A Robust Mathematical Model for Blood Supply Chain Network using Game Theory

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Abstract—No alternative to human blood has been found so far, and the only source is blood donation by donors. This study presents a blood supply chain optimization model focusing on the location and inventory management of different centers. The main purpose of this model is to reduce total costs, including hospital construction costs, patient allocation costs, patient service costs, expected time-out fines, non-absorbed blood fines, and outsourcing process costs. We then calculate the cost savings of collaborating in each hospital coalition to calculate the fair allocation of cost savings across hospitals. The proposed model is developed based on the data for the city of Tehran and previous studies in the field of the blood supply chain as well as using four Cooperative Game Theory (CGT) methods such as Shapley value, τ -Value, core-center and least core, to reduce the total cost and the fair profit sharing between hospitals have been evaluated.

Keywords— Blood Supply Chain; Location-Inventory; Outsourcing; Cooperative; Cost

I. INTRODUCTION

Despite technological advances, there has always been a need for blood donation [1]. On the one hand, blood donation is relatively irregular and on the other hand, the demand for this product is also likely to be permanent and not at a fixed rate [2]. Therefore, it is very difficult to effectively match supply and demand in this chain. In addition, any deficiency in the supply of this vital commodity is very costly and can lead to the death of humans [3]. blood is a perishable product and has a shelf life [4]. The special characteristics of the blood and its expiration impose an enormous waste on the system and add to its complexity [5]. Given these challenges, blood supply chain management has always been a challenge for governments' health systems [6]. In this study, we propose a stochastic planning model for blood inventory management policies that focuses on reducing operating costs, as well as blood shortages and irregularities, along with demand uncertainty and outsourcing. This research specifically addresses the following questions:

- 1) How can inter-clinic collaboration be utilized in the blood inventory management process?
- 2) How can the total cost be reduced in the blood inventory management process?
- 3) How to deal with demand uncertainty in managing blood inventory?

An efficient Blood Supply Chain (BSC) should be able to meet demand while reducing losses and costs. Costs are imposed on the system in several different ways, including costs of collection, testing, segmentation (separation of whole blood into by-products, of which there is a wide range), storage and distribution. However, achieving cost-effective operations for BSC entails a very complex challenge because of the uncertain nature of demand coupled with the short life span of most blood products. To solve this problem, we will use an outsourced hub. In the event of a blood shortage in a particular clinic, the request will be sent to the hospital covered by the same clinic and if the request is not covered, the request will be sent to the nearest clinic and the request will be covered. This is part of the innovation of this paper. Given the fluctuations in blood supply from donors, as blood donors are the sole providers of this chain [7], and the time restrictions for some patients, a time window is considered for storing and distributing blood and its products. The main purpose of this study is to present a mathematical model for the problem of cooperative-based blood inventory management.

The remainder of this paper is presented as a mathematical model is introduced in sections III and IV. In section V, the model is implemented for real data in GAMS software and the results of the model solution are evaluated. Finally, the section VI discusses the concluding remarks with further suggestions.

II. RESEARCH GAP AND CONTRIBUTIONS

Since patients' requests are stochastic, we assume that the demand function follows Bernoulli distribution as the first innovation in this study. We also assume hospitals are overseen by clinics given the sensitivity of supplying demand in the proposed model. These hospitals are used in clinics if there is a shortage of blood. In addition, if there is no blood supply to cover patient demand at the clinic or hospital, the nearest clinic or the hospital covered by that clinic is requested to meet that demand. We call this process as blood outsourcing.

A few articles can be found that used the time window to cover patients' demand, which is another innovation of this study. The time window in the proposed model helps to determine the interval is required to meet the patients' demand. We consider a penalty ρ_i for not meeting patients' demand. This penalty obliges the clinic to refer the claim to a nearby hospital or clinic if it is not available.

