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BLOOD SUPPLY CHAIN NETWORK DESIGN UNDER UNCERTAINTY: A COMPREHENSIVE REVIEW FOR FUTURE RESEARCH DIRECTION

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Abstract

This paper presents a comprehensive review of studies in the field of blood supply chain management. This study is organized in two phases. The types of blood products, potential issues, and stages of blood supply chain have been discussed in the first phase of the study whereas in the second phase, optimization techniques deal with uncertainty such as stochastic programming, robust optimization and mixed integer programming are explored. The scope of the study is to entangle the dimensions which have not yet been explored and it would be given substantial input to upcoming researchers. The most striking effort of this study is to develop the robust blood supply chain model to support that could tradeoff between the demand and supply which minimizes shortages and cost.

Keywords: Blood supply chain network design, Blood products, Uncertainty, Robust optimization.

1. Introduction

Blood is the base for human existence and survival. It saves thousands of lives. The need for blood is paramount and universal, so that importance of blood is inexplicable and there is no substitute of blood. It is possible through blood donation and creation of blood bank. Blood loss occurs due to many reasons, health issues, and accidents and severe injuries. These problems are very serious. Therefore, there has been growing the importance for blood supply chain management. Blood supply chain management plays the critical role in the society. It starts with donor and quits with the patient that would appear very critical section along with the inventory and distribution problems (Oswalt 1976). In blood management technique, simply whole blood collects from the donors who are from different regions donating blood which will be close permanent or temporary blood donation centers. Then donated blood is transferred to blood banks and different process is done such as blood purification, filtration and extraction of blood products including red cells, platelets, plasma. Then blood products are stored in blood bank, and requested amount of blood products are delivers in to the hospitals wherever they are transfused in to patients (Sapountzis 1981). The supply of blood donor is fairly irregular but the demand for blood is high and produce is a minimum of as random. Various technique are to be achieve on the blood make available in the chain, the number of donors who are tending to donate regularly, seasonal elements affecting donation campus by the government and private organizations e.g.in winter college blood donation campus, public holidays (Asllani et al. 2013).The blood contribution is promising to appropriately predict the number of units of blood required throughout the year ,to ensure that they know the overstock and therefore make the bigger wastage ,the clinicians consciousness of splendid blood ordering and transfusion and the hospital laboratories ability to make sure sufficient stock but have minimal wastage(Thomson et al. 1998). It is important that every body of staff working at each blood donation center is aware of their duties to make the smallest waste of these resources freely distributed. Therefore, education and training and facts collection are important elements of the blood furnish chain. The online blood bank management system is to generate and e-information about the contributor and the manger that are associated to donating the blood .The website and the android software links all the blood banks in order to know about the required volume resulting in the ease of getting entry for the customers (Sanchez et al. 2001). The goal of internet site and the app is to build a solution to the ever-developing requirement of blood grant due to accidents and number of health problem, the gadget is to developed for having access to the records about a variety of blood banks and hospitals in order to understand about their blood stock of quite number of blood groups. The essential objective is to automate the complete operations of blood bank. The blood bank wants to maintain heaps of record (Cheragi et al. 2016). It would also ease the task of looking for the blood of the required blood team and would instantly get the required type through this website. This is a web-based database application gadget that is to be used via the blood banks or blood donors as an imply to advertise the state expensive donation occasions to the public and the same time permit the public to make the online reservations and request for the blood. This machine has ability to keep track of the donor's information and stock of blood in the blood bank (Dijk et al. 2009). The present research is pertaining to associate the demand in an economical manner. The requirement of blood products and the shortages lead to the high prices for society, since they will cause increase of the mortality rate (Dumas et al. 2015). Many interacting decisions should be created at the strategic policies, strategic method and working plan of the achievement levels. The region unit plagued with the requirement to manage to minimize the outdating, waste and prices, overall to manage the shortage level (Eandi et al. 2015). References cited in the obtained manuscript were reviewed to find the additional publications. We ended up with a total set of 60 manuscripts. To illustrate the distribution of the paper according to the publication date, we included a distribution figure.

