Blood Banks Location Model for Blood Distribution Planning in Makassar City

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Abstract. Regionalization of local blood bank facility becomes interesting issue to discuss recently. Determining distribution allocation of blood product is a strategic decision-making in the blood supply chain in order to fulfill demands in both normal and emergency conditions. In this work, we develop a generalized network optimization model for the blood transportation and allocation model in Makassar City South Sulawesi Indonesia. Today, there are two main blood bank facilities in the city that operate by government and local Red Cross organization. Each hospital will connect to the one of the blood bank facility. Each hospital is to be assigned to a regional blood bank facility which will periodically supply the hospital's blood demand for each period. The supply process depends on the maximum capacity of the each regional blood bank facility. We present algorithms to decide how many bloods banking to set up, where to locate them, how to allocate the hospital to the banks and how to route the periodic supply operation, so that the total fixed costs and transportation costs of blood bank facility location are minimum.

Keywords: blood banks, facility location

1. INTRODUCTION

The location and availability of blood banks, which will serve some hospitals, is a strategic decision in health care system. In addition to well-known importance of the subject, it is a fact that grave shortages of blood occur in over 80% of the countries in the world, one of the reason is inadequate funding of the local transfusion service (Thomas, 2007), that may result from an inefficient allocation of sources in generally. Some cost-structure analyses included distribution and delivery costs of blood as some significant variables. Besides, accessibility to a blood bank is an important component of an organ transplant program. Transplantation requires more blood then most other surgeries, for instance, 100 units of blood for a liver transplant patient (Lindsey and McGlynn, 1988). Moreover, blood banks facilities also serve as important education centers for medical staff from universities and hospitals (Amin et al. 2004).

The location of blood bank facilities is an important issue in any application area for both industry and academia. Poor location decision will impact to such as increased expenses, capital costs and degraded customer service (Daskin and Dean, 2004). In health care system, the facility location decisions, which are strategic not an everyday decision (Ozcan, 2005), are more critical due to that any anomaly may lead to mortality and morbidity (Daskin and Dean, 2004).

In this paper, we primarily focus on blood banks location model for bloods distribution planning in Makassar City, South Sulawesi, Indonesia. Today, there are 17 hospitals in Makassar city and two regional blood center (RBC).

2. LITERATURE REVIEW

This section discusses the research related to the distribution problem of blood banks including decision models. Blood banks can be organized in multiple manners, ranging between the two extremes of centralization and decentralization. In the book Operations Research and Health Care: Handbook on Methods and Applications,

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Pierskalla (2004) presents an interesting overview paper, which is probably one of the most widely read papers in the area of blood supply chain management. Pierskalla's paper describes strategic models for assigning donor areas and transfusion centers to community blood centers, determining the number of community blood centers in the region, locating these centers and coordinating supply and demand. The models also consider tactical and operational issues in collecting blood, inventory management, blood allocation to hospitals, blood delivery and cross matching.

In the literature, the research on blood supply chain focuses on the complexity of effectiveness and efficiency of blood location-allocation. Or and Pierskalla (1979) conducted research a regional blood management problem where hospitals were applied by a regional blood bank in their region, and developed a location-allocation model that minimizes the sum of the transportation costs and the system costs. Sapountzis (1984) introduced an integer-programming model to allocate blood from a Regional blood center (RBC) to hospitals. Brodheim and Prastacos (1979) showed a prototype for RBC and the hospital blood banks in order to optimize blood availability and utilization. The objective his model is to minimize the total expected number of units of expired blood. Jacobs et al. (1996) developed an integer-programming model for blood collection and distribution system. Their research presented an analysis of alternative locations and service areas of American Red Cross blood facilities. Şahin et al. (2007) presented a blood bank location model and developed several location-allocation models to solve the problems of regionalization based on a hierarchical structure; however, the facilities fixed costs of the RBC were not considered. Recent research by Çetin and Sarul (2009) presented a mathematical programming model for location of blood banks among hospitals or clinics. Their objectives aim to minimize the total fixed cost of LBBs and the total traveled distance between the blood bank and hospitals.

