

## Modified allocation capacitated planning model in blood supply chain management

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**Abstract.** Blood supply chain management (BSCM) is a complex process management that involves many cooperating stakeholders. BSCM involves four echelon processes, which are blood collection or procurement, production, inventory, and distribution. This research develops an optimization model of blood distribution planning. The efficiency of decentralization and centralization policies in a blood distribution chain are compared, by optimizing the amount of blood delivered from a blood center to a blood bank. This model is developed based on allocation problem of capacitated planning model. At the first stage, the capacity and the cost of transportation are considered to create an initial capacitated planning model. Then, the inventory holding and shortage costs are added to the model. These additional parameters of inventory costs lead the model to be more realistic and accurate.

### 1. Introduction

Blood management has been considered critical in these past years, resulting in the emergence of blood center as a specialized organization for blood management. The blood center regulates and manages the blood distribution from the donors to hospitals. "One size does not fit all" is an apt description for blood management, since the problems and challenges are uniquely entitled to each country. This indicates that the blood management system in each country requires to be adjusted and customized based on the characteristics of the corresponding country [1][2][3][4][5]. One of the challenges in synchronizing supply and demand of blood management is the difficulties in determining the exact number of demand and accessible supply. This is because the procurement mechanism of blood supply is conducted through volunteering act and unpredictable demand [6]. Meanwhile, blood is a perishable product as the useful lifetime is limited. As a result, when blood passed a certain period of time it becomes unsafe to use and turn to waste [7]. The expired blood will cause a large amount of cost for procurement and processing unit, and also extra expenditure for blood waste disposal [8].

The main risks in blood management are the supply stockout problem and an abundant amount of outdated blood. Blood supply stockout could lead to mortality risk for untreated patients in emergency need of blood. The supply stockout will also lead to the high cost of a sudden blood procurement, since there are costly operational actions to be taken, such as bring in the blood supply from another institution when the shortage occurs. An intensive effort to cover blood stockout will add transportation cost and other extra costs [9]. This is the main reason why blood management is more than just maintaining the availability of blood stock, but also creating efficiency in the blood management operational. Hence,



management distribution and other things related to whole cost minimization in blood stock procurement are essential [5].

Blood supply chain (BSC) consists of four stages or echelons. First stage is collection in which the blood is collected from donors. The second phase is production, where blood processed using various process into each product types. The third stage is inventory, which represents special storage in blood centers or hospitals. Then, the distribution echelon, which reflects blood transported to hospitals, so that the transfusion for patients could be conducted [10][7][11], the challenges that are needed to overcome is determining the amount of blood stock to be transported and distribution route from blood processing unit to hospitals. The precision of blood stock, punctuality, and minimum cost become three main consideration for distribution management [12][1][13][14].

This research aims to developed distribution blood model, hence, it can minimize the allocation cost, decrease the stock out and expired date risk. A contribution given from this research is the development of allocation capacitated planning model by consider the variable which affects the blood management.

## 2. Literature Review

Blood supply chain (BSC) become essentials since blood is a highly valued commodity. It has a strict safety regulation, bear in mind that perishable characteristic of blood could play a big part in patients' health, and its tendency of enlarging the gap between a number of donors with the blood demands [15]. The effective supply chain in blood management is expected to optimize the number of blood stock, as a result, creating balance and match between supply and demand. In order to support this purpose, precise production planning system should match the blood procurement scheduling through blood donor activities [16]. Guaranteeing the balance between demand and supply in blood supply chain is a critical factor to be noticed. It needs good coordination to the supply source (vendor) in order to lower blood supply chain risk. Since the early step of the supply chain, coordination should have been planned by reinforcing the importance of it to all stakeholder, including the vendor, so that the scheduling could have done right [5].

The distribution activities can happen between blood centers, or from blood center to hospital blood bank. Good distribution management will ensure short lead time and minimum cost. In the strategic level, distribution policies include vehicle type selection, capacities and staff number involved in the activities. While at operational level, the decision is focused on transported blood stock, picking point, and time constraint.

Hosseinifard & Abbasi **Error! Reference source not found.** have attempted to compare decentralization system to centralization system effectivity in distribution chain from blood centers to hospitals. The scenario, in this case, is that the hospitals which were located in close proximity were asked to conduct collaborative planning and ordering (collaboration and sharing information), by assuming that all orders could be fulfilled by blood center. As a result, centralized model is deemed to fit this scenario more, by implementing the system that the hospital with the most strategical position is appointed to be the blood bank for other hospital coalition members. Yet, this research only focused on blood inventory number and have not considered the efficiency nor distribution cost.

