Optimizing the Issue of Blood Supply Chain Network Design with a Reliability Approach

by Yuesti Et Al

Industrial Engineering
& Management Systems
Vol 21, No 2, June 2022, pp.151-00
ISSN 1598-7248 | EISSN 2234-6473 |

https://doi.org/10.7232/iems.2022.21.2.151
© 2022 KIIE

Optimizing the Issue of Blood Supply Chain Network Design with a Reliability Approach

Anik Yuesti*
Universitas Mahasaraswati Denpasar, Indonesia

Paitoon Chetthamrongchai
Faculty of Business Administration, Kasetsart University, Bangkok, Thailand

Alim Al Ayub Ahmed
School of Accounting, Jiujiang University, China

Vera Anitra
Department of Management, Faculty of Economics Business and Politics, Universitas Muhammadiyah Kalimantan Timur, Samarinda, Indonesia

A. Sutarto
Universitas Pendidikan Mandalika, Mataram, Indonesia

Ravil Akhmadeev
Department of Accounting and Taxation, Plekhanov Russian University of Economics (PRUE), Stremyanny Lane 36, 117997, Moscow, Russian Federation

Dedy Achmad Kurniady
Educational administrations, universitas pendidikan indonesia, Bandung, Indonesia

Clara Neltje Meini Rotinsulu
Department of Management, Tompotika University, Banggai, Indonesia

M. Kavitha
Department of ECE, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India

(Received: December 00, 2020 / Revised: December 00, 2020 / Accepted: December 00, 2020)

ABSTRACT

Supply chain network design of a product is one of the primary and strategic measures in supply chain management that plays a vital role in supply chain performance. Since blood is a special commodity and has no substitute, supply chain management and optimization have a special place among researchers. In this research, for the first time, a two- objective nonlinear mixed integer model is presented to help make strategic and operational decisions in the blood supply chain. The first objective function is related to cost minimization and the second objective function is related tosupply chain reliability maximization, which is considered as a series-parallel system. To check the validity of the model, a numerical example is solved using GAMS software, then using MOPSO meta-heuristic algorithm, the model is solved in larger dimensions and while comparing the performance criteria of multi-objective algorithms, the results are reviewed.

Keywords: Blood Supply Chain; Reliability; Mathematical Modeling; Metaphorical Algorithms

* Corresponding Author, E-mail:anikyuesti@unmas.ac.id

The part marked in red seems to be an error.
Please check it and add it to the references.

1. INTRODUCTION

Supply chain management (SCM) encompasses the integrated planning and execution of processes in a supply chain in an efficient manner (Zahiri *et al*., 2015; Al-Zyoud *et al*., 2021; ALSoud *et al*., 2021). In fact, designing a supply chain network is one of the strategic decisions in SCM, playing a vital role in supply chain performance. In general, designing a supply chain network requires finding the optimal number, location and capacities of facilities and optimizing a product's flow through long-term and multi-period planning (Ab Yajid, 2020a, 2020b). Research in the field of the supply chain is not merely limited to industrial goods (with the objective of maximizing profit while minimizing costs), and many researchers have focused on new areas, such as health supply chains, in the past two decades (Rahman *et al*., 2018; Jaapar *et al*., 2020). Human blood is a scarce resource that is produced only by humans, and there is still no chemical option or process that can produce it (Sakinahmohdshukri and bin Jaharadak, 2020). Blood carries various substances to cells including nutrients and oxygen. In addition, useful components, namely red blood cells, plasma, white blood cells, serum or platelets, can be separated from blood mechanically, which can be used to different patients and purposes (Gunpinar and Centeno, 2015).

To date, various studies have been conducted on blood supply chain (BSC) optimization with the objective of inventory management (Puranam *et al*., 2017) and solving a facility location problem. Some researchers divided blood into two categories of fresh (for patients with rare diseases and operations such as open-heart surgery) and old blood (Gunpinar and Centeno, 2015), whereas others have assessed the compatibility of different blood groups in the blood donation supply chain regardless of blood freshness (Duan and Liao, 2014). However, blood is perishable, and studies on perishable product supply chain initiated in 1960. Various solutions for blood inventory control and supply chain problems have been analyzed by researchers, some of which include simulation techniques (Goli *et al*., 2019; Goli *et al*., Goli20; Goli *et al*., 2021), using mathematical arguments (Almansour, 2021; Jagannathan and Sen, 1991), dynamic programming (Blake, 2009), and integer programming (Hemmelmayr *et al*., 2010). It is worth noting that the mentioned approaches have been used individually and in combination with each other. Moreover, both blood demand certainty (Goli *et al*. Goli20; Goli *et al*., 2021) and uncertainty (Hemmelmayr *et al*., 2010; Puranam *et al*., 2017) have been considered in the relevant literature. Some researchers have considered the objective function as minimization of inventory costs, including ordering, warehousing, shortage and cost of waste or corruption (Gunpinar and Centeno, 2015; Sudarmilah and Maelani, 2021). Meanwhile, others have considered the objective function as minimization of costs of construction and relocation of facilities. In the latest research, Goli and Malmir (2020) presented a new mathematical model for the distribution of resources in critical situations. In this model, researchers presented an allocation and routing model for relief vehicles in the areas affected by a disaster. Attempts were made to analyze various solutions and report the most efficient one using the fuzzy validity theory approach. In the present research, the main objective is to minimize the facility construction costs and reliability-related costs while maximizing the reliability of an important part of the supply chain.

