Journal of Medical Systems (2019) 43: 28
https://doi.org/10.1007/s10916-018-1141-0

SYSTEMS-LEVEL QUALITY IMPROVEMENT

An Analysis of Re-configured Blood Transfusion Network of Urban India to Improve the Service Level: a Simulation Approach

S. Selvakumar[1] · P. Shahabudeen[1] · T. Paul Robert[1]

Received: 31 October 2018 / Accepted: 17 December 2018 / Published online: 3 January 2019

Abstract

In India, blood banks are owned by state hospitals, private hospitals, NGOs and private laboratories. The aim of this study is to improve the service levels of the blood supply chain by maximizing the availability and minimizing the wastage of blood. New configuration approaches are adapted from the successful methods of manufacturing sectors. In this retrospective cross-sectional study, whole blood (WB) demand and supply data between April 2015 to March 2016 has been taken. Data analytics tool "R" is used for statistical analysis. Two new configurations, namely a) Zonal Network and b) Pull system models have been developed to compare the existing blood supply chain. The performances of the proposed configurations have been compared with the existing system using suitable indicators computed using Arena simulation software12.0. The total shortage index (TSI) and total wastage index (TWI) are used as indicators of performance measures. Weights are assigned for shortage and wastage indices to the reconfigured models. The pull system model outperforms existing model and zone model by achieving zero wastage. In transfusion medicine, importance is given to the achievement of lesser percentage shortage than wastage. If the WB inventory in blood centers is sufficient enough and we have more than one zone for distribution, then we can reduce wastages level in the blood supply chain.

Keywords Healthcare supply chain · Blood transfusion · Data analytics · Clustering · Pull system · Simulation

Introduction

The supply chain network of blood in India comprises of government blood banks, private hospital blood banks, and voluntary blood banks. According to the report "Assessment of Blood banks in India – 2016" released by NBTC (National Blood Transfusion Council) and NACO, the annual blood collection from 2760 blood banks across India during 2015 was 11,645,790 units [1]. Out of this, voluntary blood donations contribute to 71.9 percentage and the remaining from replacement donations. The study by Shukla (2007) reveals that the deficit of blood in some states of India is of the order 20–50 percentage [2]. The majority of the blood banks (76 percentage) are attached to hospitals, 22 percentage are standalone and the remaining 2 percentage are attached to laboratories. Many methodologies have been applied to find solutions and insights that would improve the efficiency and effectiveness of the blood supply chain.

Garraud et al. (2017) have observed more business-like models of transfusion medicine creating a less humanistic approach between the patients and the service providers [3]. They have developed a model which strongly believes that transfusion medicine can reconnect its roots by adapting care and cure with a humanitarian approach. Pierskalla et al. (2005) have provided a broad analysis including different network configurations, location, allocation and distribution decisions as well as areas for further research such as scheduling of donors, planning the production and distribution [4].

Katsaliaki (2008) has recommended alternative policies and has tested on the computer simulation model [5]. This result helps to identify ordering, inventory and distribution practices towards a more cost-effective management of the blood supply chain in the UK. It also proves that simulation was the best tool for blood bank problems and it provides a great range of experimental capabilities in a risk-free environment.

This article is part of the Topical Collection on *Systems-Level Quality Improvement*

✉ S. Selvakumar
selva68annaunivedu@gmail.com

[1] Department of Industrial Engineering, College of Engineering Guindy, Anna University, Chennai 600025, Tamilnadu, India

Erhabor and Adias (2011) have recommended the importance of blood components therapy and also suggested that blood safety in developing countries can be improved by more appropriate use of blood components rather than whole blood transfusion [6]. Alfonso et al. (2012) have developed a simulation-based model of blood collection systems for both fixed as well as mobile blood collection centers with walk-in whole blood donors and scheduled donors [7].

Dhingra (2013) has suggested a holistic approach to policy development and planning for a self – sufficient safe blood and blood products based on VNRBD [8]. Lowalekar and Ravichandran (2013) have reported literature such as demand estimation of blood products, ordering and collection policies, issuing and cross-matching policies, componentizing policies, effects of substitution and extending the lifetime, blood collection and distribution planning, information systems enabled operations of blood products and briefing about the future research opportunities in the Indian blood bank [9].