Allocation capacitated planning is planning model that will allocate a number of the source with certain capacities to a number of the consumer with certain demand level, where its purpose is minimizing production distribution cost from the source to destination [17]. Allocation capacitated planning is modelled by Chopra & Meindl [18] as follow:

$$\text{Min} \sum_{i=1}^n \left[ f_i Y_i + \sum_{j=1}^m c_{ij} X_{ij} \right] \quad (1)$$

Subject to:

$$\sum_{i=1}^n X_{ij} = D_j \quad \forall j \quad (2)$$

$$\sum_{j=1}^m X_{ij} \leq K_i y_i \quad \forall i \quad (3)$$

$$y_i \in \{0,1\} \quad (4)$$

The above model has the objective to minimize the costs of allocation of a number of products from multiple sources to multiple destinations with which based on fixed costs for production and shipping costs, the assumptions used in inventory carrying costs are ignored and all requests can be met. Where in case of blood management, the model can be explained as follows.

$X_{ijl}$  = number of blood bag  $l$  to be transported from PMI  $i$  to Hospital Blood Bank (BDRS)  $j$

$Y_i$  = the value will be equal to 1 if PMI  $i$  is chosen and 0 if it is not chosen.

The parameters could be defined as follows.

$i$  = index for PMI

$j$  = index for Hospital Blood Bank (Bank Darah Rumah Sakit/BDRS)

$l$  = index for blood bag

$D_j$  = demand per period from BDRS  $j$ .

$K_i$  = blood capacity that is available to be supplied by PMI  $i$ .

$F_i$  = fixed cost for PMI  $i$  operational.

$C_{ijl}$  = production and distribution cost for 1 blood bag  $l$  in PMI  $i$  to BDRS  $j$ .

### 3. Proposed Model

This research is the development of Chopra & Meindl [18] model, where there is a consideration that the initial model has not been able to accommodate the decreasing a value of perishable products and the penalty when the products are out of stock. Whereas both matters are important to notice in blood management.

Centralization and decentralization model were studied in this research because both model already implemented in many countries. Differences of both models are related to the planning system, production and distribution. However, the focus of this research is in distribution management.

#### 3.1. Decentralization Model

Blood management in Indonesia officially conducted under authorization of Palang Merah Indonesia (PMI). This model giving an opportunity to each independent PMI to distribute blood bags for several hospitals. The function of the modified model could be formulated as decentralization model, as follows:

$$\text{Min} \sum_{i=1}^n \left[ \sum_{l=1}^4 \sum_{t=1}^5 f_{ilt} Y_{ilt} + \sum_{j=1}^m \sum_{l=1}^4 \sum_{t=1}^5 c_{ijlt} X_{ijlt} + \sum_{l=1}^4 \left( \sum_{t=1}^5 U_{ilt} H_{ilt} + Z_{ilt} S_{ilt} \right) \right] \quad (5)$$

Subject to:

$$\sum_{i=1}^n X_{ijlt} = D_{jlt} \quad \forall j, l, t \quad (6)$$

$$\sum_{j=1}^4 X_{ijlt} \leq K_{ilt} Y_{ilt} \quad \forall i, l, t \quad (7)$$

$$S_{ilt} = \begin{cases} 0, & \text{if } X_{ijlt} > D_{jlt} \\ X_{ijlt} - D_{jlt}, & \text{if } X_{ijlt} \leq D_{jlt} \end{cases}, \quad \forall i \quad (8)$$

$$H_{ijlt} = X_{ijlt} - D_{jlt}, \quad \forall i \quad (9)$$

$$Y_{ilt} \in \{0,1\} \quad (10)$$

$$X_{ijlt} \text{ integer} \quad (11)$$

This model represents the decentralized system. This is because of each PMI has impartial decentralization which expects more opportunity to provide supply the same to the hospital, so that a solution will be chosen based on the minimal cost of each hospital.

### 3.2 Centralized Model

The next model is developed with a centralized model, where certain PMI will serve as a central storage of blood from another PMI and distribution will be done centralized of PMI designated as the center. In the centralized model, there are two suggested scenarios, which are centralization in blood center and centralization in BDRS. This paper focused in blood center centralization, the proposed model is formulated below:

$$\text{Min} \sum_{i=1}^n \left[ f_i Y_i + \sum_{j=1}^m c_{ijlt} X_{ijlt} + \sum_l \left( \sum_t^5 U_{ilt} H_{ilt} + Z_{ilt} S_{ilt} \right) \right] + C_T \quad (12)$$