2. STATEMENT OF THE PROBLEM

The blood supply chain in the present research is designed based on the actual situation of Iran. Overall, a four-layer supply chain can be considered based on Figure 1. The first layer includes blood donors, classified based on the location's geography. The second layer encompasses mobile blood collection facilities, whereas the second layer comprises permanent blood collection facilities, where different tests and segregation of blood products are carried out. In addition, the fourth layer includes blood applicants. It is worth mentioning that in this problem, blood donors can refer to permanent or mobile facilities (not both) and donate blood. It is notable that the blood donated to mobile facilities must be transferred to permanent facilities, and applicants must receive blood only from permanent centers.

To simplify the reliability calculation process while considering real conditions, only mobile and permanent facilities, which are at the important level of the supply chain, are considered in the calculations (only the relationship between these two levels of the supply chain are considered in reliability calculation process). While the

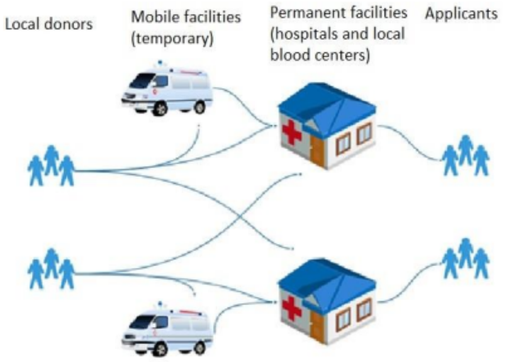

Figure 1. Schematic representation of BSC network in the present article.

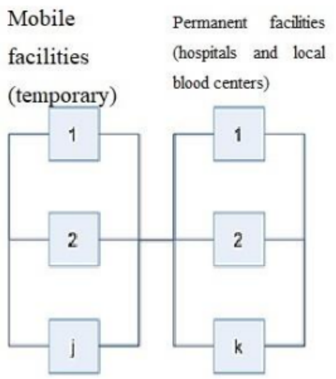

Figure 2. The series-parallel system.

reliability of mobile facilities is lower than permanent facilities, the permanent facility construction costs are extremely higher than mobile facilities. In this study, the problem is considered to be two-objective since the maximization of reliability and minimization of costs are two contradictory objectives. It is notable that an increase in reliability results in an increase in related costs. Moreover, the reliability number is a function of different parameters, including facility quality and whether candidate sites are in the path of flood or fault or not. Reliability-related costs include surplus costs that must be paid simply to achieve higher reliability, such as providing safe means of transportation or selecting and providing a place of permanent facilities in safe places. Figure 2 exhibits a schematic presentation of a series-parallel system in the present research.

3. METHODOLOGY

As mentioned in the previous section, a new mathematical model is presented with the following premises to design a BSC network.

- The constraints of donor groups, mobile facilities and permanent facilities are clear.
- The costs of permanent and mobile facility construction, the cost of blood transfer from mobile to permanent facilities, facility reliability-related costs, and the level of facility reliability are clear.
- The blood demand rate is clear.
- Donors are allowed to donate blood in either permanent or mobile centers. However, blood collected at mobile centers must be transferred to permanent centers.
- The model is of single-period type.
- A shortage is not allowed.

Sets

I	donor groups (i = 1,…, I) (based on geographical areas)
J	Candidate sites for mobile (temporary) blood collection facilities
K	Candidate sites for permanent facilities (hospitals and local blood centers)

Parameters

C_j	Construction (location) cost of a mobile facility to collect blood on site
C'_k	Construction (location) cost of a permanent facility to collect blood on site
C''_{jk}	Cost of transporting a unit (pack) of blood from mobile facility to permanent facility
cre_j	Reliability-related costs for mobile facilities
cre_k	Reliability-related costs for permanent facilities
De	Total blood demand (whole blood)
r_{ij}	Distance between donor group center and mobile facilities
r_0	Maximum coverage radius of the mobile facilities (if the center of the donor group is covered by the facility)
w_{ik}	Distance between donor group center and permanent facilities
w_0	Maximum coverage radius of the permanent facilities (if the center of the donor group is covered by the facility)
q_{jk}	Distance between candidate sites for mobile and permanent facilities
q_0	Maximum coverage of the permanent facilities for temporary facilities (if the facility is covered by the facility)
U_0	Maximum blood collection capacity in mobile facilities
V_k	Maximum blood collection capacity in permanent facilities
d_i	Number of donated blood units of the donor group (potentials of blood donation in geographical areas)
re_j	Reliability of mobile facilities
re_k	Reliability of mobile facilities
ω	Minimum percentage of blood demand coverage

Decision variables

- The model is of single-product type (whole blood).