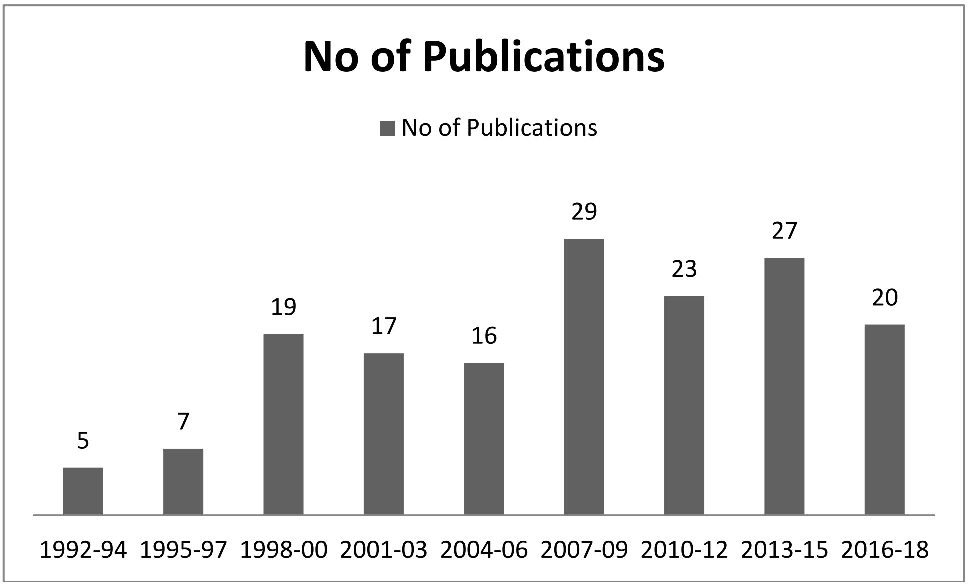

Figure 1: Number of Publications by Publication Period

We structure the literature review using different perspective. However; a researcher can query a list of manuscript according to his specific needs. The residue of this paper is organized as follows; in Section 2, types of blood product are discussed. In Section 3, types of problem are discussed. Different approach level is discussed in Section 4. Optimization aspects related literatures are investigated in Section 5. The studies addressing real world application are introduced in Section 6. Finally, in Section 7, a discussion, conclusion and future research direction are explicated.

2. Type of Blood Product

The types of blood are Whole blood, blood plasma and frozen blood, blood cells, blood platelets. All of these components are consumable, this paper investigates the same, white blood cells or different aspects are now not protected in this review. The frozen blood is mainly frozen red blood cells. Feeble papers mention fresh-frozen plasma and no paper have not discussed about using frozen blood (Ericson et al. 2008). We feel the issues of frozen pink blood cells, because this is the most important blood product. Nevertheless, most papers are clear about which blood merchandise they are considering, so we expect this is a useful perspective for classifying the literature. Figure 1 lists the papers according to the type of blood product.

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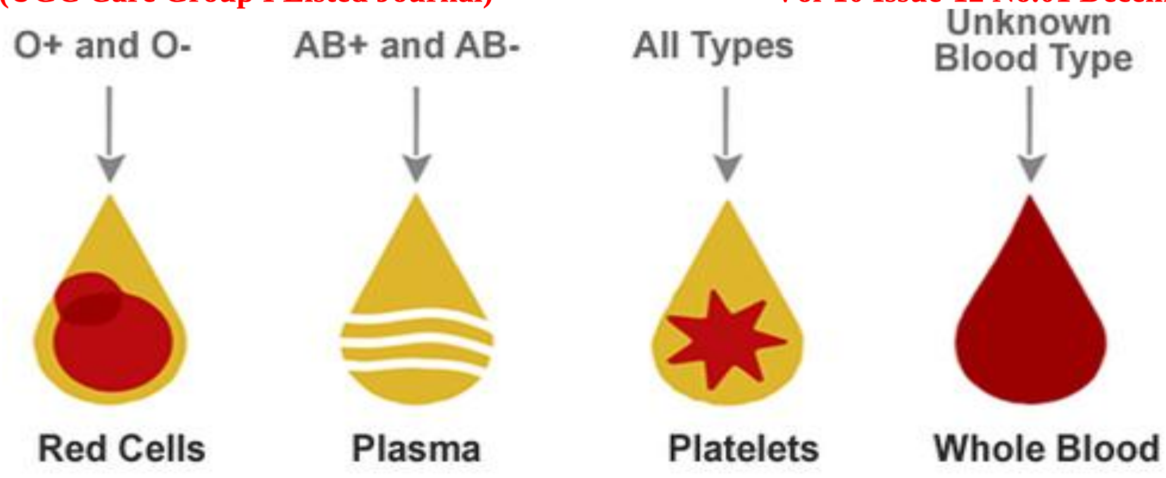