Alfonso et al. (2013) have studied management of donor appointments on day to day basis [10]. They have found that the donor service level are depended on both adequate human resources capacity and appropriate appointment strategies. Duan and Liao (2014) have proposed ABO compatible substitution, which has been showing a clear trend of the increased use of group O blood [11]. Varela and Tjahjono (2014) have tried to bridge the gap between big data analytics and supply chain management [12]. They have also recommended shifting from standard supply chain approach to a combined approach of supply chain management and data analytics to have a greater understanding of the system and attain higher efficiency.

Jabbarzadeh et al. (2014) have extensively focused on location and allocation decisions on blood supply chain network design of disaster-affected zones. Their robust optimization approach has outperformed the Expected Value approach [13].

Ganesh et al. (2014) have given cost-effective routing solutions for managers with information on quantities to be delivered and collected being known by the end of the previous day, by the proposed heuristic that can be conveniently incorporated in a decision [14]. Bhatia et al. (2016) have mentioned that Indian blood transfusion network is plagued by an inadequacy of blood storage centers due to corporate sector's dominance in all the aspects such as technology, business model, IT structure and investment policies [15]. The challenges to overcome such hindrances may be the unification of blood transfusion services to maintain the standard, cooperation between different national agencies to ensure safe blood and blood products and risk-free transfusion. Lowalekar and Ravi (2017) have shown that for complex systems, TOC's thinking process tools can be extremely powerful in constructing win-win solutions [16].

Hosseinifard and Abbasi (2018) demonstrated that centralization of hospitals' inventory is a key factor in the blood supply chain and can increase the sustainability and resilient of the blood supply chain [17]. The second tier hospitals receiving external demands other than their own demands which in close proximity (within 250mts to 900mts distance). By doing that it was observed that reducing the number of hospitals that hold inventory from 7 to 3 decreases outdated and shortage in the supply chain by 21 percentage and 40 percentage respectively.

Ramezanian and Behboodi (2017) have proposed a deterministic location-allocation model by applying a mixed integer linear programming (MILP) optimization [18]. The aim was to increase utility and motivate blood donors to donate blood. Due to the stochastic nature of demand and cost parameters, the aforementioned model has been developed to incorporate uncertainty using a robust optimization approach that can overcome the limitations of scenario-based solution methods, i.e., without excessive changes in complexity of the underlying base deterministic model. Rajmohan et al. (2017) have proposed a facility location model which provides solutions for locating the organ procurement organizations (OPOs) and their associated transplant centers [19]. This paper demonstrated how the efficiency of the Indian healthcare system improved when locations of services are taken into accounts. Wang et al. (2015) have reviewed many papers about services supply chain and they focused on reviewing those works that apply OR tools to achieve better business decisions for the service supply chain [20].

Osorio et al. (2018) redesign the national blood supply chain under a range of realistic travel time limitations. They concluded that centralized systems are more efficient than decentralized systems [21]. But the latter may be preferred for political or geographical reasons. Their model allows decision-makers to redesign the supply network per local circumstances and determine optimal collection and production strategies that minimize total costs. Su and Lu (2018) formulated mixed integer programming model to work out the optimal allocation network scheme and the optimal inventory setting for every department within a government hospital of shanghai [22]. The results of the numerical example demonstrate that this centralization method could considerably reduce blood shortage and wastage in hospital by about 72 percentage and 90 percentage respectively.

Nagurney and Masoumi (2012) have developed a sustainable network design with a multicriteria system-optimization approach [23]. It captured several critical concerns associated with blood banking systems including but not limited to the determination of the optimal capacities and the optimal allocations, the induced supply-side risk, and the induced cost of discarding potentially hazardous blood waste, while the uncertain demand for blood is satisfied as closely as possible. Testik et al. (2012) have utilized the Two-Step Cluster method and the Classification and Regression Trees method in succession to identify both daily and hourly blood donor arrival patterns [24]. Data mining and clustering techniques are used to understand the donor arrival pattern Discovery of these patterns are especially important for managerial decisions on the workforce requirement plans. Blake and Hardy (2013) have studied the service level of blood supply network in Canada when they merge two facilities into a single production facility by the simulation tool [25].