Z_j

Z'_k

X_{ij}

X'_{ik}

X''_{jk}

A binary variable; 1, if mobile facility is constructed in candidate site; otherwise, 0.

A binary variable; 1, if permanent facility is constructed in candidate site; otherwise, 0.

A binary variable; 1, if the donor group is allocated to the facility; otherwise, 0.

A binary variable; 1, if the donor group is allocated to the facility; otherwise, 0.

A binary variable; 1, if the mobile facility is

	assigned to the facility; otherwise, 0.
S_{ij}	The amount of blood collected (number of whole blood packs) from the group of donor s in mobile facilities
S'_{ik}	The amount of blood collected from the donor group in permanent facilities
S''_{jk}	The amount of blood transported from the mobile facility to the permanent facility

Objective Function and Constraints

$$\mathrm{Min}Z_1 = \sum_j z_j c_j + \sum_k z'_k c'_k + \sum_j \sum_k s''_{jk} c''_{jk} + \sum_j z_j cre_j + \sum_k z'_k cre'_k \tag{1}$$

$$\mathrm{Max}Z_2 = [1-\prod_j (1-z_j re_j)][1-\prod_k \left(1-z'_k re'_k\right)] \tag{2}$$

s.t.

$$\sum_j x_{ij} + \sum_k x_{ik} \le 1 \qquad \forall i \tag{3}$$

$$x_{ij} r_{ij} \le r_0 z_j \qquad \forall i,j \tag{4}$$

$$x'_{ik} w_{ik} \le w_0 z'_k \qquad \forall i,k \tag{5}$$

$$x''_{jk} q_{jk} \le q_0 z'_k \qquad \forall j,k \tag{6}$$

$$S_{ij} \le Mx_{ij} \qquad \forall i,j \tag{7}$$

$$s'_{ik} \le Mx'_{ik} \qquad \forall i,k \tag{8}$$

$$s''_{jk} \le Mx''_{jk} \qquad \forall j,k \tag{9}$$

$$\sum_i s'_{ik} + \sum_j s''_{jk} \le V_k \qquad \forall k \tag{10}$$

$$\sum_i S_{ij} \le U_0 \qquad \forall j \tag{11}$$

$$\sum_j S_{ij} + \sum_k s'_{ik} \le d_i \qquad \forall i \tag{12}$$

$$\sum_i \sum_k S'_{ik} + \sum_j \sum_k s''_{jk} \ge \omega De \tag{13}$$

$$\sum_i s_{ij} = \sum_k s''_{jk} \qquad \forall j \tag{14}$$

$$x_{ij}, x'_{ik}, x''_{jk}, z_j, z'_k \in \{0,1\}, \qquad \forall i,j \tag{15}$$

facilities and cost of using facilities with higher reliability at permanent and mobile facilities. Objective function 2 shows the maximization of supply chain reliability, which is considered as a series-parallel system encompassing two subsystems of mobile facilities (mobile facilities are parallel to each other) and permanent facilities (permanent facilities are parallel to each other). Constraints 3 allocate the donor groups to each mobile or permanent facility. In this regard, donor group allocation to centers means that the donors of a certain area are expected to refer to the desired centers based on the geographical location and coverage radius of mobile and permanent facilities. This prevents the allocation of a group to two (permanent or mobile) centers. Constraints 4-6 consider the coverage radiuses of each facility while Constraints 4 guarantee that if the donor group is allocated to the mobile facility, the facility has been previously constructed and donors of the facility are predetermined. Constraints 5 guarantee that if a donor group is allocated to the permanent facility, the facility is previously built and donors allocated to the facility is in the predetermined coverage area. Constraints 6 guarantee that if the mobile facility is allocated to a permanent facility, the mentioned facility has been already constructed and the mobile facility is in the predetermined coverage area for the permanent facility. Constraints 7-9 guarantee that blood unit flow (whole blood) is established from donors to the mobile facilities, from donors to permanent facilities, from mobile facilities to permanent facilities only if the facilities have been already constructed. Constraints 10 and 11 respectively show that the blood volume donated to the permanent facilities and transferred from mobile to permanent facilities, as well as the volume of blood donated to mobile facilities do not exceed the blood collection capacity. Constraints 12 guarantee that the total blood volume donated by the donor group to permanent and mobile facilities does not exceed the number of blood units donated by the donor group. Constraints 13 argue that the total blood volume donated to permanent and mobile facilities must cover the minimum amount of the coefficient (percentage label) of the total demand rate. Constraints 14 guarantee that all blood volume donated to mobile facilities is transferred to permanent facilities. In addition, constraints 15 and 16 define the type of decision variables.

3.1 Solution Method

In the present study, five numerical examples are produced to validate the model. The examples are solved by using GAMS and BARON. Depending on the com-

$$s_{ij}, s_{ik}, s_{jk} \geq 0 \quad \forall i,j,k \quad (16)$$

Objective function 1 shows the minimization ofcosts of mobile facility construction, permanent facility construction, blood transfer from mobile to permanent

plexity of the problem and the time-consuming nature of the solution process, the five examples are solved by a metaheuristic algorithm and the results are assessed. In addition, the criteria for assessing the efficiency of meta-heuristic algorithms are calculated and evaluated.

