19	4
3	3	38	9	14	3	10	10	46	9	17	1
4	4	15	15	16	11	11	11	13	17	19	9
5	5	4	7	23	4	12	12	19	13	31	4
6	6	14	11	19	2	13	13	12	10	16	10
7	7	6	8	16	2	14	14	15	1	18	6

Besides that, Table 6 gives the request from a hospital which became one place of distribution of platelets for 14 days in

February. The demand on the first and the second days is zero. This is according to constrain (3) that a hospital never receive any unit of blood group in one or two days old.

Table 6. *Platelets Blood Demand February 2017.*

No	Date	Blood group				No	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	0	0	0	0	8	8	13	0	25	2
2	2	0	0	0	0	9	9	5	0	8	0
3	3	8*	0	34	1	10	10	0	9	13	0
4	4	15	1	12	1	11	11	3	10	20	3
5	5	44	10	10	0	12	12	22	5	4	0
6	6	0	0	22	0	13	13	13	5	3	4
7	7	0	7	5	2	14	14	10	8	16	0

This calculation also gives the damage data of wastage of the blood in February 2017 at *PMI UTD* City of Pekanbaru. Table 7 presents the wastage of the blood.

Table 7. *Platelets Blood Wastage February 2017.*

No.	Date	Blood group				No.	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	1*	0	0	0	8	8	1	1	2	0
2	2	2	2	2	0	9	9	2	2	3	0
3	3	2	1	0	1	10	10	2	1	1	1
4	4	1	3	4	1	11	11	1	1	4	0
5	5	3	1	3	0	12	12	3	2	3	0
6	6	2	2	2	0	13	13	2	2	3	0
7	7	1	1	4	0	14	14	1	1	1	1

In addition, calculation for the data of the new blood stock in February 2017 is generated by a subtraction from Table 5 and Table 7. For example: date 1 in Table 8 blood type A is 19 units, this value is got from the date 1 in Table 5 blood type A and date 1 in Table 3 Blood type A, for example: 20 – 1 = 19 units. If this counting is continued it would be obtained Table 8 presenting the new blood stock.

Table 8. *New Blood Platelets Stock February 2017.*

No	Date	Blood group				No	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	19*	5	16	1	8	8	5	6	9	3
2	2	24*	1	25	1	9	9	3	7	16	4
3	3	36	8	14	2	10	10	44	8	16	0
4	4	14	12	12	10	11	11	12	16	15	9
5	5	1	6	20	4	12	12	16	11	28	4
6	6	12	9	17	2	13	13	10	8	13	10
7	7	5	7	12	2	14	14	14	0	17	5

Furthermore, the calculation for the management of the blood supply chain for a blood bank and a hospital also gives the old blood for 14 days. Table 9 presents the old blood platelet stock for 14 days in February 2017.

Table 9. *Old Blood Platelets Stock February 2017.*

No	Date	Blood group				No	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	0	0	0	0	8	8	30	23	35	16
2	2	0	0	0	0	9	9	22	30	22	16
3	3	19*	5	16	1	10	10	22	36	23	19
4	4	35*	6	25	1	11	11	25	34	26	23
5	5	56	13	27	2	12	12	58	32	22	9
6	6	26	15	29	12	13	13	48	43	33	18
7	7	27	21	27	16	14	14	41	49	58	18

Table 9 is generated by adding each cell in Table 8 and Table 10 at the end of each time period. For example: date 3 in Table 9 blood type A is 19 units, this value is got from Table 8 in date 1 blood type A according to constraint (4). This is due to the age of the blood type A in date 1 in Table 8 has been 3 days old in Table 9 and this blood can be used for transfusion. Now, continued to date 4 in Table 9 with 35 units, this value is got from date 2 in Table 8 and date 3 in Table 10 for blood type A, for example: 24 + 11 = 3. This is due to the age of blood type A in date 2 Table 8 has 3 days old in Table 9 and this blood can be used to transfusion. If this counting is continued it would be obtained that the Table 9 and Table 10.

In the Table 9, shows that the values for the first and the second days there is no old blood stock for each blood group. This is according to constraint (11). Table 10 presents the blood invetory levels at *PMI UTD* City of Pekanbaru.