Figure 2: Types of Blood Products

2.1 Whole blood and red blood cells (RBC)

It contains every one of the components of blood that are important for oxygen conveyance and homeostasis, in almost physiologic proportions and fixations. Whole blood can be hidden away refrigeration for as long as 35 days. It holds satisfactory hemostatic capacity, however supplementation with explicit blood products, coagulation factors etc. (Eskandarpour et al. 2015). The whole blood can be gathered from blood donor in a mobile blood donation center to give feasible stimulation when completely tried put away entire blood or blood segments are inaccessible and the requirement for transfusion is terrible (Ferrari 2010). Accessible clinical information propose that entire blood is in any event comparable if not better than segment treatment in the revival of perilous discharge.

2.2 Plasma

Plasma, additionally called blood plasma, the fluid segment of blood. Plasma fills in as a vehicle mode for transmission supplements to the cells of the different organs of the body and for delivery waste items got from cell absorption to the kidneys, liver, and lungs for discharge. Moreover, a vehicle structure for platelets and it assumes a basic job in keeping up typical pulse. Plasma disseminates heat all through the body and to look after homeostasis (Gunpinar et al. 2015).

2.3 Frozen blood

Freezing and thawing are two important operations in plasma fractionation. The fluid component of the blood plasma is mostly made up of water (up to 95% by volume) but also contains glucose, dissolved proteins, hormones, electrolytes, clotting factors, and respiratory gases. (Gure et al. 2016) Freezing and thawing plasma helps in producing concentrated solutions of individual plasma components, such as clotting factors, for patient transfusion. In order to protector the red blood cells from damaging impacts of freezing, which disrupts the cellular membranes is delivered to this biological fluid (Haijemetal et al. 2009). The efficiency of preserving frozen red blood cellular stock seems quite low, furthermore a biological fluid also approaches that the cells should be washed after thawing. These examples point out the high expenses (Hassian 2017). However, this fulfilled through maintaining list of donors with exceptional phenomenon.

2.4 Blood Platelets

We protected significantly fewer papers approximately blood platelets, as compared to red blood cells and whole Blood. Platelets are that they have got a very quick projection survival in comparison to different blood products (Heidari et al. 2019). This result is increased complexity, in addition to, probably in geographical location. It introduces a new solution approach, closing a gap in the literature which has existed for a long, while due to the complex nature of the problem. (Hoseeinifriad et al. 2015) formulate the perishable inventory problem via the dynamic programming (DP) technique. The problem is that it is very difficult to solve a DP model of realistic size. They dealt with this by suggesting a multistep procedure, combining simulation with dynamic programming.

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3. Type of Problem

Supply chain management consists of various sub-problems There are two types of problem inbound problem and out problem. Inbound problems are consisting of inventory problem and planning, collection of blood products. (Imran et al. 2015) Outbound problem consists of scheduling distribution of blood problem.

