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Bibliometric Review of Inventory Management in Blood Supply Chain: A Systematic Review

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ABSTRACT

Management of blood inventories includes all procedures involved in ordering, storing, handling, and distributing blood products. To guarantee proper use of this priceless resource: Blood; effective inventory management is required. The overall objective of this study is to explore the optimization approaches in inventory management of blood supply chains. By summarizing the optimization techniques used, a framework was created, literature review was analyzed, variables and complexities affecting blood inventory performance were found and examined. As advice for upcoming researchers in this field, this paper includes the current state of knowledge, potential research areas, and gaps that are present in this field. Concerns were raised about managing the blood supply during the coronavirus disease 2019 (COVID-19) pandemic. Due to travel restrictions and concern over contracting the virus while visiting blood banks, blood donations during the pandemic significantly decreased. As a result, the purpose of this review is to analyze the research literature already in existence that deals with the modelling of blood collection, provide a detailed classification of the selected articles, and thus identify any areas that may benefit for further research.

KEYWORDS- Inventory management, Blood, Supply chain, Blood banks, Platelets

INTRODUCTION

BLOOD: as abundant and renewable a resource this is inside the human body, outside it this is just as scarce and thus, precious. Even though the human body is constantly pumping blood, the human race is not constantly and consistently donating it. Currently only 6% of the UK population give blood, although 60% are eligible to donate (NHS Direct, 2004). The figures are even worse in the USA (5%) (Jones, 2003) and Canada (3.7%) (Canadian Blood Services, 2005; http://www.bloodservices.ca/,accessed 12 September 2005) (Gunawardana, 2020). Additionally, the supply of blood products is irregular (due to donor uncertainties) and its demand stochastic (Belien & Force,2012). U.S. (Barbee I. Whitaker, 2007):the blood supply is frequently reported to be just 2 days away from running out; hospitals report as many as 120 days of surgical delays due to blood shortage (Katsaliaki K. M., 2014). At the same time blood also happens to be a perishable substance, reaffirming how precious a commodity it is. It also happens to be a costly item and thus, its wastage is in no way desirable. Introduction of more sophisticated technologies for collecting blood, are constantly increasing costs within the blood supply system (Katsaliaki K. B., 2007). Furthermore, inventory management and distribution of blood are seen as major components of the cost for blood (Stanger, 2012). However, it is not like other common commodities given that its unavailability could be detrimental to a person's life. This is why studying inventory management in the blood supply chain and devising solutions to make it more efficient become so very important.

With this rationale in mind, we have compiled a bibliographic review on the Inventory Management in Blood Supply Chain after analysing papers from the past couple of decades. The data for majority of the papers and models under our review come from the following five countries:-

i. India
ii. United Kingdom
iii. Australia
iv. United States of America & Canada
v. Germany

Blood inventory management is a trade-off between shortage and wastage (Stanger, 2012). Apart from wastage, unpredictable challenges caused by unplanned surgeries, natural disasters, equipment breakdown, war and labor strikes lead to significant disruptions and losses within the blood supply chain and consequently, unsatisfied demands (Haeri, 2020). Therefore, it is crucial to preserving public health, that policies are adopted that assimilate the concept of 'resilience' into planning and inventory management to remain reliable despite unexpected challenges (Rajendran, 2020)

The perishable nature of blood, uncertain nature of the demand for blood units, and significant subjective bias toward factors other than cost minimization make managing stocks in the blood supply chain a difficult task. (Mary Dillon).

An effective blood supply chain should be able to satisfy demand while minimizing waste and expenses. Along the way, expenses are incurred for labor, testing, fractionation (the division of whole blood into by-products with a wide potential range), storage, and distribution.

However, achieving a cost-efficient operation for the blood supply chain is a highly complicated problem because the demand is unpredictable and most blood products have a short shelf life, imposing severe limits that significantly raise the risk of shortages.

Hence, the real world importance of the blood supply chain is self-evident, since human lives are at stake.

Although over a hundred different products can be extracted from blood; platelets, red blood cells and plasma are the most important components (Ejohwomu, 2021). Which is why the study focusses on papers talking about the supply chain and inventory management of these three components only.

According to recent studies, some patient populations may benefit more from the transfusion of younger red blood cells. This means that a blood supply chain should not only minimize its shortages and outdates, but it also needs to minimize the age of the items that are transfused. Therefore, the outdated rates, shortage rates, and average age of issues can all be used to measure how well a blood supply chain is performing.

When determining safety stocks, blood banks do not take inventory holding costs into account because they are insignificant in comparison to out-of-date and shortage costs. However, with perishable goods like RBCs, the outdate rate rises as the stock level does, adding to the system's costs.(Zahra Hosseinifard)

It would be beneficial to find the blood supply chain system that should be used in order to overcome this complexity through organized inventory management, which is achieved by comprehending the intricate relationships between supply and demand and other factors that affect them.