Subject to:

$$\sum_{t=1}^5 X_{jlt} = D_{jt} \quad \forall j, l, t \quad (13)$$

$$\sum_{j=1}^m \sum_{t=0}^5 X_{jlt} \leq K'_t, \quad \text{Where } K'_t = \sum_i K_{it} \quad (14)$$

$$S_{ilt} = \begin{cases} 0, & \text{if } X_{ijlt} > D_{jlt} \\ X_{ijlt} - D_{jlt}, & \text{if } X_{ijlt} \leq D_{jlt} \end{cases}, \quad \forall j, l \quad (15)$$

$$H_{ijlt} = X_{ijlt} - D_{jlt}, \quad \forall j, l$$

$$X_i, D_i, y_i \in \{0,1\} \quad (16)$$

Where:

$Z_{ilt}$  = stock out cost for blood inventory  $l$  in PMI  $i$  at period  $t$ .

$S_{ilt}$  = number of a shortage of blood inventory  $l$  in PMI  $i$  at period  $t$ .

$U_{ilt}$  = holding cost for blood inventory  $l$  in PMI  $i$  on  $t$  period ( $U_{(il,t-1)} \ll U_{(il,t)}$ )

$H_{ilt}$  = number of blood inventory  $l$  in PMI  $i$  on  $t$  period

$l$  = blood type (1 = A, 2 = B, 3 = AB, 4 = O)

$t$  = blood life span (platelet) (integer: 0,1,2,3,4,5)

$C_T$  = Transportation Cost, from PMI  $i$  to central PMI

## 4. Result and Discussion

Research about optimization cost for product allocation often only based on transportation cost. While model that developed in this research offers related variables to be included in the distribution, such as inventory cost, stock out and expired cost. Terminology that was developed are decentralization and

centralization model. It is based on consideration that in Indonesia the blood distribution is using decentralization concept, where each PMI has the same opportunity to gather, produce and distribute the blood to several hospitals. Whilst, the model system will be compared with the centralization concept that implemented in several countries. In centralization planning model, production and distribution conducted by one blood banking, hence this definitely giving different impact for the cost. Disadvantage from this research are, has not provided an in-depth study of the probability of shortages or expired date in any deliveries made and has not yet developed an alternative supply between PMI and hospitals.

Illustration of centralization model can be used in the following scenario: in which one PMI is selected as a distribution center. The arrival of blood to PMI occurs in every period 1 and will be sent to BDRS for 5 periods. The holding cost should be calculated when blood inventory in PMI surpasses 1 or more period. In this research, the time frame used is 5 period (t) with the assumption that expiration date for blood is equal or more than 5 (t). The value of inventory cost is different in each period, the longer blood stored, the more expensive the inventory cost is, at  $t = 1$  inventory cost is 0 and will be increasing every period with formula  $t+n$ . This caused by the degenerating blood quality over time, so the declining value of bloodstock charged toward inventory cost. The stockout cost happened when PMI could not be able to fulfill the blood demand. This scenario pictured and simulated one blood center to serve two BDRS.

**Table 1.** Scenario of blood allocation problem at centralization model.

Type		Period (t)	Deliv. + hold cost to BDRS1				Deliv. + Hold cost to BDRS2				Demand/ period
Stock			A	B	AB	O	A	B	AB	O	
10000	A	1	3	-	-	-	3	-	-	-	5000
		2	4	-	-	-	4	-	-	-	3000
		3	5	-	-	-	5	-	-	-	1000
		4	6	-	-	-	6	-	-	-	2000
		5	7	-	-	-	7	-	-	-	2000
8000	B	1	-	3	-	-	-	3	-	-	3000
		2	-	4	-	-	-	4	-	-	2000
		3	-	5	-	-	-	5	-	-	2000
		4	-	6	-	-	-	6	-	-	3000
		5	-	7	-	-	-	7	-	-	2000
9000	AB	1	-	-	3	-	-	-	3	-	3000
		2	-	-	4	-	-	-	4	-	1000
		3	-	-	5	-	-	-	5	-	3000
		4	-	-	6	-	-	-	6	-	2000
		5	-	-	7	-	-	-	7	-	1000
10000	0	1	-	-	-	3	-	-	-	3	3000
		2	-	-	-	4	-	-	-	4	4000
		3	-	-	-	5	-	-	-	5	3000
		4	-	-	-	6	-	-	-	6	2000
		5	-	-	-	7	-	-	-	7	3000
Demand			10000	8000	3000	5000	3000	4000	7000	10000	

From Table 1, stock of blood in PMI is delivered to BDRS that have a demand at period (t), inability to fulfill the demand will be given a penalty stock out cost and every blood bag that has not been distribute will give a holding cost.