Table 1. Parameters tuned for MOPSO algorithm

Column	Parameter	Optimization Level
1	MaxIt	300
2	Npar	30
3	Nrep	30
4	Ngrid	3
5	Beta	2
6	Lambda	2
7	C1	2
8	C2	2
10	Wdamp	0.9

3.2 MOPSO Algorithm

Given the extraordinary success of PSO algorithms in solving single-objective optimization problems, many researchers and scientists have attempted to solve multi-objective problems by this algorithm. Today, multiple versions of the PSO algorithm have been proposed to solve multi-objective problems. In this regard, one of the most famous algorithms has been introduced by Coelho *et al*. (2013), which is entitled MOPSO. This name is exclusively used for the mentioned algorithm. The parameters tuned for the MOPSO algorithm based on the mathematical model proposed in the present study are completely new and are obtained by trial and error and solving multiple examples, as shown in Table 1.

3.3 Performance Criteria

The multi-objective algorithm comparison criteria, which are assessed based on a study by Zitler and Thiele (1998), are as follows:

- Algorithm execution time: CPU time is one of the most important indices related to the performance of each metaheuristic algorithm that is specifically used for large-scale problems. In general, the lower the value of this index, the better.
- The number of Pareto solutions: the Number of (approximate) Pareto Solutions (NPS) shows the optimal Pareto solutions. The higher the value of NPS, the better.
- Mean ideal distance: mean ideal distance (MID) was used by Zitler and Thiele (1998), to estimate the mean distance of Pareto solutions from the origin of coordinates. It is estimated based on the equation below. The lower its value, the better the performance of the algorithm.

In this equation, ci is the amount of distance to the ideal point.

$$\sum^{n} \sqrt{\left(f_{1i}-f_{1}^{best}\right)^{2}+\left(f_{2i}-f_{2}^{best}\right)^{2}}$$

n is the number of solutions in the Pareto set.

- Spacing index: the value of the spacing metric (SM) calculates the relative distance of consecutive solutions and was first introduced by Schott (1995). The lower the value of this index, the better. The index is calculated, as follows:

$$\mathrm{SM}=\frac{\sum_{i=1}^{n-1}\left|\bar{d}-d_{i}\right|}{(n-1)\bar{d}} \tag{18}$$

As observed, the distance measured is equal to the lowest value of the absolute value of the difference in the values of the objective functions between the i-th solution and actual solutions in the final non-dominated set.

- The diversification metric: introduced Zitler and Thiele (1998), the diversification metric (DM) shows the breadth of Pareto solutions of an algorithm. In the two-objective model of the present study, this criterion is equal to the Euclidean distance between two boundary solutions in the objective space. The higher the value of this index, the better the performance of the algorithm. The following equation is used to calculate the criterion:

$$\mathrm{DM}=\sqrt{\left(\frac{\max f_{1i}-\min f_{1i}}{f_{1,total}^{max}-f_{1,total}^{min}}\right)^{2}+\left(\frac{\max f_{2i}-\min f_{2i}}{f_{2,total}^{max}-f_{2,total}^{min}}\right)^{2}} \tag{19}$$

4. COMPUTATIONAL RESULTS

To solve the mathematical model, we prepare five numerical examples based on Table 2.

Example 1 is solved by GAMS and BARON software. Given the GAMS software limitations in solving multi-objective problems, we used the weighing method to solve the two-objective model. To this end, W_1 and W_2 weights were prepared for the first (cost minimiza- tion) and second (reliability maximization) objective functions based on experts' opinions, as shown in Table 3. The final objective function was obtained according to Equation 20.

$$\mathrm{Min}Z_{t}=w_{1}z_{1}-w_{2}z_{2} \tag{20}$$

$$\mathrm{MID}=\frac{\qquad}{n} \tag{17}$$

According to Equation 20, costs must be minimized simultaneously with W_1 weight and reliability must be maximized simultaneously with W_2. It is notable that there was no need for the sum of weights to equate to one given that the objective functions are not normalized. Forinstance, the definite optimal solutions are obtained basedon the parameters presented in the above tables, as shownin Table 4:

Table 2. Numerical examples

Problem Number	(I*J*K)	c_j	c'_k	c''_{jk}	De	r_{ij}	r_0	w_{ik}		w_0
1	[5,6,6]	[10,15]	[1000,3000]	[1.01,0.05]	[700, 950]	[50,500]	[100,300]	[50,500]		[100,300]
2	[10,20,14]	[10,15]	[1000,3000]	[1.01,0.05]	[700,950]	[50,500]	[100,300]	[50,500]		[100,300]
3	[15,12,6]	[10,15]	[1000,3000]	[1.03,0.05]	[700, 950]	[50,500]	[100,300]	[50,500]		[100,300]
4	[15,30,24]	[10,15]	[1000,3000]	[1.03,0.05]	[1000, 1100]	[50,500]	[100,300]	[50,500]		[100,300]
5	[15,30,24]	[10,15]	[1000,3000]	[1.03,0.05]	[700,950]	[50,500]	[100,300]	[50,500]		[100,300]
Problem Number	g_{jk}	q_0	U_0	V_k	d_i	ω	re_j	cre_j	cre'_k	re'_k
1	[50,500]	[100,300]	[300,500]	[1000,2000]	[150,300]	0.9	[0.7, 0.8]	[15,30]	[600,900]	[0.95,0.99]
2	[50,500]	[100,300]	[300,500]	[1000,2000]	[150,300]	0.9	[0.5,0.6]	[15,30]	[100.200]	[0.6,0.8]
3	[50,500]	[100,300]	[300,500]	[1000,2000]	[150,300]	0.9	[0.5,0.6]	[15,30]	[100,200]	[0.6,0.8]
4	[50,500]	[100,300]	[300,500]	[1000,2000]	[150,300]	0.9	[0.5,0.6]	[15,30]	[100.200]	[0.6,0.8]
5	[50,500]	[100,300]	[300,500]	[1000,2000]	[150,300]	0.9	[0.4,0.5]	[15,30]	[100,200]	[0.6,0.8]

Table 3. Final objective function weights

Parameters	Value
W_1	= 0.6
W_2	= 0.8

Table guide: for columns related to decision variables, the number inside the parenthesis indicates the index and the number after the equals sign indicates the amount of variable.

According to Table 3, a number of mobile and permanent facilities are constantly opened and are allocated, donor groups. In addition, any newly developed mobile facility must be covered by a permanent facility, and all donated blood units must be transferred to permanent facilities, which is also shown by the solutions. Moreover, the facility establishment costs and the costs of transferring blood units to from permanent to temporary facilities are minimized. Furthermore, since blood might be lost during the transfer process because of temperature or a traffic accident, existence of blood centers in unsafe locations, or natural disasters (e.g., flood and earthquake), it is necessary to quantify the reliability of these cases using the opinion of experts and enter them into the model. Meanwhile, the second objective function shows this phenomenon as well and only considers the relationship between the permanent and mobile facilities while maximizing the reliability of an important part of BSC. Therefore, it is evident that the higher the number of permanent and mobile facilities, the higher the reliability of the BSC. Evaluation of examples 2-5 sheds light on the issue. In this study, the two-objective mathematical models are solved by obtaining a set of points, each having a superiority related to the objective functions over others (Pareto front or optimal points). The decision-maker determines the reliability obtained per cost minimization at each level. Figure 3 shows the Pareto front of numerical examples by using MOPSO (13). The results are obtained by MATLAB (2015) using a computer with a Corei5@ 2.6 GHz processor.

Before the analysis of the mentioned Pareto fronts, the table related to the Pareto front of the first example must be evaluated based on GAMS results related to algorithm validation (Table 5). According to Figure 3, the solutions obtained from the metaheuristic algorithm are not more efficient, compared to the GAMS solution, but are very close to the optimal solution.

Table 4. Solutions obtained from GAMS software

Problem Number	z_j	z'_k	x_{ij}	x'_{ik}	x''_{jk}	s_{ij}	s'_{ik}	s''_{jk}	Z_1^*	Z_2^*	Z_t^*
1	4,5	3	14,35,44	23,53	43,53	(14) = 188, (35) = 21, (44) = 245	(23) = 186, (53) = 197	(43) = 433 (53) = 21	2003.249	0.901	1201.2286

Table 5. Coordinates of points in the Pareto front (Problem No. 1)