3.1 Inbound Problem

In blood supply chain management inbound problem plays vital role in collecting the blood products. Mini-max models are the combination of the model with ordering points with fixed order interval (Alfonso et al. 2012) represents Inventory allocation problems concern the efficient allocation on the inventory in the supply chain. The issue of the success deals with centralized structure which diestrum the decentralized structure of the blood bank (Haijema et al. 2009). The present paper focused on the distribution of blood products from the regional center to a given setup location with random demands. A cross matching policy reduces the issues, when the entire cross matched units are actually used attempt to reduce the blood wastage and alternative cross matching policy. In the case o single cross matching single unit of blood is reserved for two potential users instead of one. In case of double cross matching ,single unit of blood is reserved or two user instead on one ,while ensuring blood is available for both when it is needed This technique increases the probability of blood unit will be used during the reservation period, (Katsalikali et al. 2008) dedicated to store the cross matched blood (Kendall 1948),who describes the optimal issue for particular classes of inventory problems and example the issue of whole blood from a blood bank is included to accompany (Kenneth et al. 1978).This paper classify in the different sub category like cross matching inventory management ad issuing policy.

3.2 Outbound Problem

In supply chain management outbound problem says that how to increase the supply of blood donor. The network optimization strategic aims to minimize the establishment cost blood collection facility cost, blood delivery cost from the temporary facilities to the main acclimation center. Area of the demand and geographical dispersion of the demand point in each period associated with the cost. The blood donation can directly occur at either temporary facilitation center or permanent facilitation center (Gure et al. 2016). Temporary facility center must one or more blood bank at each of the time period. In the view of demand points, the volume of the blood donation in each period and the transportation cost between the facilitation centers must be calculated. In blood distribution system as a sample for a regional blood center and the hospital blood bank deliveries of the blood distribution depend upon a statistical estimation or his hospital. The real requirement is also arranged to adjust when delivery is necessary (James et al. 1195).

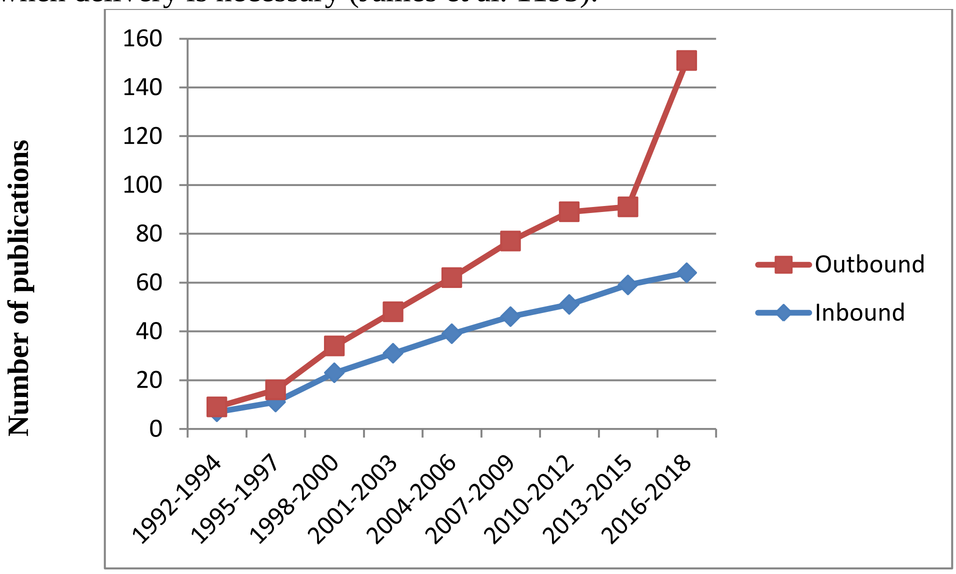

Figure 3: Trends in Inbound versus Outbound Problems

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4. Approach Level

Current inventory level and the future demand determines the need for the blood products, for example platelet have highly demand on low inventory level. Many papers are classification according to criterion is inappropriate. For the point of view, current papers deal through forecasting are constantly stochastic in observation of the nature of the problem. A further example where this distinction is not relevant is studies dealing with benchmarking. However same type of the blood products chosen for the transfusion. This paper represents by deterministic model and robust model discussed delivery technique for the blood product. The investigation of deterministic setting up the demand and probability distribution is known for the researcher. In outstanding only 17 papers are settings in the deterministic whereas 42 papers are setting in robust. This paper involving robust setting have always at no paper involving in the deterministic setting. During the last one decade, the difference has only become the larger. This trend represents that the future research will continue with robust model (Kohneh et al. 2016).