Previous researchers have proposed different models for the issue of the blood supply chain, but studies show that there is no study to consider how to model the supply chain problem that several clinics have decided to work with each other. We call this method Co-BSC. At Co-BSC, the agreement between clinics depends on the costs they save when working together. Therefore, an analytical method for estimating cost savings and cost savings allocation should be adopted in Co-BSC, which is another innovation of this study.

The model under consideration seeks to reduce overall supply chain costs. These include clinic construction costs, patient allocation costs, patient service costs, penalties for failure to pay, non-absorbed blood fines, and outsourcing process costs.

III. PROBLEM FORMULATION

In this section, we develop a mathematical model for CGT to independently determine target costs and cell order when operating clinics in designated areas. As mentioned, the first step is to solve this model for a region independently and then to formulate a model for all coalitions between two regions in the next section. Then, the model is solved for all the alliances between the three regions, etc. until a large coalition is reached. We apply the following assumptions to create a CGT model for several regions under non-coalition conditions..

Assumption 1: Clinics are required to provide patients with all blood received. In this model, storage blood is not allowed and the clinic is obliged to send it to other clinics or hospitals if it has excess blood.

Assumption 2: All clinics only offer full blood services. This means that blood products are not produced and delivered in any clinic. This is the same for all clinics and hospitals.

Assumption 3: The distance between clinics and hospitals is the same. This assumption is made to maintain the performance of all clinics uniform. It does not impose any delay on the time wasted when referring the request to other clinics.

Assumption 4: No clinic is allowed to work independently. All clinics form a coherent whole, and single and standalone services are not allowed.

Now, suppose $i = \{1, 2, \dots, I\}$, is a set of clinic indices, and $j = \{1, 2, \dots, J\}$, is a set of available patient indices. In many cases, patients' blood requirements are determined by the "quantity" of those demands. The amount of such requests is in fact the amount of clinic capacity that must meet those demands. In this study, each blood request is considered a unit, meaning that each request uses one unit of the relevant clinic capacity. The blood requirement of each patient is represented by a random variable γ_j , so that if patient j requires blood, this variable will take a value of one, otherwise zero. Thus, in this study, it is possible that some patients may have had some or no blood. Since patient requests follow a probability distribution function, the random variable γ_j is expressed as follows. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

$$\gamma_j = \begin{cases} 1, & p_j, \\ 0, & 1 - p_j, \end{cases} \quad \forall j \in J, \quad (1)$$

Where parameter p_j indicates the probability of requesting a patient's blood. In this study, it is assumed that the variable γ_j has a Bernoulli distribution function, so the probability function γ_j can be written as follows.

$$f(\gamma_j, p_j) = p_j^{\gamma_j} (1 - p_j)^{1 - \gamma_j}, \quad \forall j \in J, \quad (2)$$

This means that every patient with p_j probability has a demand and with probability $1 - p_j$. In addition, given that time plays a vital role in the supply chain and sometimes even minutes may result in the death of a patient, we set a strict time window to serve patients promptly. In this time window, clinics are required to serve patients at scheduled times, otherwise, they would have to pay the penalty specified by ρ_i . The notations used in this study are as follows:

k	Volunteers donate blood
g_{ki}	Volunteer Referral to Clinic for Blood Donation
μ_{ki}	The number of volunteers who went to the clinic i but the clinic was unable to absorb their blood.
f_i	Fixed costs for building a clinic at the candidate's place.
co_{ij}	The cost of allocating j patient to the clinic i .
cs_{ij}	Cost of patient service j from clinic i .
α_i	The cost of outsourced blood supply to the clinic i by the hospital covered by this clinic.
$\beta_{ii'}$	The cost of outsourcing blood to clinic i by another clinic $i' \in I \setminus i$.
Δa_i	Early service time for clinic i .
Δb_i	Amount of service delay time for i .
e_i	The earliest when any patient request can be covered.
T_i	The length of time window for blood to be delivered to the patient at the i
ρ_i	Penalty for violation of unit time for each clinic i
δ_i	Penalty for failure to absorb any blood units by clinic i
s_i	Maximum number of patients who cannot receive service from Clinic i .
n_i	Maximum number of requests from the clinic i .
M	A big number