In this study the research questions considered are (i) effectively address the shortages and wastages of the precious lifesaving product by reconfiguring the existing configuration of the Indian blood banking system and (ii) assess the change in the performance measure of the existing blood supply chain when the region taken is clustered into more than two zones.

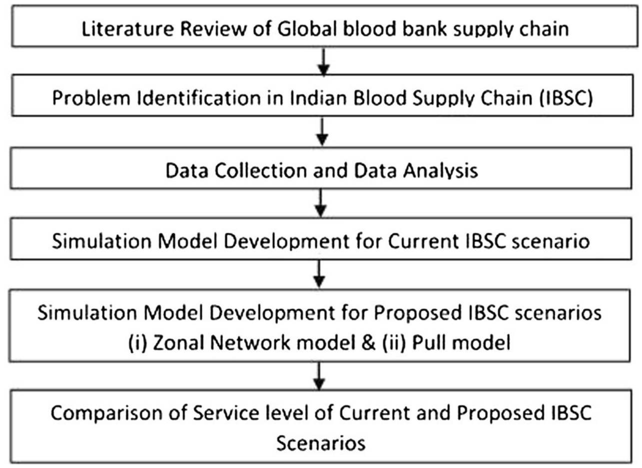

Fig. 1 Flowchart for the Methodology

Material and methods

In this retrospective cross-sectional study, whole blood cell (WBC) demand and supply data between April 2015 to March 2016 has been taken. This blood center is serving the demands of 152 large and medium size multispecialty hospitals in Chennai, an Indian urban city. Using R environment, the data have been analyzed to find out the patterns and distribution of each blood group and statistical analysis such as the mean, median, standard deviation for each group are determined. The whole blood - group wise details are given in Table 1.

Model development

Whenever an order for blood is generated the stock is verified for the specific group of blood. If the stock is available, the demand is fulfilled and the stock at the blood bank is updated. If the stock is not sufficient, then possible demand size is dispatched and the shortage is updated. Figure 1 shows the flowchart for the methodology section which will help in understanding the structure of the paper.

The Shelf life of blood is 42 days. That is considered as a constraint in a simulation model. In this study the authors assumed the first in first out (FIFO) queuing policy to model the blood supply chain. This is the policy normally followed by blood bank managers to avoid wastages due to outdating of blood. This study is focusing on whole blood only which has the shelf life time of 42 days. If a blood product crossed 42 days in inventory from the time of collection date, it has to add in the discarded inventory, which will be sent out of the system. The possible next four events in the model are arrival of supply, expiry of blood, demand arrival and end simulation. Figure 2 represents the Arena model of the existing blood supply chain.

Warm up time or the transient period is the duration of time until which the simulation model doesn't give a consistent output or in other words achieves a steady state. From the start time to the warm-up time, the output given by the model will be an unreliable representation of the system being analyzed. So the warm-up time is taken as 1000 h. The simulation of the model was run for a period of one year. That is 365 days, which equates to 8760 h. The model was replicated twenty times to get more accurate results by leveling the variations.

Table 1 Demand and Supply Distribution of Indian urban blood supply chain

Sl. No.	Blood Group	Demand			Supply		
		Distribution	Mean	SD	Distribution	Mean	SD
1	O + VE	beta	1.79,	9.73	Beta	0.558	1.33
2	O–VE	expo	1.41	–	Weibull	2.57	0.611
3	A + VE	beta	1.83	13.5	Normal	45.8	30.6
4	A–VE	expo	1.37	–	Beta	0.112	0.387
5	B + VE	beta	0.863	2.91	Beta	0.518	0.875
6	B-VE	expo	1.19	–	Beta	0.212	0.925
7	AB+VE	expo	2.8	–	Beta	0.29	0.709
8	AB-VE	expo	0.828		Beta	0.947	0.71