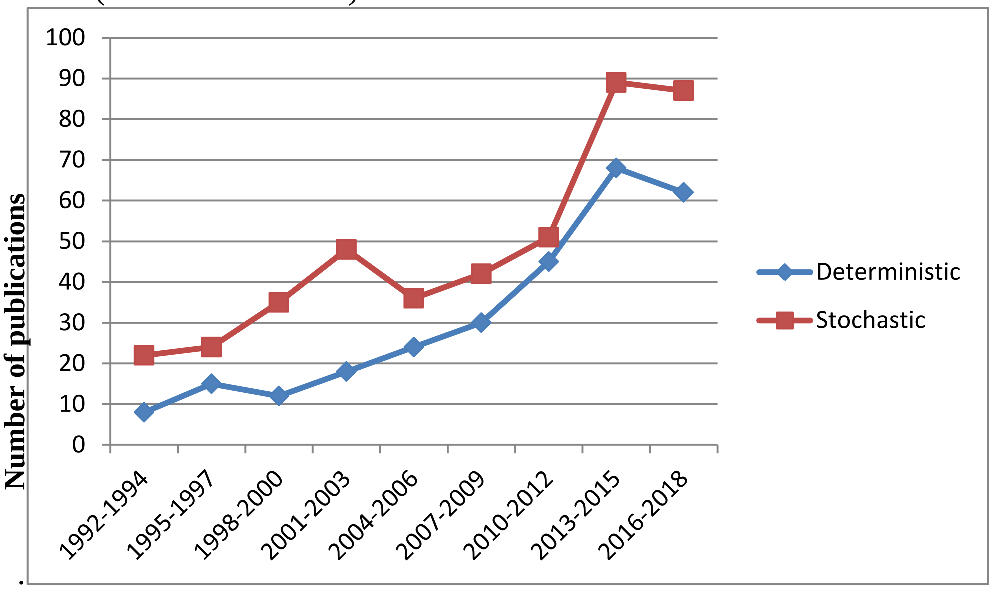

Figure 4: Trends in Types of Approach

5. Solution Method

(Mansur et al. 2008) divides the decision-making environment in to three categories. (i) certainty (ii) risk (iii) uncertainty. In certainty situation, all the parameters are deterministic and known. In risk Situation, all the parameters are uncertain but their values are governed by probability distribution. Problems under risk situation are called stochastic optimization. In uncertainty situation several parameters like cost demand, supply involve the randomness. and there is no information about the probability distribution. The problems under uncertainty are known as robust optimization. The objective of robust optimization is to find the solution which will be better perform under any possible realization of the random parameter and it attempts to optimize the worst-case performance of supply chain network design. Robust optimization, first introduce by (mulvey et al. 1994) has been adopted as an effective tool for optimal design and supply chain management operating in uncertain environments. (Li et al. 2012) have been investigated Practical application of robust optimization and production planning. Robust optimization tackles the preferred risk aversion or service level function through expressing the values of critical input data in a set of scenarios. (Mulvey et al. 1994) define two measures of robustness; a solution to an optimization model is defined as solution of robust if it remains close to optimal for all scenarios of the input data and model robust if it is almost feasible for all data scenarios. Robust optimization openly incorporates the conflicting objectives of solution and model robustness by using a parameter reflecting the decision maker.