One of the most-popular models for public facility location problem is the P-median model. The P-median problem, originally proposed by Hakimi (1964) is that of locating P facilities to minimize the sum of the demand weighted total distance between each demand node and the nearest facility. Daskin and Dean (2004) proposed the location model of P facilities to minimize the coverage distance subjected to a requirement that all demands are covered.

Hriber and Daskin (1997) proposed a greedy heuristic for the P-median problem. The heuristics restrict the size of the state space of a dynamic programming algorithm. Correa *et al.* (2004) described the application of the capacitated P-median model to a real-world problem and proposed a genetic algorithm to solve the P-median model.
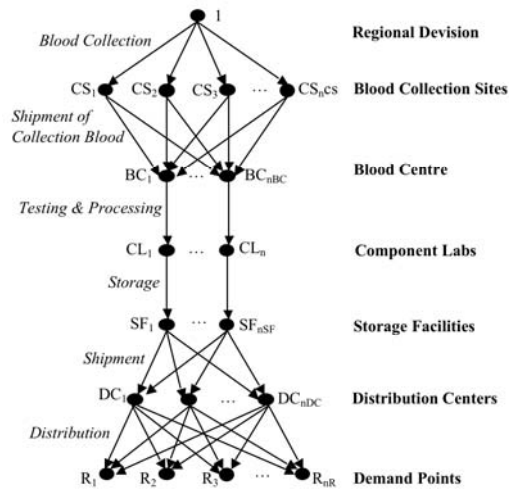

Figure 1: Supply Chain Network Topology for regionalized blood banks

Church (1990) proposed the regionally constrained P-median problem (RCPMP), which can be described in terms of P-median problem with two additional sets of constraints, one to ensure a minimum number of facilities for each region and the other to prevent more than a specified maximum. Nagurney (2011) described the supply chain network topology for a regionalized blood bank in American Red Cross (ARC) the ARC is the major supplier of blood products to hospitals and medical centers satisfying over 45% of the demand for blood components in US (Figure 1).

Gerrard and Church (1995) built upon the RCPMP by allowing regional constraints to be violated and formulating a model that sought to minimize both the total weighted distance and the number of regional constraints that were violated. Their model allows for identification of non-inferior combinations of system accessibility and regional constraint enforcement.

However, the maximum traveled distance between supply node and demand node are not considered in P-median model.

3. MODEL FORMULATION

Through this paper, we concerned with blood distribution problem in Makassar city that consist of two blood banks known as PMI (Indonesian Red Cross) and UTDP (Regional Blood Center) will supply to 17 hospitals. We proposed two of the model such as single allocation model and double allocation model. Number of blood bags can be collected during 2013 as shown in Table 1. Table 2 shows the blood supply and demand from each hospital.

Table 1. Number of blood bags can be collected

No	Blood Banks	quantity
1	PMI	29078
2	UTDP	11844

Table 2. Blood supply distance and demand

No	Hospitals	Demand (bag)	Distance (km) PMI	Distance (km) UTDP
1	Jala Ammari	672	4.7	14.4
2	Akademis Jauri	1551	3.2	12.4
3	Pelamonia	2591	2.3	12.2
4	Mitra Husada	300	1.3	12.4
5	Stella Maris	3238	2.4	13.2
6	Hikmah	1011	1.8	13.3
7	Dadi	1015	0.1	13.1
8	Labuang Baji	2768	2	15.1
9	Bhayangkara	3833	3.9	15.2
10	Haji	1736	4.6	15.5
11	Grestelina	2180	3.8	9.9
12	Islam Faisal	2534	2.4	12.6
13	Ibnu Sina	2421	4.2	8.1
14	Awal Bros	2864	4.6	9.5
15	W.Sudirohusodo	17210	10.4	2.5
16	Pendidikan Unhas	1310	10.1	2.2
17	Daya	2216	15	3.1