Cost	Reliability
2401.1	0.92303
3439.7	0.95156

3445.3	0.95347
4519.1	0.96374

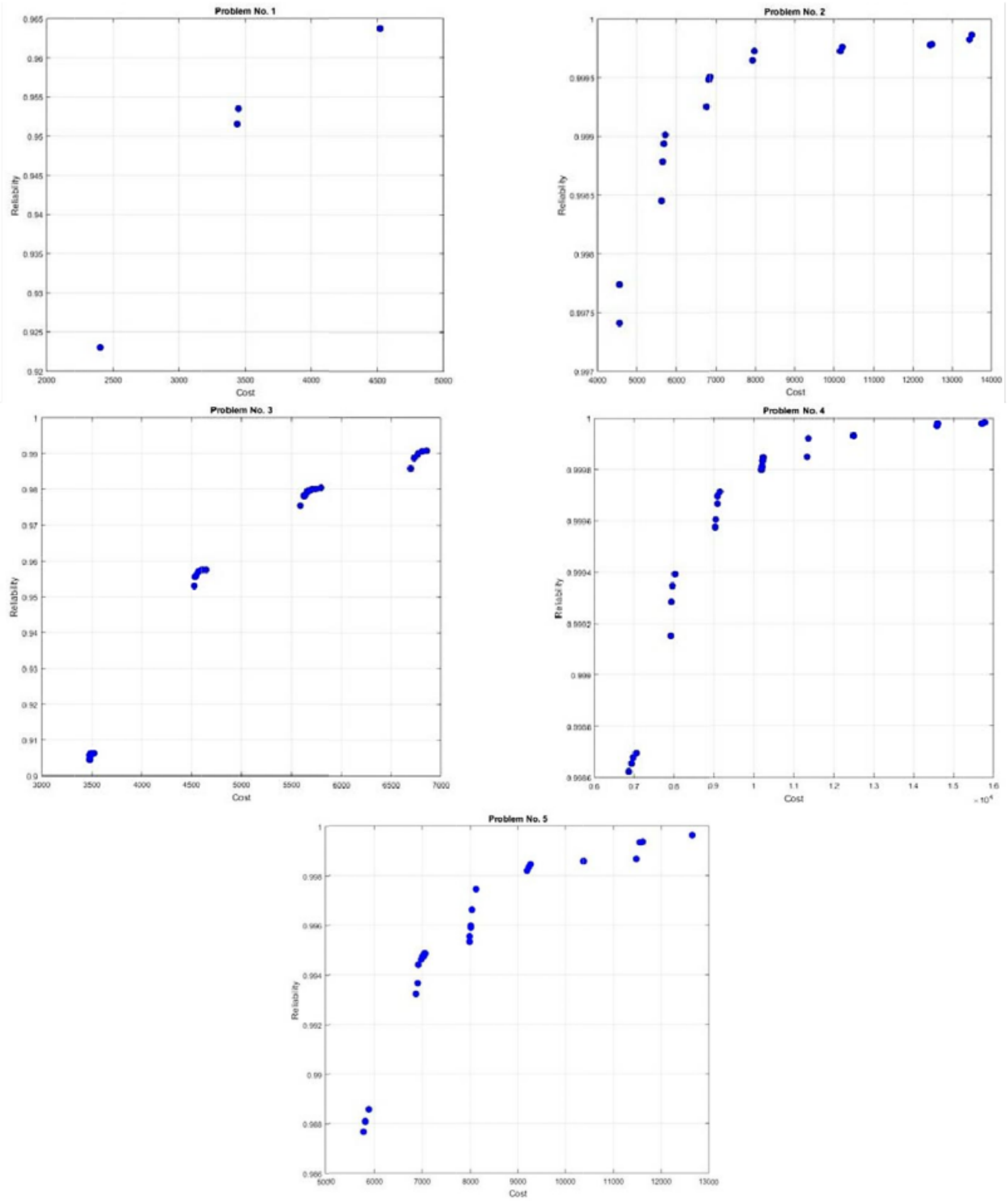

Figure 3. Pareto front of MOPSO

Using the results obtained from solving the numerical examples, which are shown in Figure 3, a low number of feasible solutions are observed in the first example considering the limited number of facilities and inclusion of coverage radiuses. Even though there is a low number of points in the Pareto front, they reveal leaps in cost and reliability axes. Notably, leaps in the horizontal axis (cost) are equal to the cost of the development of a new facility. There is a higher number of points in the Pareto front of numerical examples 2-5 due to the increased number of candidate sites for permanent and mobile facility construction and, consequently, the expansion of the feasible space. Nevertheless, there are some leap points in the diagrams. According to the results, permanent facilities must enter the supply chain in order to achieve higher reliability since new mobile facilities and donors can be entered into the supply chain based on the coverage radius constraints in addition to having higher facility reliability compared to mobile facilities. Evidently, the construction of permanent facilities in earthquake faults and flood routes significantly reduces supply chain reliability. Moreover, the use of mobile facilities in crowded city parts is not justifiable. The results obtained from the calculation of performance criteria of metaheuristic algorithms are shown in Table 6 and Figures 4-6.

Table 6. Performance assessment criteria of metaheuristic algorithms

Problem Number	SM	DM	MID	NPS	CPU Time
1	0.6474	60.5775878	0.9806	3.92789	18.4234
2	1.2271	295.8962835	0.90309	16.2869	25.3377
3	1.4978	200.0393889	0.91617	25.9048	23.2293
4	1.3429	338.1185385	0.96436	24.2849	31.7725
5	1.3421	325.5077473	0.9287	25.6456	31.9444
6	1.3607	353.0762	0.8946	26.8639	33.2092
7	1.4657	367.9130	0.8833	26.9966	34.8230
8	1.4667	379.8476	0.8695	28.9616	37.3222
9	1.5915	392.6784	0.7934	31.5196	38.4757
10	1.7311	417.8472	0.7696	32.2851	39.9435
Mean	1.3673	313.1502	0.8903	24.2677	31.4481