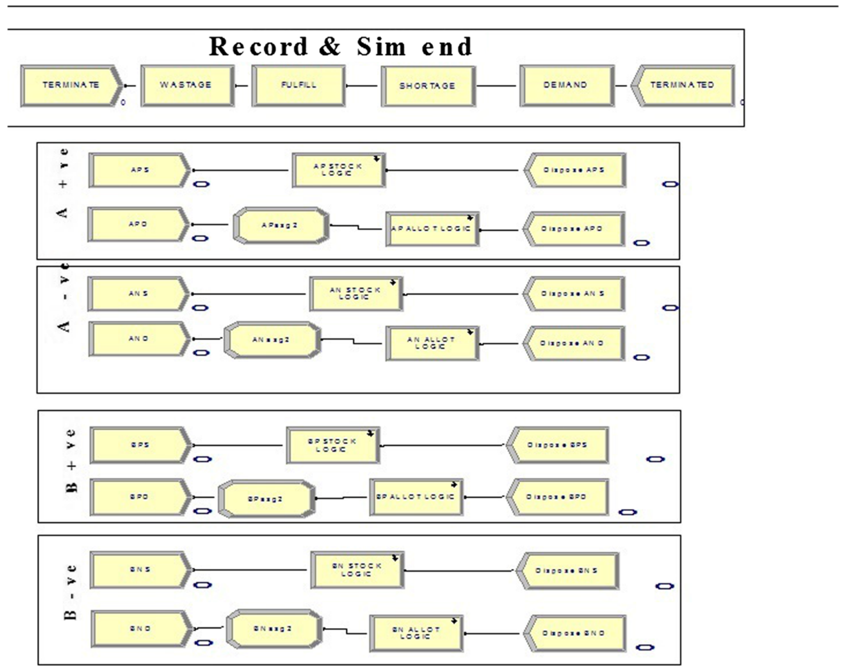

Fig. 2 Arena model of Existing supply chain

Proposed strategies

Zonal Network Model (ZNM) by clustering of the hospitals

In the Indian context, the question of surplus is not at all in a picture as nearly 20 percentage of a shortage is encountered on an average every year. But in the case of an organization of special donation camps, a lot of surplus and wastage happens. Our model does not capture the stochastically of such instances through the proposed model has the adaptability as we decentralizing and increase the number of zones, the surplus is shared within the zones without any wastage as suggested by the results.

The agglomerative approach of hierarchical clustering was used to cluster 152 hospitals that the blood bank was serving in the one-year period. Clustering was done based on the distance obtained from the longitude and latitude data of the hospitals as shown in Fig. 3. This process was repeated for the clusters formed with an objective to lower the total demand per cluster. The clustering of the center was done based upon the distance as a parameter. In the proposed Zonal Network Model (ZNM) the above mentioned approach is used to cluster as separate zones. The performance measure namely the service level will be improved for the proposed model by way of reducing the wastage and shortage.

To improve operations, it has been proposed to introduce multiple control centers by grouping the units into various clusters. The clustering has been performed based on demand. There are many methods that are used to identify patterns in data and form clusters. After the machine learning techniques emerged, many types of pattern recognition algorithms have been developed. The agglomerative approach of hierarchical clustering has been used to cluster the 152 hospitals that a single blood bank has been serving. In the existing system, one single facility is catering to 152 hospitals. In the proposed ZNM, there are four zonal blood banks and a group of hospitals as recommended by the above clustering method, that are attached to each zonal blood bank, which is presented in Fig. 4.