In addition, we assume that when a clinic is built, at least l_i patients should be allocated to it. We also consider σ_i as the upper limit for the number of patients who can be referred to clinic i , and τ_i as the upper limit for the number of patients who can be served at the hospital covered by clinic i . In the follow-up to this study, we call every patient requesting blood. We also assume that each clinic has a limited capacity and a hospital that also has a capacity limit. Note that the capacity limitation of both clinics and hospitals reflects the maximum number of patients who can receive services from these clinics and hospitals and does not affect the number of patients that can be assigned to each clinic. Therefore, our model is likely to outnumber the capacity of patients assigned to a clinic.

To meet these surplus demands, we refer to other clinics or hospitals under their cover, this process is called "outsourcing" (Fig. 1). In addition, these surplus demands are called "outsourced demand". Now if Ω_i represents the set of patients

assigned to clinic i and φ_i represents the number of patients assigned to clinic i (i.e., $\varphi_i = \sum_{j \in \Omega_i} \gamma_j$). If, among the patients assigned to clinic i , their number does not exceed the limit of σ_i , then all those patients will be referred from the respective clinic. Otherwise, if the value of φ_i exceeds the upper limit of σ_i , we will refer to an outsourcing policy to resolve this discrepancy. Outsourcing can be done here in several ways. We know that each clinic i , $i \in I$, has a hospital with a high limit of τ_i .

Fig. 1. Illustrates the relationships between clinics, hospitals, donors, and patients

In addition, any clinic can refer to other clinics or hospitals under their cover to meet outsourced requirements. If $\sigma_i < \varphi_i \leq \sigma_i + \tau_i$, the Clinic i could initially use its corresponding hospital capacity to meet these outsourced demands. If $\varphi_i > \sigma_i + \tau_i$ (that is, when the number of patients referred to clinic i is greater than the total capacity of the clinic and the hospital capacity covered), clinic i must first go to other clinics with free capacity (when $\varphi_{i'} < \sigma_{i'}, i' \in I \setminus i$). If there is no clinic with free capacity (that is, when $\varphi_{i'} \geq \sigma_{i'}, i' \in I \setminus i$), the clinic can refer to their hospitals. Each of these outsourcing processes has a specific cost that is added to the total cost function if it occurs.

It is important to know that for each hospital, service to its respective clinic is a priority. This means that each hospital will first serve its respective clinic and if it has the capacity, it can provide it to other clinics if needed. On the other hand, there is a possibility that the volunteer k is referred to clinic i for blood donation (μ_{ki}), and for whatever reason clinic i cannot absorb the donated blood. To formulate the mathematical programming of this model, a set of variables is considered as follows.

IV. MATHEMATICAL MODEL

We are also looking to find the optimal clinic location through a range of candidate locations and allocate patients with potential clinic demand and capacity resources. The objective function seeks to minimize total costs, including clinic construction costs, patient allocation costs, and service costs, penalties for failure to meet expected time, non-absorbed blood fines, and outsourcing process costs. To formulate the model, several binary variables are defined as follows.

$U_{i,j}$	1 if no clinic can serve patients until the time window is completed, 0 otherwise.	$\forall i \in I, j \in J$
q_i	1 if a clinic built in the i place, 0 otherwise.	$\forall i \in I$
z_{ij}	1 if patient j is assigned to clinic, 0 otherwise.	$\forall i \in I, j \in J$
Y_{ki}	1 if volunteer goes to clinic i for blood donation, 0 otherwise.	$\forall i \in I, k \in N$
$r_{ii'}$	The number of outsourced applications from my clinic i that have been funded by clinic i'	$\forall i, i' \in I, i' \neq i$
$v_{ii'}$	The number of outsourced applications from my clinic i that have been funded by hospital i'	$\forall i, i' \in I, i' \neq i$

$$\psi_i = \begin{cases} 1, & \sigma_i - s_i \geq 0, \\ 0, & o.w., \end{cases} \quad \forall i \in I, \quad (3)$$

$$\lambda_i = \begin{cases} 1, & s_i - \sigma_i \geq 0, \\ 0, & o.w., \end{cases} \quad \forall i \in I, \quad (4)$$

$$\omega_i = \begin{cases} 1, & \tau_i - (s_i - \sigma_i)\lambda_i \geq 0, \\ 0, & o.w., \end{cases} \quad \forall i \in I. \quad (5)$$