5.1 Robust optimization in the context of blood supply chain network design

To best our knowledge, few studies have focused on the application of robust techniques for the design of blood supply chain. In this section optimization aspects of the related literature are investigated. Moreover, the reference paper is studied in terms of mathematical modeling, solution method, and optimization technique. (Cheragi et al. 2016) used the robust optimization technique which deals with the randomness of the parameter. The researchers illustrate the usefulness of the model. Two accurate work methods have been employed and standard deviation of pressure violations under a random number of observations to evaluate the performance of the stability and determination of the models. In some cases, they deal with epistemic uncertainty, when enough data are not available or number of repetitions of a specific action is realized. (Kohneh et al. 2016) presents a robust optimization model for the supply of blood during the disaster period. The researchers developed a model that can help in blood facility location and allocation decisions for the multiple post-disaster periods. The location decision involves the number and location of permanent temporary blood facilities and allocation decisions concern the assignment of facilities to the blood donors as well as determining blood inventory levels at each period. The proposed model aims coordinate supply with demand at minimum costs. The projected optimization model is design for an actual blood supply chain, which involved in the supply of blood during the potential earthquakes. Location and allocation are determined in a set of earthquake scenarios developed using different combinations of critical parameters including injury to death ratio, hospital admission rate and blood transfusion rate. (Heydari et al. 2018) proposed the dynamic, multi objective location-allocation mathematical model for designing a blood supply chain for after disaster period. The mathematical model is consisted from three distinguishable set of nodes; blood donors, temporary blood collection facilities, and processing and storage centers. The objective function is to minimize the maximum possible shortage and minimizing the total cost. The proposed mathematical model proves too useful in short disaster time period.(Erickson et al. 2008) addresses a new multi-objective and multi-period model for the supply chain planning under uncertainty considering the quantity discounts. The researcher proposed a mathematical model to maximize the current profit of the distributor by making a balance between the total costs of the supply chain and the distributor companies revenues of selling products and also maximizes the company’s expected profit by introducing the brand and taking the risk .They proposed a model is promising approach to run an efficient supply chain. (James et al. 1195) presents an analysis on robust optimization model to decrease blood shortage, wastage and cost in each scenario. (Jabbarzadeh et al. 2014) proposed a robust optimization model for blood supply chain network design under different disaster scenarios in which supply chain including blood donors, blood facilities, and blood centers. In their model, blood facilities collecting blood from donors and send to the blood donors. (Ramezanian et al. 2017) developed a new approach to increase blood donor’s utility in order to reduce shortages and harmful damages. Parameters including distance of blood donors from facilities, experience factors of donors and advertising budget are considered as the social aspects. (Filhoet al. 2013) Proposed a robust model is curbing the mismatch between surplus and shortage of blood units at blood banks. This proposed model has three main echelons: forecast the demand of blood units at the blood bank; determine the optimal allocation of units from blood banks with surplus to a blood bank with shortage; select the optimal route for the delivery of the allocations. Further, it has been shown empirically with the previous years’ data that SARIMA model is a very efficient forecasting methodology in blood supply management. (Manatkaret al. 2016) designed a mathematical model during several periods based on minimizing the cost of the blood supply chain network and maximizing the reliability of the selectable paths for blood transportation. This model determines the optimal number and locations for establishing the facilities as well as determining the allocation of blood to various facilities, and, on the other hand, optimal routes for blood transportation among facilities. (Simamora et al. 2014) improved the co-ordination of blood supply and demand. In this regard a robust model is proposed to strive for simultaneous investigation on three independent challenges by which the simultaneous location and capacity decision are supported. The model is also extended to handle the combinatorial risk of uncertainty.

In Table 1, all the studies in the area of scenario based robust supply chain network design are categorized with respect to their solution, approaches, objective functions and mathematical model.