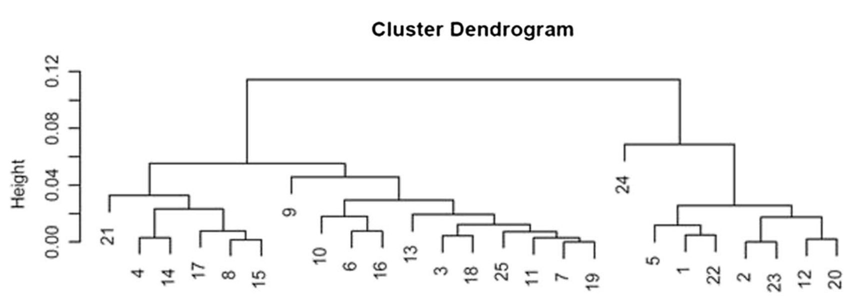

Fig. 3 Dendrogram of second stage clustering of the hospitals

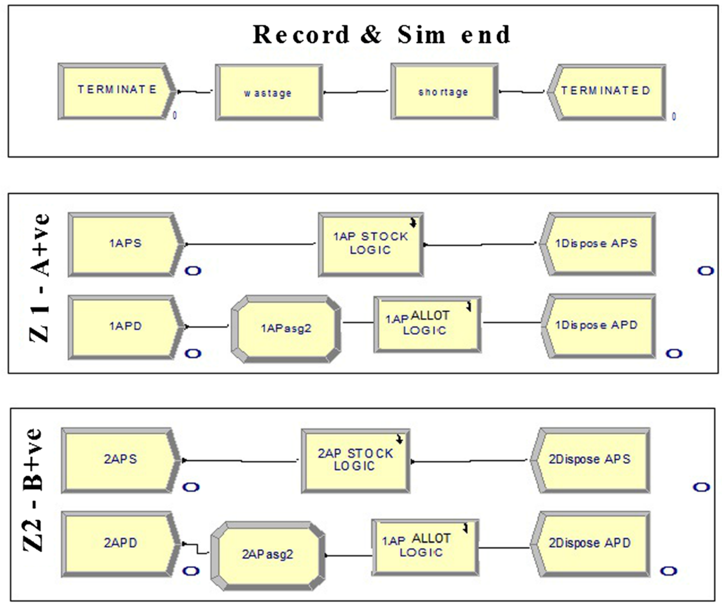

Fig. 4 Arena model of the zonal network blood supply chain

Pull system model

The pull system is the one in which the control information flow should be in the opposite direction to the material flow. In the proposed pull system model, there are four zonal blood banks and a group of hospitals as recommended by the above clustering method, that are attached to each zonal blood bank, which is presented in Fig. 5. The assumption of inventory level here is set at 95 percentile value of daily demand. The supply order is generated at the blood bank inventory system when the inventory level falls below certain levels. The level of proportion considered (i) If the proportion of stock to the initial inventory is above 0.5, then no order is made, (ii) If the proportion is below 0.5 but above 0.25, then an order for 50 percentage of the initial inventory level is placed and (iii) If the proportion goes below 0.25, then the order size is equal to the initial inventory level.

Evaluation of the proposed strategies

In order to compare the performance of the strategies, suitable measures are developed. The major conflicting issues in the