We develop the model using the following notation:

Subscripts:
  i = index of blood banks
  j = index of hospitals
Sets:
  I = set of all blood banks
  J = set of hospitals
Parameters :
  f_i = fixed cost blood banks i
  h_j = demand of hospital j
  c_{ij} = delivery cost from blood banks i to hospital j
  y_{ij} = the fraction of hospitals demand satisfied by the blood banks
  u_i = capacity of blood banks i

Decision variable:

$$x_i = \begin{cases} 1, & \text{if hospital open as blood distribution} \\ 0, & \text{if hospital close for blood distribution} \end{cases}$$

3.1 Single Allocation Model

Single allocation assumed that the demand of blood from the hospital blood can be supplied only from single blood banks.

The objective function
Minimize

$$\sum_{i \in I} f_i x_i + \sum_{j \in J} \sum_{i \in I} h_i c_{ij} y_i \tag{1}$$

Subject to:

$$\sum_{i \in I} y_{ij} = 1, \quad \forall j \in J \tag{2}$$

$$y_{ij} \le x_j, \quad \forall i \in I, \quad \forall j \in J \tag{3}$$

$$\sum_{j \in J} h_i y_{ij} \le u_i, \quad \forall i \in I \tag{4}$$

$$x_j \in \{0,1\}, \quad \forall i \in I \tag{5}$$

$$y_{ij} \ge 0, \quad \forall i \in I, \quad \forall j \in J \tag{6}$$

The objective function (1) minimizes the total cost of blood banks fixed cost, delivery cost. Constraint (2) states that each hospital must be assigned to exactly one blood bank. Constraint (3) guarantee that a hospital select a blood bank only from among those are chosen. Constraint (4) states that blood supply for each blood bank must not exceed the blood capacity of each blood bank. Constraint (5) and (6) are the standard integrality constraints.

3.1 Double Allocation Model

Double allocation assumed that the demand of blood from the hospital blood can be supplied from both existing blood banks.

The objective function
Minimize

$$\sum_{i \in I} f_i x_i + \sum_{j \in J} \sum_{i \in I} c_{ij} y_{ij} \tag{7}$$

Subject to:

$$\sum_{j \in J} y_{ij} = h_i, \quad \forall j \in J \tag{8}$$

$$\sum_{i \in I} y_{ij} \le u_j x_j, \quad \forall j \in J \tag{9}$$

$$y_{ij} \ge 0, \quad \forall i \in I, \quad \forall j \in J \tag{10}$$

The objective function (7) minimizes the total cost of blood banks fixed cost, delivery cost. Constraint (8) guarantee that a hospital select a blood bank only from

among those are chosen. Constraint (9) states that blood supply for each blood bank must not exceed the blood capacity of each blood bank. Constraint (10) is the standard integrality constraints.

4. COMPUTATIONAL RESULTS

In this section, computational experiments were performed for two allocation model from data set as summarized in Table 1 and 2. Computational experiments are presented to evaluate the behavior of total cost form two allocation model and to compare the optimal distribution planning from two existing blood banks to 17 hospitals. The experiments are performed for two allocation models, single and double allocation model. The computational experiments are solved by ILOG CPLEX 12.2 optimization software using a computer with 2.66GHz core 2 duo processor and 2 GB of RAM.
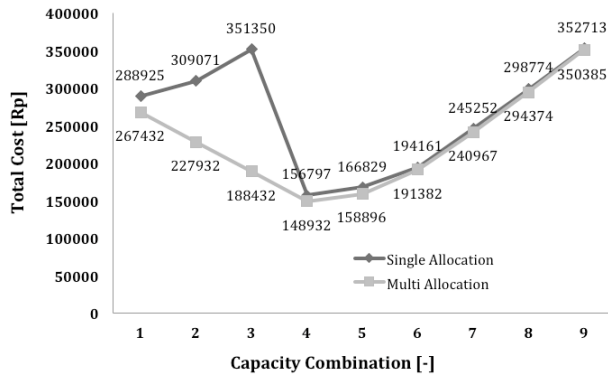

Figure 2: Total cost comparison between single allocation and double allocation

Every node denoting the hospitals is generated from actual location and distances to blood banks are generated from shortest distance road to hospitals using Google maps application. Then, we get the unit delivery cost by multiplying the unit 1.0 with the distance between blood banks to hospitals.