Table 1: Summary of Related Researches

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Sl. No.	Author	P	C	S	W	DI	DE	R	F	SI	ST	IP	HA	SA	SP	MP
1	Pereira et al.(2006)		*											*		*
2	Srikar (2018)			*										*		*
3	Edgar et al. (2012)		*		*					*				*	*	
4	Sauche et al. (2001)				*									*		*
5	Arvan (2015)		*			*	*					*	*		*	
6	Asllaniben et al.(2014)				*					*	*		*		*	
7	Cheragi et al.(2016)		*				*	*				*				*
8	Supountzis(1984)				*							*		*	*	
9	Zhuge et al.(2016)	*									*	*				*
10	Dening et al.(2015)		*	*							*					*
11	Gunpinar et al. (2015)		*	*			*				*				*	
12	Heidari (2017)		*										*		*	
13	Hosseinrad et al.(2016)			*			*				*				*	
14	Jaberazzadeh et al.(2014)		*					*								*
15	Jafer et al. (2018)		*	*				*				*				*
16	Maeng et al.(2018)			*			*							*		*
17	Katsaliaki et al.(2008)		*	*						*				*	*	
18	Kendall et al.(2015)		*	*						*				*	*	
19	Kohneh et al. .(2016)		*	*					*			*				*
20	Katslina (2011)	*					*							*	*	
21	Ramezani et al.(2013)	*					*	*					*	*		*
22	Mannat et al.(2015)		*										*			*
23	Matthew et al.(2014)	*						*				*			*	
24	Michelle (2008)			*	*									*	*	
25	Mohamed et al.(2019)		*	*				*								*
26	Muhamed et al.(2018)	*		*	*				*		*					*
27	Nagurency (2012)		*										*			*
28	Nicovan et al. (2009)		*	*										*	*	
29	Silva et al.(2013)		*	*										*	*	
30	Pierskall et al.(2012)		*	*									*			*
31	Pornpimal (2014)			*							*		*	*		*
32	Quinglin et al.(2014)				*									*	*	
33	Thomas et			*	*									*		*

Sl. No.	Author	P	C	S	W	DI	DE	R	F	SI	ST	IP	HA	SA	SP	MP
	al.(1998)															
34	James et al.(1995)	*		*		*	*		*				*	*	*	
35	Oswalt (1975)	*						*				*				*
36	Raemierfan et al.(2018)		*					*				*				*
37	Rajinikumar et al.(2016)	*									*	*				*
38	Ramezani et al.(2013)		*	*		*	*	*				*				*
39	Rezas et al.(2017)	*			*			*	*		*	*		*		*
40	Simomora et al.(2014)		*	*				*						*	*	
41	Sumazly et al.(2008)		*	*				*						*		*
42	Chang et al.(2011)	*			*		*		*			*	*		*	
43	Mojib et al.(2015)		*		*	*					*			*	*	
44	Pattnaik (2020)	*			*	*	*					*	*	*	*	
45	Pattnaik (2012)		*				*		*						*	
46	Pattnaik and Gahan (2020)	*					*					*	*	*	*	

**P: Profit; C: Cost; S: Shortage; W: Wastage; DI: Distance; DE: Deterministic; R: Robust; F: Fuzzy; SI: Simulation; ST: Stochastic; IP: Integer programming; HA: Heuristic Approach; SA: Statistical Analysis; SP: Single period; MP: Multiple period*

6. Case study

Research on awareness of blood bank has been conducted by some researchers. Yet, no researches have not discussed about the policies related flexibility level in blood supply chain management. This is an opportunity to explore the current research. According to National Blood Transfusion Council (NBTC) and Ministry of Health and Family Welfare government of India published a Report on Assessment of Blood banks, investigated there are 91 blood banks in the state of Odisha in 2018, the assessment exercise identified 79 functional blood banks. It is evident from the assessment that blood bank focused on quality improvement systems perform better than others. Discrete simulation method, dynamic programming, integer programming, mixed integer programming, stochastic programming, taguchi method, markov decision method, stochastic optimization, robust optimization (Mohamed et al. 2019), fuzzy optimization was used to construct to decrease the shortage level, minimize the cost, expiry the blood Products. Big data analytics tools and techniques would be helpful for the future research work. So, that several improvements should require in blood supply chain management. The current research has focused on shortage level, blood production combination, determining the allocating the permanent facility location and temporary facility location, the quantity of blood requirement for the facility and blood inventory level at end of each period. Moreover, the present research is new type of review in blood supply chain management, in paradigm of geographical location in Odisha. In blood supply chain, it is investigating that the low quality of information, advertisement budget, long distance, experience factor are the parameters are the cause for poor coordination among the echelons. The Present paper proposes traceability blood system to emphasize the co-ordination among the echelons in the blood supply chain network. The mathematical model could demonstrate the potential profit that will extend from each donor, blood bank and hospital for improving the performance in blood supply chain. In Odisha blood bank, there is a breach about the awareness of the donors. It is normal to find an area that has been well informed, further supply also found another area that has less to none understanding regarding the blood donor. This will reason the large inconsistency between the blood supply from one area to another area and also this is a major cause for the demand will eventually exceed the supply. Therefore, good co-ordination should be required among the nearest blood bank. Across Odisha, Blood quest is divided in two conditions like normal condition and special condition. In normal condition there is no unexpected situation that could cause a sudden point in blood demand. Special condition is a certain condition that affects blood demand directly. Based on the phenomenon adoptive blood management model is indeed. Since the responsibility of blood supply chain management is to changes in every system rapidly and flexible. Blood Management is expected to be adaptive on demand variation and blood supply. The most important thing is to schedule blood transfusions that can make the client want it.