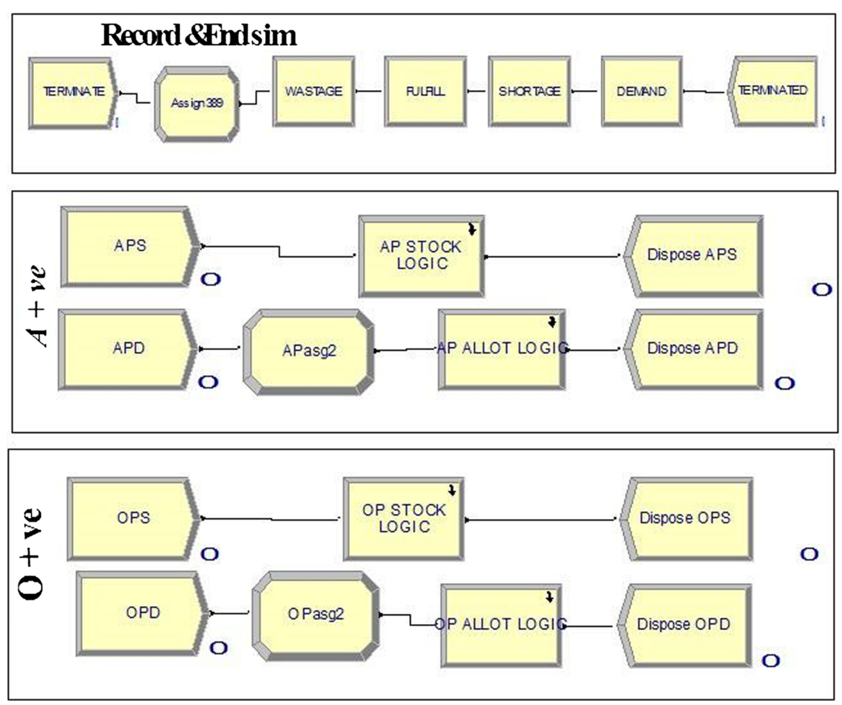

Fig. 5 Arena model of the pull system model blood supply chain

blood supply chain are the shortage of blood and wastage of blood.

Performance measures

a) Shortage index (SI) refers to the ratio of total shortage encountered for the blood of all groups in all hospitals to the total demand for the blood of all groups in all hospitals.

$$SI = \sum_{j=1}^{m} \frac{S_{ij}}{D_{ij}} \quad \forall i \tag{1}$$

S_j Shortage units for blood group '*i*' in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

D_j Demand units for blood group '*i*' in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

b) ***Wastage index*** **(WI***)* refers to the ratio of total blood discarded due to expiry date for all groups in all hospitals to the total blood received for all groups in all hospitals.

$$WI = \sum_{j=1}^{m} \frac{E_{ij}}{R_{ij}} \quad \forall i \tag{2}$$

E_j Expired units of blood for group '*i*' in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

R_j Received units of blood for group '*i*' in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

A performance measure combining the above two issues is formed as follows.

$$\text{MVI} = (0.7 \times \text{TSI}) + (0.3 \times \text{TWI}) \tag{3}$$

MVI Model Vulnerability Index.

Where,

$$TSI = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{S_{ij}}{D_{ij}} \tag{4}$$

TSI Total Shortage Index

S_{ij} Shortage for blood group '*i*' in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

D_{ij} Demand for blood group '*i*' in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

$$TWI = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{E_{ij}}{R_{ij}} \tag{5}$$

TWI Total Wastage Index

E_{ij} Group '*i*' blood wasted in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

R_{ij} Group '*i*' blood received in hospital '*j*' (*i* = *1…. n, j* = *1….m)*

Results

In the existing supply chain, the blood collection and distribution center serves 152 hospitals, for the demand of all the eight blood groups. The center follows the First in First out (FCFS) queuing system as the delivery strategy for deterministic demand and following Last in First out (LCFS) in case of stochastic (Emergency) demands.

The SI and WI values are calculated using Eqs. (1) and (2). As shown in Table 2 the results recorded from the Arena simulation model for the present system indicates that AB – Negative blood is having higher value shortage index as 10.17 percentage among all the blood groups. In wastage index

Table 2 Existing system Simulation output

Blood Group	A + VE	A -VE	B + VE	B -VE	AB +VE	AB -VE	O + VE	O -VE
Received	7532	1060	9594	877	2003	519	12,503	863
Demand	5915	621	7092	541	1834	344	8053	672
Fulfilled	5840	582	6959	520	1824	309	7962	653
Shortage	75	37	129	21	10	35	91	19
Wastage	1692	478	2635	357	179	210	4541	210
SI (%)	1.27	5.96	1.82	3.88	0.55	10.17	1.13	2.83
WI (%)	22.46	45.09	27.47	40.71	8.9	40.46	36.32	24.33

Table 3 The zonal network blood supply chain output

Blood group	A + VE				B + VE				O + VE			
Zones	1	2	3	4	1	2	3	4	1	2	3	4
Total supply	622	1245	3226	1205	782	1569	3922	1573	974	1971	4889	1954
Total demand	552	1172	2989	1210	709	1425	3548	1418	805	1610	4028	1615
Fulfilled	535	1141	2970	1205	695	1394	3483	1398	793	1608	3981	1591
Total shortage	17	26	22	5	12	32	61	25	8	17	41	19
Total wastage	87	104	256	0	87	175	439	175	181	363	908	363
SI %	3.08	2.22	0.74	0.41	1.69	2.25	1.72	1.76	0.99	1.06	1.02	1.18
WI %	16.26	9.11	8.62	0.00	12.52	12.55	12.60	12.52	22.82	22.57	22.81	22.82

category A- Negative has recorded 45.09 percentage among all blood groups.