## 5. Conclusion

The conclusions for this research is that it has succeeded in developing blood distribution model with a minimum cost under consideration of delivery cost, inventory cost and the possibility of incurred stockout cost. This result is different with the previous allocation capacity model. The previous model did not facilitate cost adjustment on the inventory and stock out. Moreover, for the future research suggested could be approached by incorporating blood span or lifetime as consideration in advancing the blood distribution model.

## References

- [1] Blake J T and Hardy M 2014 A generic modelling framework to evaluate network blood management policies: The Canadian Blood Services experience *Operations Research for Health Care* **3** pp 116–128 <https://doi.org/101016/jorhc201405002>
- [2] Lowalekar H and Ravichandran N 2013 Blood bank inventory management in India *Opsearch* **51** pp 376–399 <https://doi.org/101007/s12597-013-0148-z>
- [3] Zahraee S M, Rohani J M, Firouzi A and Shahpanah A 2015 Efficiency Improvement of Blood Supply Chain System Using Taguchi Method and Dynamic Simulation *Procedia Manufacturing* **2** pp 1–5 <https://doi.org/101016/jppromfg201507001>
- [4] Bahrami H 1997 *How Can Canadian Blood Services Product And Hospital Services In Bc And Yukon Region Implement A More Effective Blood Supply Chain Model To Achieve Its Vision ?* Microbiology UBC 1994 RT Medical Laboratory Technology BCIT
- [5] Stanger S H W 2013 *Vendor managed inventory in the blood supply chain in Germany Evidence from multiple case studies* <https://doi.org/101108/17538291311316054>
- [6] Beliën J and Forcé H 2012 Supply chain management of blood products: A literature review *European Journal of Operational Research* **217** pp 1–16 <https://doi.org/101016/jejor201105026>
- [7] Dillon M, Oliveira F and Abbasi B 2017 A two-stage stochastic programming model for inventory management in the blood supply chain A Two-Stage Stochastic Programming Model for Inventory Management in the Blood Supply Chain *Journal of Production Economics* **187** pp 27–41 <https://doi.org/101016/jijpe201702006>
- [8] Nahmias S 1982 Perishable inventory theory: a review *Operations Research* **304** pp 680–708 <https://doi.org/101287/opre304680>
- [9] Lowalekar H and Ravichandran N 2013 Blood bank inventory management in India *Opsearch* **513** pp 376–399 <https://doi.org/101007/s12597-013-0148-z>
- [10] Osorio A F, Brailsford S C and Smith H K 2015 A structured review of quantitative models in the blood supply chain: a taxonomic framework for decision-making *International Journal of Production Research* **11** pp 1–22 <https://doi.org/101080/0020754320151005766>
- [11] Hosseinifard Z and Abbasi B 2016 The inventory centralization impacts on sustainability of the blood supply chain *Computers and Operations Research* pp 1–7 Elsevier <https://doi.org/101016/jcor201608014>
- [12] Coleman A and Akinsola O S 2012 Effective blood distribution in rural hospitals through ICT service oriented architecture SOA framework: A case study in rural hospitals in South Africa *Studies on Ethno-Medicine* **6** pp 141–147 <https://doi.org/101007/s10287-011-0133-z>
- [13] Stanger S H W, Wilding R, Hartmann E, Yates N and Cotton S 2013 Lateral transshipments: an institutional theory perspective *International Journal of Physical Distribution and Logistics Management* **439** pp 747–767 <https://doi.org/101108/IJPDLM-09-2011-0155>

- [14] Sarkar B 2013 A production-inventory model with probabilistic deterioration in two-echelon supply chain management *Applied Mathematical Modelling* **37** pp 3138–3151 Elsevier Inc <https://doi.org/10.1016/j.apm.2012.07.026>
- [15] Reynolds E, Wickenden C and Oliver A 2001 The impact of improved safety on maintaining a sufficient blood supply *Transfusion Clinique et Biologique* **83** pp 235–239 [https://doi.org/10.1016/S1246-7820\(01\)00139-2](https://doi.org/10.1016/S1246-7820(01)00139-2)
- [16] Ghandforoush P and Sen T K 2010 A DSS to manage platelet production supply chain for regional blood centers *Decision Support Systems* **50** pp 32–42 Elsevier BV <https://doi.org/10.1016/j.dss.2010.06.005>
- [17] Pujawan N and Mahendrawati 2010 *Supply Chain Management* Guna Widya
- [18] Chopra S and Meindl P 2013 *Supply Chain Management: Strategy, Planning, and Operations* (New Jersey:Prentice Hall)

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