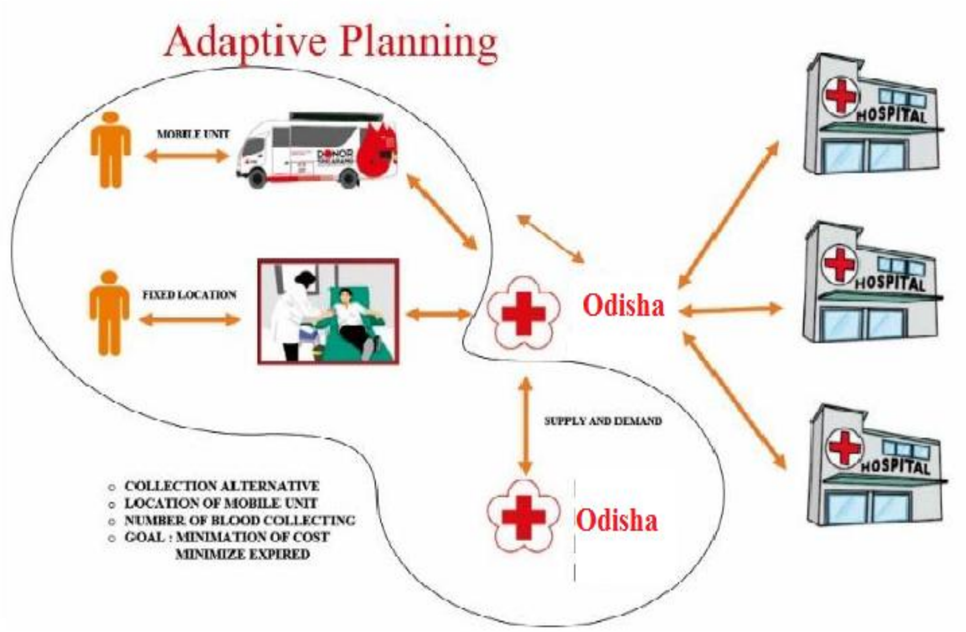

Figure 5: Adaptive Planning Scheme in Blood Supply Chain Management in Odisha

Adaptive planning will be affected by demand characteristics. If the demand pattern will change then it affects the supply level of the blood center. Target level depends on demand behavior and the condition such as normal, emergency, or special condition. The model could not give the quick response to determining the optimum stock towards our time and target. This current research is highly possible to create supply management system to minimize the cost, shortage level and outdate of blood product.

7. Conclusion

In this paper a comprehensive review was presented on the studies in the area of Blood supply chain network design problem under uncertainty. Many studies, which appear, every year have a variety of themes, aspects and methodologies. This study represents the results of an article review in the field of blood supply chain from upstream and downstream with the various products, differences in blood coordinate management system and performance management. This study reveals the research opportunity in the field of blood supply chain at the strategic level, tactical level and operational level. Many research opportunities required is to build the realism models based on real world applications and handling computational aspects to solve large size problem. Specially developing an adaptive model for blood supply chain management that could be responsive towards the demand fluctuation and developing procurement strategy for minimize cost, shortage, and outdated in supply chain level.

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