Table 10. *Blood Platelets Inventory Levels February 2017.*

No	Date	Blood group				No	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	0	0	0	0	8	8	17	23	10	14
2	2	0	0	0	0	9	9	17	30	14	16
3	3	11*	5	0	0	10	10	22	27	10	19
4	4	20	5	13	0	11	11	14	24	6	9
5	5	12	3	17	2	12	12	36	27	18	9
6	6	26	15	7	12	13	13	25	38	30	14
7	7	27	14	22	14	14	14	31	41	42	18

Then, Table 10 is generated by reduction each cell in Table 9 and Table 6 at the end of each time period. In this calculation obtained in the first and the second days there is no inventory at the beginning of the corresponding analysis period according to constraint (12). For example: date 3 in Table 10 is 11 units, this value is got from date 3 in Table 9 and date 3 in Table 6 this is for blood type A, for example: 19 - 8 = 11. Then, continue this counting until it would be obtained that the Table 10 for each blood group.

In the calculation of the model there is a shortage of the blood at *PMI UTD* City of Pekanbaru. That is 18 units for blood type O on the third day. It is cause the demand of the blood more than the inventory levels. This also gives in the Table 11 presents the blood shortages.

Table 11. *Blood Shortage Stock February 2017.*

No	Date	Blood group				No	Date	Blood group			
		A	B	O	AB			A	B	O	AB
1	1	0	0	0	0	8	8	0	0	0	0
2	2	0	0	0	0	9	9	0	0	0	0
3	3	0	0	18	0	10	10	0	0	18	0
4	4	0	0	0	0	11	11	0	0	0	0
5	5	0	0	0	0	12	12	0	0	0	0
6	6	0	0	0	0	13	13	0	0	0	0
7	7	0	0	0	0	14	14	0	0	0	0

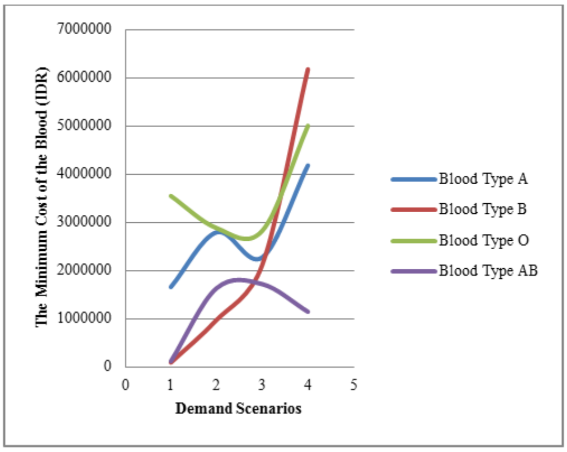

Figure 1. *Cost Analysis Using the Demand Scenarios of Blood.*

The minimum cost for each blood group occurs on the seventh day for blood type A, third day for type B, twelfth day for type O and the fifth day for the type AB. Based from the calculations, shows that the average of the blood demand at *PMI UTD* City of Pekanbaru is 3 days old satisfing of the request of the blood transfusion. This minimum cost for each blood group occurs for using four demand scenarios.

Table 12 presents the four demand scenario analysis objective functions of the optimal values under the different demand scenarios according to equation (1) in Indonesian money (IDR).

Figure 1 shows the graph of the cost analysis of the objective functions the optimal values under the different demand scenarios.

Table 12. *Cost Analysis Using the Demand Scenarios 2017.*

No	Scenario	The minimum cost of the blood (IDR)			
		A	B	O	AB
1	1	1656000	90000	3546000	116000
2	2	2793000	973000	2880000	1631000
3	3	2271000	2114000	2823000	1718000
4	4	4180000	6172000	5000000	1144000

4. Conclusion

Based on the background of the issues described before, the authors conclud that the result from blood Supply Chain Management (*MRS*) with the use of the stochastic integer programming can reduce blood wastage and blood shortage stock at a blood bank and a hospital. *MRS* could be the rigth model to increase the blood distribution process as *MRS* can make the blood bank (*PMI*) easy to manage the blood supply chain well, so that the blood distribution process becomes more efficient and effective.

PMI UTD City of Pekanbaru is the place chosen by the author to conduct the research, with data obtained from *PMI UTD* City of Pekanbaru for the Year 2017 with 4 scenarios and LINGO 16 program to obtain the calculation results. In the calculation implement this model can further reduce the wastage or shortage of the blood in the hospital and in the blood banks.

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