The objective function of the problem can be described as follows. If we have considered $\mathbb{E}_\gamma$ as an expected value, Therefore:

$$\begin{aligned} \text{Min} \quad & \sum_{i \in I} f_i q_i + \sum_{i \in I} \sum_{j \in J} c o_{ij} z_{ij} + \sum_{i \in I} \sum_{j \in J} p c s_{ij} z_{ij} \\ & + \sum_{i \in I} \rho_i (\Delta a_i + \Delta b_i) \\ & + \sum_{i \in I} \sum_{k \in K} \delta_i \mu_{ki} Y_{ki} \\ & + \mathbb{E}_\gamma [\text{Service cost} \\ & + \text{Outsourcing cost}], \end{aligned} \quad (6)$$

Where:

$$\begin{aligned} \mathbb{E}_\gamma [\text{Service cost} + \text{Outsourcing cost}] \\ = \mathbb{E}_\gamma [\text{Service cost}] \\ + \mathbb{E}_\gamma [\text{Outsourcing cost}], \end{aligned} \quad (7)$$

Finally, using expressions (1) - (7) the proposed mathematical model is formulated as follows.

$$\begin{aligned} \text{Min} \quad & \sum_{i \in I} f_i q_i + \sum_{i \in I} \sum_{j \in J} c o_{ij} z_{ij} + \sum_{i \in I} \sum_{j \in J} p c s_{ij} z_{ij} \\ & + \sum_{i \in I} \sum_{k \in K} \delta_i \mu_{ki} Y_{ki} \\ & + \sum_{i \in I} \rho_i (\Delta a_i + \Delta b_i) + \left[\sum_{i \in I} \alpha_i \sum_{s_i = \sigma_i + 1}^{\sigma_i + \tau_i} \binom{n_i}{s_i} p^{s_i} (1 \right. \\ & \left. - p)^{n_i - s_i} [s_i - \sigma_i] \right] \end{aligned} \quad (8)$$

$$+ \left[\sum_{i \in I} \sum_{s_i = \sigma_i + \tau_i + 1}^{\sigma_i + \tau_i + \sum_{i' \in I \setminus i} \sigma_{i'} + \sum_{i' \in I \setminus i} \tau_{i'}} \binom{n_i}{s_i} p^{s_i} (1-p)^{n_i - s_i} [\alpha_i \tau_i + \sum_{i' \in I \setminus i} (\beta_{ii'} r_{ii'} + (\alpha_i + \beta_{ii'}) v_{ii'})] \right]$$

The first and second parts of the objective function respectively show clinic construction costs among candidate locations and the allocation of patients to the constructed clinic. The third part represents the cost-benefit function of the patient service and the fourth part shows the outsourcing costs of the clinic.

$$\sum_{i \in I} \sum_{j \in J} z_{ij} \quad (9)$$

$$\leq \sum_{i \in I} (\sigma_i + \tau_i) q_i, \quad (10)$$

$$\sum_{i \in I} n_i \leq \sum_{i \in I} \sigma_i + \sum_{i \in I} s_i + \sum_{i \in I} \tau_i, \quad (11)$$

$$\sum_{i \in I} n_i \leq \sum_{i \in I} l_i \quad (11)$$

$$\sum_{i \in I} z_{ij} = 1, \quad \forall j \in J, \quad (12)$$

$$\sum_{k \in K} \mu_{ki} \leq \sum_{k \in K} g_{ki} \quad \forall i \in I, \quad (13)$$