Figure 2 shows the relationship between the total cost and the proposed capacity combination of blood banks. We proposed 9 combinations for blood banks capacity, among them are 1(45000, 500), 2(40000,10000), 3(35000,15000), 4(30000,20000), 5(25000,25000), 6(20000,30000), 7(15000,35000), 8(10000,40000), and 9(5000,45000). The total costs, when assigning the capacity of A larger than B, decrease gradually when capacity A decrease and B increase gradually. The optimal solution for both allocation models found in the capacity combination number 4 which is represent as A (PMI) with the proposed capacity 30000

and B (UTDP) with the proposed capacity 20000. The total costs increase gradually when capacity A decrease and B increase gradually.

In Figure 3 and Figure 4 illustrated the distribution of blood product for single allocation model and double allocation model respectively. More detail results for distribution allocation from blood banks to each hospital for single and double allocation are summarized in Table 3.
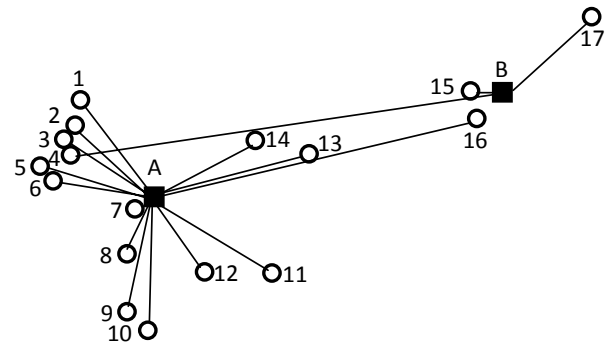

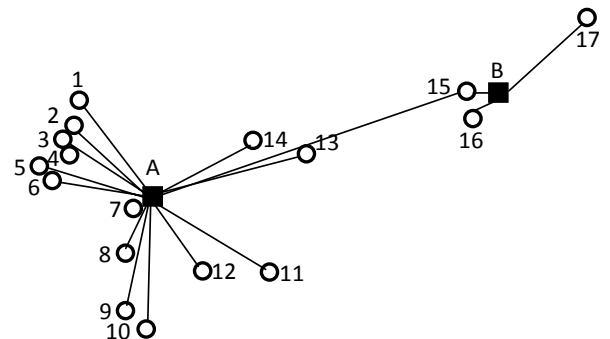Figure 3: The optimal blood distribution for single allocation model

Figure 4: The optimal blood distribution for double allocation model

4. CONCLUSION

The single allocation model and double allocation model that we proposed in this paper is a capacitated facility location problem to accommodate blood demand fulfillment in Makassar city. Both models are integer programming model. The objective is to minimize the total cost of blood banks fixed cost and delivery cost. The proposed mathematical model can solve for optimal distribution planning from existing blood banks to 17 hospitals. The solution can be used to define which hospitals should be supplied by existing blood banks with minimum delivery cost. Some direction for future research

can be done by modifying this model to help analyzing the optimal distribution planning when the number of blood banks and hospitals increased. Considering applying center of gravity method of continues location models in order to find the optimal number blood banks for the city.