Both measures show that the system needs to be improved to attain a better performance measure. To overcome this underperformance, the demand region has been divided into four zones and sharing is allowed between zones if necessary and if available. The results are shown in Table 3. The distribution of blood groups among the overall Indian population has been taken for consideration in this study. The major three groups (A + VE, B + VE and O + VE) cover 88.3 percentage of the total volume taken for the study. The remaining part of the blood groups has not shown any significant changes.

The MVI value has been calculated using Eq. (3). Table 4 shows the comparisons between all the proposed methods based on the MVI value (Eq. 1). The pull model outperforms the zone model by giving zero wastage and achieved nearly 10 percentage of the shortage of the zone model. From the MVI values the comparison between models can be made. Existing model has the highest MVI values which indicate the poorest performance among the alternatives. The zonal network model performs marginally better than the existing model, but the reason behind it is highly reduced wastage. The MVI value of the pull system is the least. Very marginal shortage and zero wastage are the reasons behind such performance.

Discussions

Two modifications to the existing systems are proposed namely ZNM and Pull models. In the present scenario, all the units are controlled by a single center. To improve the operations, it is proposed to divide this into zones by grouping the hospitals into various clusters. The clustering is attempted based on demand. There are four zonal banks doesn't have sufficient blood and a group of hospitals attached to blood banks. The hospital's needs are primarily supplied by the zonal blood bank. If any of the zonal banks does not have sufficient blood it will get the blood from other zonal centers if available. All other operational mechanisms remain the same. The other modification proposed is the pull system. The supply order is received at the blood bank only when the inventory level falls below certain proportions. For existing as well as the proposed system the shortage and wastage index are computed using a simulation model. The proposed model has been validated for pilot testing and the complete implementation of the model in the system is in process.

Table 4 MVI values for all models

MODELS	TSI	TWI	MVI
Existing model	1.66	17.17	7.86
ZN model	1.52	9.35	3.87
Pull model	0.17	0.0	0.12

Conclusion

This paper aims at the development of simulation model to address the wastage and shortage issues in blood supply chain network involving blood collection center, blood process facility, hospitals with blood banks under deterministic and stochastic environments. Hierarchical clustering of hospitals in to zones based on distance similarity is done using R analytics and fed as input to the developed simulation model. The performance of the two proposed models (ZNM and pull system) is compared with the existing system. In the proposed ZNM model, results show that there is a significant change in SI and WI, when the number of zones increases from 1 to 4 for all blood groups except O + ve. Further, this work can be extended by incorporating ABO substitution policy among blood groups and blood componentization which is the current technology adopted by model blood banks in India and other developed countries. This work has taken the distance between the hospital and the blood center for clustering. The future research could have extended by clustering based on the demand of the hospitals and distance from the blood center, by using weightages for both distance and demand.