$$\sum_{j \in J} z_{ij} \geq q_i l_i, \quad \forall i \in I, \quad (14)$$

$$\sum_{i' \in I \setminus i} r_{ii'} + \sum_{i' \in I \setminus i} v_{ii'} \geq s_i \quad \forall i, i' \in I, i' \neq i, \quad (15)$$

$$\sum_{i \in I} r_{ii'} \leq (\sigma_{i'} - s_{i'}) \psi_{i'}, \quad \forall i, i' \in I, i' \neq i, \quad (16)$$

$$\sum_{i \in I} v_{ii'} \leq (\tau_{i'} - s_{i'}) \lambda_{i'}, \quad \forall i, i' \in I, i' \neq i, \quad (17)$$

$$\leq (\tau_{i'} - (s_{i'} - \sigma_{i'}) \lambda_{i'}) \omega_{i'}, \quad (18)$$

$$2\sigma_{i'} \psi_{i'} - 2s_{i'} \lambda_{i'} \geq \sigma_{i'} - s_{i'}, \quad \forall i, i' \in I, i' \neq i, \quad (19)$$

$$2\tau_{i'} \omega_{i'} - 2s_{i'} \lambda_{i'} \omega_{i'} \geq \tau_{i'} - s_{i'}, \quad \forall i, i' \in I, i' \neq i, \quad (20)$$

$$+ 2\sigma_{i'} \lambda_{i'} \omega_{i'} \geq \tau_{i'} - s_{i'} \lambda_{i'} + \sigma_{i'} \lambda_{i'}, \quad (21)$$

$$t_0 - T_i \leq M \cdot u_{ij} \quad \forall i \in I, j \in J \quad (22)$$

$$\Delta a_i \geq e_i - t_0 \quad \forall i \in I, \quad (23)$$

$$\Delta b_i \geq t_0 - T_i \quad \forall i \in I, \quad (24)$$

$$q_i, z_{ij}, \psi_{i'}, \lambda_{i'}, \omega_{i'} \in \{0,1\}, \quad \forall i, i' \in I, i' \neq i, j \in J, \quad (25)$$

$$s_i, s_{i'}, r_{ii'}, v_{ii'} \in \text{integer}, \quad \forall i, i' \in I, i' \neq i, j \in J, \quad (25)$$

Clinic capacity constraints are expressed by constraints (9). Constraints (10) and (11) guarantee the current balance. Constraint (12) ensure that each patient is assigned to only one clinic. Constraints (13) indicates that the number of volunteers whose blood donation is not absorbed cannot exceed the total number of volunteers. Constraint (14) indicate the minimum number of patients to be assigned to each clinic. Constraints (15)

provide the minimum number of outsourced applications per clinic. Constraint (16) specify the maximum number of capacities each clinic can provide to meet the outsourced demands of another clinic. Constraint (17) indicate the maximum number of capacity that each clinic's hospital can provide to meet the outsourced demands of another clinic. Constraints (18) indicate, when clinic i' is able to provide additional capacity to another clinic, the variable $\psi_{i'}$ takes the number (1), otherwise Zero, we replaced. Constraints (2) and (3) guarantee that, when a clinic's hospital is able to deliver its capacity to another clinic, the variable $\lambda_{i'}$ takes a number, otherwise zero, and with a Constraints (19) and (20) are replaced in the proposed model. Restriction (21) ensures that no clinic can serve patients before the time window. Constraints (22) and (23) relate to the time window. Constraints (24) and (25) represent the variables of zero and one integer, respectively.

V. CASE STUDY

The case study is carried out in three districts of Tehran. In each of these areas, there is a populated area with several clinics. There is also a hospital for each clinic to use as a precautionary reserve if blood is needed. These clinics can also serve patients in addition to the task of keeping blood. Routes between clinics and hospitals have also been determined. We divide the city of Tehran into three regions. Figure 2. shows an overview of infirmaries and hospitals in Tehran.

Fig. 2. Shows the collaboration between infirmaries.