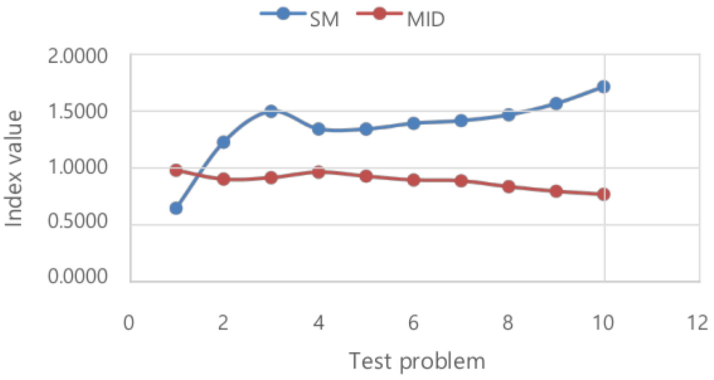

Figure 4. A comparison of SM and MID indices

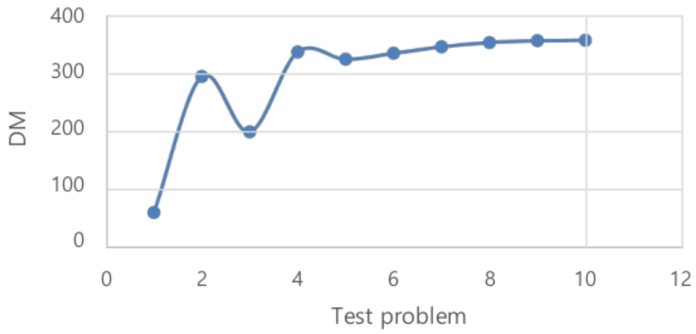

Figure 5. DM index values in various problems.

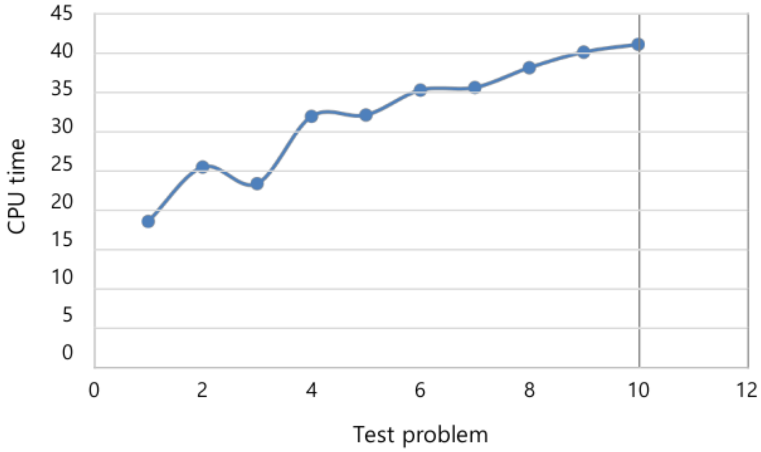

Figure 6. Solution time process in different solved problems

Evaluation and analysis of results in figures 4-6 reveal that the solution complexity increases with increasing the problem's dimensions, such that a significant increase is observed in the solution time. Moreover, the number of Pareto solutions increases with an increase in the problem's dimensions, which is why the SM and DM indices increase while the MID index decreases.

5. CONCLUSION AND RECOMMENDATIONS

The present study evaluated a BSC in a series-parallel form between permanent and mobile facilities for the first time to improve system reliability. A two-objective non-linear mixed-integer model was proposed to strategically and operationally make decisions in a BSC. The objective functions focused on the minimization of costs and maximization of supply chain reliability in a series-parallel system. To validate the model, a numerical example was solved by GAMS and BARON after mathematical modeling, and the results were analyzed. The model's accuracy and efficiency were approved based on its logical solution. In addition, five numerical examples were solved by MOPSO. Notably, the mathematical model was designed based on the BSC of Iran. As mentioned before, the mere increase in the number of mobile facilities will not lead to higher reliability in BSC and an increase in the number of permanent facilities is required in this regard. It is recommended that multi-product (e.g., plasma and platelets) and multi-period models be considered in future studies. In addition, it is suggested the flow of products in the supply chain be considered in reliability calculations. Furthermore, it is recommended that various parameters affecting reliability be evaluated in future studies, and attention be paid to the reliability of blood product isolation facilities.

REFERENCES

Ab Yajid, M. S. (2020a), An analysis of the consumer's price and service quality preferences: A case of airline industry in Malaysia, *Systematic Reviews in Pharmacy*, **11**(1), 808-816.

Ab Yajid, M. S. (2020b), Mediating role of organizational culture on the association between business social responsibility and organization performance in Nigeria, *Systematic Reviews in Pharmacy*, **11**(1), 646-653.

Al-Zyoud, M. F., Al-Mu'ani, L., Alsoud, M., and Alsoud, A. (2021), The role of TQMk in increasing the effectiveness of e-marketing within the jordanian telecommunication sector, *Journal of Theoretical and Applied Electronic Commerce Research*, **16**(5), 1353-1368.

Almansour, B. Y. (2021), The volatility of dow jones conventional and Islamic indices: Does Covid-19 pandemic matter?, *Industrial Engineering & Management Systems*, **20**(4), 795-807.