Table 3. Allocation distribution for blood bank capacity combination 4(30000,20000)

No	Hospitals	Single Allocation		Double Allocation	
		PMI (A)	UTDP (B)	PMI (A)	UTDP (B)
1	Jala Ammari	672	-	672	-
2	Akademis Jauri	1551	-	1551	-
3	Pelamonia	2591	-	2591	-
4	Mitra Husada	-	300	300	-
5	Stella Maris	3238	-	3238	-
6	Hikmah	1011	-	1011	-
7	Dadi	1015	-	1015	-
8	Labuang Baji	2768	-	2768	-
9	Bhayangkara	3833	-	3833	-
10	Haji	1736	-	1736	-
11	Grestelina	2180	-	2180	-
12	Islam Faisal	2534	-	2534	-
13	Ibnu Sina	2421	-	2421	-
14	Awal Bros	2864	-	2864	-
15	W.S. Husodo	-	17210	736	16474
16	Pend. Unhas	1310		-	1310
17	Daya	-	2216	-	2216

REFERENCES

Amin, M., Fergusson, D., Wilson, K., Tinmouth, A., Aziz,A., Coyle, D., Hebert, P. (2004) The societal unit cost of allergenic red blood cells and red blood cell transfusion in Canada, *Transfusion.* 44, 10: 1479-86

Brodheim, E., and Prastacos, G.P. (1979) The long island blood distribution systems as a prototype for regional blood management. *Interfaces*, **9**, 3-20.

Çetin, E., and Sarul, L.A. (2009) A Blood Bank Location Model: A Multiobjective Approach, *European Journal of Pure and Applied Mathematics*, **2**,112-124.

Church, R.L. (1990) The Regionally Constrained P-median Problem. *Geographical Analysis*, **22**.

Correa, E.S., Steiner, M.T.A., Freitas, A.A., and Carnieri, C. (2004) A Genetic Algorithm for Solving a Capacitated P-median Problem. *Numerical Algorithms*, **35**, 373-388.

Daskin, M.S. and L.K. Dean. (2004) Location of health care facilities. In: Sainfort F, Brandeau M, Pierskalla W, editors. Handbook of OR/MS in health care: *A Handbook of Methods and Applications*. USA: Kluwer, 43-76

Gerrard, R.A., and Church, R.L. (1995) A General Construct for the Zonally Constrained P-median Problem. *Environment and Planning B: Planning and Design*, **22**.

Hakimi, S.L. (1964) Optimum Locations of Switching Centers and the Absolute Centers and Medians of a Graph. *Operations Research.*,13, 450-459.

Hribar, M., and Daskin, M.S. (1997) A Dynamic programming heuristic for P-median Problem. *European Journal of Operational Research*, **101**, 499-508

Jacobs, D.A., Silan, M.N., and Clemson, B.A. (1996) An Analysis of Alternative Locations and Service Areas of American Red Cross Blood Facilities, *Interfaces*, **26**, 40-50.

Lindsey, P.A., McGlynn, E.A. (1988) Pew Memorial Trust policy synthesis: 5. State coverage for organ transplantation: a framework for decision making. *Health Services Research,* **22**,881-922

Nagurney, A., Masoumi. A.H., and Yu, M. (2012) Supply Chain Network Operations Management of a Blood Banking System with Cost and Risk Minimization, *Computational Management Science*, **9**. 205-231.

Or, I., Pierskalla, W.P. (1979) A transportation location-allocation model for regional blood banking. AIIE *Transactions*, **9**, 86-95.

Ozcan, Y.A. (2005) *Quantitative Methods in Health Care Management: Techniques and Applications*. San Francisco CA: Jossey-Bass/Wiley.

Pierskalla, W.P. (2004) *Supply chain management of blood banks*, in: M.L.Brandeau, F. Sainfort, W.P. Pierskalla (Eds.), Operations Research and Health Care: A Handbook of Methods and Applications, Kluwer Academic Publishers, 103–145.

Şahin, G., Sural, H., and Meral, S. (2007) Locational Analysis for Regionalization of Turkish Red Crescent Blood Service, *Computer & Operations Research*, **34**, 692-704.

Sapountzis, C. (1984) Allocating blood to hospitals from a central blood bank. *European Journal of Operational Research*, **16**, 157-162.

Thomas, M.J. (2007) The management of overseas emergencies. *Travel Medicine and Infectious Disease.* 5, 113-116 .