The utility of the network for each coalition situation should be greater than the sum of the utility of the network for each of the three areas and the coalition members as shown in the following relation [8, 9].

$$v(C_m) \geq \sum_{p_i \in C_m} v(P_i) \quad \forall C_m \in P \quad (26)$$

In the above relation, $v(C_m)$ is the utility of C_m and $v(P_i)$ is the utility of each coalition member. P is also a collection of players or members of the coalition. For example, for a network of 3 members, the 3 member coalition must be greater than the single coalition and the two members of that network. [10].

$$EU(C_m) = v(C_m) - \sum_{p_i \in C_m} v(P_i) \quad (27)$$

The above relationships are favorable for a mathematical model and change to a cost-saving model as follows.

$$v(C_m) \leq \sum_{p_i \in C_m} v(P_i) \quad \forall C_m \in P \quad (28)$$

$$EU(C_m) = \sum_{p_i \in C_m} v(P_i) - v(C_m) \quad (29)$$

The additional utility generated or the cost savings to be made should be assessed with regard to the utility of the coalition members, following which is a reliable scale for calculating coalition cooperation [11].

$$Synergy(C_m) = \frac{EU(C_m)}{v(C_m)} \quad (30)$$

Since the proposed model is a minimization model with the aim of reducing total costs and unmet demand, the cost reduction in the 7 coalitions together with the synergy criterion is given in the Table I.

TABLE I. COSTS OF COALITIONS AND COALITION SYNERGIES

Coalition	Coalition Cost (TC)	Cost Reduced (CS)	Synergy
{1}	265268740	0	0
{2}	326214960	0	0
{3}	296534210	0	0
{1,2}	585624820	5,858,880.00	0.010004494
{1,3}	556356140	5,446,810.00	0.00979015
{2,3}	616326540	6,422,630.00	0.010420823
{1,2,3}	878628400	9,389,510.00	0.010686554

In the table above, the results of cooperative games distribution methods using TU Glab code in MATLAB software are calculated and shown in the following Table II.

TABLE II. COST SAVINGS ALLOCATION BASED ON DIFFERENT COOPERATIVE PLAY METHODS

Areas	Shapley value	τ -value	Core Center	Least Core	ESM
1	2873241.66	2616646.6	4096005.3	2966880	3681670
2	3361151.66	3592466.6	4300475.3	2892000	3681670
3	3155116.66	3180396.6	2202939.2	3530630	3681670

In Table II, the results of cooperative games distribution methods using TU Glab code in MATLAB software are calculated and shown in Figure 3.

Fig. 3. Core space and values created in CGT methods

The green space in the images above shows the Core. If in a collaborative game with 3 players the Core space touches each side created by the assigned ratios, it is said to be convex [12].

Given the above, this game is not convex. Figure 3 shows the set space of the assigned ratios and the set of core and values created in the methods presented in the collaborative game in the Core space are specified. In the figure above, the savings shown by reducing the cost allocated to the first and second triple zones are shown. The amount assigned to the third player is implicit.

Coalition C satisfaction with allocation ratios $\vec{y} = (y_1, y_2, \dots, y_n)$, the difference between the cost savings (assigned utility) of the total coalition, and the cost savings (utility) that if Coalition C executes independently, is defined and is as follows [13]:

$$F_s(C, \vec{y}) = \sum_{i \in C} y_i - CS(C) = -e(C, y) \quad (31)$$

The relative satisfaction is also equal to:

$$\frac{F_s(C, \vec{y})}{v(C)} \quad (32)$$

According to Table II, the percentage of alliance satisfaction decreases as the alliance grows. In addition, the degree of satisfaction of each region in the formed coalitions depends on the structure of the supply chain network under different scenarios. Figure 4. shows a sensitivity analysis of cooperative gaming techniques.

Fig. 4. Sensitivity analysis of the results of CGT techniques

Based on the sensitivity analysis and the above illustrations, it is clear that in all methods of cooperative games, there is a downward trend for the three regions.