ALSoud, A. R., Abdeljaber, O., Ab Yajid, M. S., Johar, M. G. M., Al-masaeed, S., and Azam, S. F. (2021), Adoption of information communication technology (ICT) in international entrepreneurship: A way to promote international relations among business entities, *Croatian International Relations Review*, **27**(87), 1-31.

Barzamini, H. and Ghassemian, M. (2019), Comparison analysis of electricity theft detection methods for advanced metering infrastructure in smart grid, *International Journal of Electronic Security and Digital Forensics*, **11**(3), 265-280. – not cited

Blake, J. T. (2009), On the use of operational research for managing platelet inventory and ordering, *Transfusion*, **49**(3), 396-401.

Coelho, L. C., Cordeau, J. F., and Laporte, G. (2012), Consistency in multi-vehicle inventory-routing, *Transportation Research Part C: Emerging Technologies*, **24**, 270-287.

Duan, Q. and Liao, T. W. (2014), Optimization of blood supply chain with shortened shelf lives and ABO compatibility, *International Journal of Production Economics*, **153**, 113-129.

Gunpinar, S. and Centeno, G. (2015), Stochastic integer programming models for reducing wastages and shortages of blood products at hospitals, *Computers & Operations Research*, **54**, 129-141.

Hemmelmayr, V., Doerner, K. F., Hartl, R. F., and Savelsbergh, M. W. (2010), Vendor managed inventory for environments with stochastic product usage, *European Journal of Operational Research*, **202**(3), 686-695.

Jaapar, A. F. Y. B., Helmi, R. A. A., Jamal, A., and Aisha, M. (2020), Employee abuse online reporting application, *International Journal of Medical Toxicology & Legal Medicine*, **23**(1and2), 100-104.

Jagannathan, R. and Sen, T. (1991), Storing crossmatched blood: A perishable inventory model with prior allocation, *Management Science*, **37**(3), 251-266.

Kurilova, A. A. (2021), A mathematical model of the vehicles routing problem of perishable materials using genetic algorithm, *Industrial Engineering & Management Systems*, **20**(2), 315-321. – not cited

Puranam, K., Novak, D. C., Lucas, M. T., and Fung, M. (2017), Managing blood inventory with multiple independent sources of supply, *European Journal of Operational Research*, **259**(2), 500-511.

Qazani, M. R. C., Asadi, H., Bellmann, T., Mohamed, S., Lim, C. P., and Nahavandi, S. (2020), Adaptive washout filter based on fuzzy logic for a motion simulation platform with consideration of joints' limitations, *IEEE Transactions on Vehicular Technology*, **69**(11), 12547-12558. – not cited

Qazani, M. R. C., Asadi, H., Mohamed, S., Lim, C. P., and Nahavandi, S. (2022), An optimal washout filter for motion platform using neural network and fuzzy logic, *Engineering Applications of Artificial Intelligence*, **108**, 104564. – not cited

Rahman, N. R. A., Othman, M. Z. F., Yajid, M. S. A., Rahman, S. F. A. Yaakob, A. M., Masri, R., Ramli, S., and Ibrahim, Z. (2018), Impact of strategic leadership on organizational performance, strategic orientation and operational strategy, *Management Science Letters*, **8**(12), 1387-1398.

Sakinahmohdshukri, S. M. and Bin Jaharadak, A. A. (2020), Role of e-business in the wholesale market of China, *Systematic Reviews in Pharmacy*, **11**(1), 711-717.

Schott, J. R. (1995), *Fault tolerant design using single and multicriteria genetic algorithms optimization*, Master's thesis, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA.

Sudarmilah, E. and Maelani, A. (2021), Augmented reality based-learning media of computers, *Procedia Environmental Science, Engineering and Management*, **8**(4), 819-835.

Zahiri, B., Torabi, S. A., Mousazadeh, M., and Mansouri, S. A. (2015), Blood collection management: Methodology and application, *Applied Mathematical Modelling*, **39**(23-24), 7680-7696.

Zitler, E. and Thiele, L. (1998), Multiobjective optimization using evolutionary algorithms a comparative case study. In: A. E. Eiben, T. Back, M. Schoenauer and H. P. Schwefel (Eds.), *Proceedings of the 5th International Conference on Parallel Problem Solving from Nature*, Berlin, Germany, 292-304.

Zitler, E. and Thiele, L. (1999), Multi objective evolutionary algorithms: A comparative case study and the strength Pareto approach, *Evolutionary Computation, IEEE Transactions on*, **3**(4), 257-271. – not cited

AUTHOR BIO

Optimizing the Issue of Blood Supply Chain Network Design with a Reliability Approach

ORIGINALITY REPORT

2%	0%	2%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Nazanin Haghjoo, Reza Tavakkoli-Moghaddam, Hani Shahmoradi-Moghadam, Yaser Rahimi. "Reliable blood supply chain network design with facility disruption: A real-world application", Engineering Applications of Artificial Intelligence, 2020 Publication	2%

Exclude quotes	Off	Exclude matches	< 2%
Exclude bibliography	On		