References

1. Family Welfare, N. Delhi, Assessment of Blood Banks of India - 2016. NACO report, 2017.
2. Shukla, J. C., *Second management consultation on healthcare in India. Indian Institute of Management*: Ahmedabad, 1-356, 2007.
3. Garraud, O., Politis, C., Vuk, T., and Tissot, J. D., Rethinking transfusion medicine with a more holistic approach. *Transfus. Clin. Biol.* 25(1):81–82, 2017.
4. Pierskalla, W., Supply chain management of blood banks. In: Brandeau, M., Sanfort, F., and Pierskalla, W. (Eds.), *Operations research and health care: A handbook of methods and applications*. Boston, Massachusetts: Kluwer Academic Publishers, 103–145, 2004.
5. Katsaliaki, K., Cost-effective practices in the blood service sector. *Health policy (Amsterdam, Netherlands)* 86(2–3):276–287, 2008.
6. Erhabor, O., and Adias, T. C., From whole blood to component therapy: The economic, supply/demand need for implementation of component therapy in sub-Saharan Africa. *Transfus. Clin. Biol.* 18(5–6):516–526, 2011.
7. Alfonso, E., Xie, X., Augusto, V., and Garraud, O., Modeling and simulation of blood collection systems. *Health Care Manag. Sci.* 15(1):63–78, 2012.
8. Dhingra, N., International challenges of self-sufficiency in blood products. *Transfus. Clin. Biol.* 20(2):148–152, 2013.
9. Lowalekar, H., and Ravichandran, N., Blood bank inventory management in India. *Op. Search* 51(3):376–399, 2013.
10. Alfonso, E., Xie, X., Augusto, V., and Garraud, O., Modelling and simulation of blood collection systems: Improvement of human resources allocation for better cost-effectiveness and reduction of candidate donor abandonment. *Vox Sang.* 104(3):225–233, 2013.
11. Duan, Q., and Liao, T. W., Optimization of blood supply chain with shortened shelf lives and ABO compatibility. *Int. J. Prod. Econ.* 153:113–129, 2014.
12. Varela, I. R., and Tjahjono, B., *Big data analytics in supply chain management: trends and related research*. In: 6th International Conference on Operations and Supply Chain Management. Vol. 1(1):2013–2014, 2014.
13. Jabbarzadeh, A., Fahimnia, B., and Seuring, S., Dynamic supply chain network design for the supply of blood in disasters: A robust model with real world application. *Transport. Res. E-Log.* 70(1): 225–244, 2014.
14. Ganesh, K., Narendran, T. T., and Anbuudayasankar, S. P., Evolving cost-effective routing of vehicles for blood bank logistics. *International Journal of Logistics Systems and Management* 17(4): 381, 2014.
15. Bhatia, V., Raghuwanshi, B., and Sahoo, J., Current status of blood banks in India. *Global Journal of Transfusion Medicine* 1(2):72, 2016.
16. Lowalekar, H., and Ravi, R. R., Revolutionizing blood bank inventory management using the TOC thinking process: An Indian case study. *Int. J. Prod. Econ.* 186(February):89–122, 2017.
17. Hosseinifard, Z., and Abbasi, B., The inventory centralization impacts on sustainability of the blood supply chain. *Comput. Oper. Res.* 89:206–212, 2018.
18. Ramezanian, R., and Behboodi, Z., Blood supply chain network design under uncertainties in supply and demand considering social aspects. *Transport. Res. E-Log.* 104:69–82, 2017.
19. Rajmohan, M., Theophilus, C., Sumalatha, M. R., Saravanakumar, S., Facility location of organ procurement organisations in Indian health care supply chain management. *S. Afr. J. Ind. Eng*. 28(1):90–102, 2017.
20. Wang, Y. et al., Service supply chain management: A review of operational models. *Eur. J. Oper. Res.* 247(3):685–698, 2015.
21. Osorio, A. F., Brailsford, S. C., Smith, H. K. and Blake, J., Designing the blood supply chain: how much, how and where? *Vox Sang.* 113(8):760–769, 2018.
22. Duan, J., Su, Q., Zhu, Y., Lu,Y., Study on the centralization strategy of the blood allocation among different departments within a hospital. *J. Syst. Sci. Syst. Eng*. 27(4):417–434, 2018.
23. Nagurney, A., and Masoumi, A. H., Supply chain network design of a sustainable blood banking system, sustainable supply chains: models, methods and public policy implications. Springer 49–72, 2012.
24. Testik, M. C. et al., Discovering blood donor arrival patterns using data mining: A method to investigate service quality at blood centers. *J. Med. Syst.* 36(2):579–594, 2012.
25. Blake, J., and Hardy, M., Using simulation to evaluate a blood supply network in the Canadian maritime provinces. *J. Enterp. Inf. Manag*. 26(2):119–134, 2013.