VI. CONCLUSION AND FURTHER RESEARCH

This study has targeted private clinics in Tehran who want to share their additional capacity. This leads to more demand being met. In other words, the outsourcing process by the hospital of the same clinic (if possible) or another clinic or hospital covered by another clinic covered the surplus demand of one clinic. It was also a step towards bringing the proposed model to reality by considering the demand function as a Bernoulli distribution function.

On the other hand, a mathematical programming model for Co-BSC has been developed for the problem of supply chain management in this research. Using the concept of the CGT, Collaborative Game Theory, it has been shown that by forming a coalition, clinics are able to reduce total costs by sharing

capacities. In fact, the synergy of their cooperation creates incentives for clinics to organize large alliances. Of course, the successful implementation of Co-BSC depends on a fair sharing of cost savings on collaboration that encourages clinics to continue.

In this study, clinics only offer whole blood to patients. Blood products including platelets, plasma, etc. can be considered. Also, this study does not include the blood groups, which can be addressed in future research. This study also assumes that all players are ready to share the total extra capacity.

REFERENCES

- [1] J., Beliën, H., Forcé. Supply chain management of blood products: A literature review, *European Journal of Operational Research*, Volume 217, Issue 1, Pages 1-16, 2012.
- [2] Z., Hosseini, B., Abbasi. The inventory centralization impacts on sustainability of the blood supply chain, *Computers & Operations Research*, Volume 89, Pages 206-212, 2018.
- [3] Q., Duan, T.W., Liao. Optimization of blood supply chain with shortened shelf lives and ABO compatibility. *International Journal of Production Economics*.153, 113-129, 2014.
- [4] Zahiri, B., Ali Torabi, S., Mohammadi, M., Aghabegloo, M., 2018. A multi-stage stochastic programming approach for blood supply chain planning, *Computers & Industrial Engineering*, Volume 122, August 2018, Pages 1-14.
- [5] M., Dillon, F., Oliveira, B., Abbasi. A two-stage stochastic programming model for inventory management in the blood supply chain, *International Journal of Production Economics*, Volume 187, Pages 27-41, 2017.
- [6] S., Rajendran, Ravi., Ravindran. Inventory management of platelets along blood supply chain to minimize wastage and shortage, *Computers & Industrial Engineering*, Volume 130, Pages 714-730, 2019.
- [7] H., Heidari-Fathian, S. H. R., Pasandideh. Green-blood supply chain network design: Robust optimization bounded objective function & Lagrangian relaxation, *Computers & Industrial Engineering*, Volume 122, Pages 95-105, 2018.
- [8] J., Valizadeh, P., Mozafari. A novel cooperative model in the collection of infectious waste in COVID-19 pandemic. *Journal of Modelling in Management*, 2021.
- [9] J., Valizadeh, M., Aghdamigargari, A., Jamali, U., Aickelin, S., Mohammadi, H. A., Khorshidi, A., Hafezalkotob. A hybrid mathematical modelling approach for energy generation from hazardous waste during the COVID-19 pandemic. *Journal of Cleaner Production*, 315, 128157, 2021.
- [10] F., Akbari, J., Valizadeh, & A., Hafezalkotob. Robust cooperative planning of relief logistics operations under demand uncertainty: a case study on a possible earthquake in Tehran. *International Journal of Systems Science: Operations & Logistics*, 1-24, 2021.
- [11] M., Tavanayi, A., Hafezalkotob, J. Valizadeh. Cooperative cellular manufacturing system: A cooperative game theory approach. *Scientia Iranica*, 2020.
- [12] A, Hafezalkotob, A., Makui. Cooperative maximum-flow problem under uncertainty in logistic networks. *Applied Mathematics and Computation*, 250:593-604, 2015.
- [13] S., Lozano, P., Moreno, B., Adenso-Díaz, E., Algaba. Cooperative game theory approach to allocating benefits of horizontal cooperation. *European Journal of Operational Research*, 229(2):444-52, 2013.

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