The high rate of perishability of blood components and the fact that humans are the only source of these products' supply make the blood supply chain one of the most important and challenging supply chains in use today.(Pasek)

In order for any country to achieve its annual blood requirements, around 1% of its whole population must donate blood each year (WHO [2011]). But more than 40% of countries worldwide are unable to reach the 1% donation rate. (Lowalekar H. R., 2017)

Only 20% of the world's safe blood supply is accessible to around 80% of the population [5]. Children with malaria who lack access to blood die at a rate of 15% and 34%, respectively, [6], illustrating the practical impact of blood shortages. Worldwide, about 500,000 women pass away each year, with nearly 99% of these deaths occurring in underdeveloped nations [3], where insufficient blood supplies account for 21–40% of hemorrhage related deaths [1]... (McCullough, 2013)

The Covid-19 pandemic's effects on the blood supply system several businesses that offer goods or services to the consumer or end user make up the inventory management industry. In other words, the network (made up of suppliers, intermediaries, transport and logistics service providers) that depicts the flow of raw, semi-finished, and final materials represents the influence of the Covid-19 epidemic on the inventory management of the blood supply chain. Products in the customer's direction while information and money flow back. (Yadav A. K., Modeling and Solving an effect of Covid-19 pandemic on blood Supply Chain inventory management using Ant Colony Optimization., 2021)

Effects of the Covid-19 epidemic on the blood supply system the inventory management sector consists of numerous companies that provide products or services to consumers or other final users. In other words, the network that represents the flow of raw, semi-finished, and finished materials and is made up of suppliers, intermediates, transport, and logistics service providers, represents the impact of the Covid-19 outbreak on the inventory control of the blood supply chain. Products are sent in the direction of the customer, and information and funds are returned. (Yadav A. S., 2019).

Despite substantial medical progress, blood has not yet been successfully replaced with a durable alternative. Because of this, blood is a necessary and expensive resource in healthcare systems. (Najafi, 2017)

Significant progress has been made in the management of blood bank inventories over the past few decades. There has been research into the optimal methods for ordering blood, collecting blood, planning and scheduling blood distribution, cross-matching, transshipping, and other blood banking-related procedures. It is typical for channels to overfill inventory due to disorganization, such as variations in delivery time, quality, or quantity of a shipment, driving up Expense of channels needed to satisfy demand (Yadav, 2021). Governments are in charge of ensuring that all citizens have access to the best healthcare facilities available. Numerous healthcare organizations at the federal and state levels are responsible for managing a variety of healthcare systems in both urban and rural areas around the nation. (Kumar, 2015).

Since blood is a perishable item, effective inventory management is essential. The management of blood inventories involves balancing scarcity and wastage. The difficulty is to maintain sufficient inventory to guarantee a 100% supply of blood while minimizing time expiry losses. (Stanger, Yates, Wilding, & Cotton, 2012)

Blood is a vital medicinal resource that is frequently needed for trauma victims, soldiers with war wounds, numerous surgeries, organ transplants, childbirth, and patients with cancer, leukemia, and anemia. Every single unit of blood is valuable; a pint of blood can keep a premature baby alive for two weeks; a single trauma victim may need 40 or more units of blood to survive; and a leukemia patient undergoing treatment might need 8 units of platelets every day. (Delen, Madhav, & Wu, 2011)

In today’s world, supply chains are more complex than ever before. Consumers’ demand for new products as well as the still-critical economic situation require that companies, as well as organizations, be more innovative while also becoming more cost-effective in the procurement and production of their products and services as well as in their delivery. However, despite numerous significant achievements, the discipline of supply chain management (SCM) is still incapable of satisfactorily addressing many practical, real-world challenges. (Nagurney, Masoum, & Yu, 2011)

Blood is an extremely valuable commodity; perishability, various safety regulations and a trend of a declining donor base steadily increase its value (Reynolds et al., 2012) .An effective use of medical resources is required due to the rising expenses of medical care and the expanding demand for healthcare services. This issue is also prevalent in transfusion medicine, whose raw material, blood, is an outstripping supply with increasing costs of blood transfusions due to the further measures to ensure the safety of donated blood (Reynolds et al., 2012).

Blood is a perishable product as the useful lifetime is limited. As a result, when blood passed a certain period of time it becomes unsafe to use and turn to waste (Dillon M, 2017)

Only platelets that are older than 5-7 days can be used because they quickly lose their quality. Therefore, platelets should be thought of as highly perishable. Production numbers need to be carefully set because platelets are extremely expensive (the blood bank estimates a selling price of more than 450 euros per patient every treatment), and shortages could result in significant additional costs or even endanger lives. Thus, there is a reasonable and (almost) ideal trade-off between spill and shortages. (Haijema, 2007)

Blood transfusion carries a number of important dangers as well, and reducing those risks makes the procedure more difficult and expensive. The risk factor for blood transfusions that receives the greatest attention is infection transfer from a donor to a recipient. (Delen, Madhav, & Wu, 2011)

Standards/guidelines, professional leadership and dedication, human resources (quality and quantity), clinicians, and pertinent programmes put in place to support these may all intervene at different levels within the hospital context as barriers or enablers of PBM. (Mbanya, 2012)

Blood collection has multiples objectives: stable blood component supply to downstream services for preparation and qualification, reduction of blood product shortage and perished blood products, short waiting times of donors, high utilization of human and material resources, low operational costs. (Alfonso, Xie, Augusto, & Garraud, 2012)

LITERATURE REVIEW

The collection, processing, storage, and distribution of blood and its constituent parts form the blood supply chain. The blood supply chain has unique characteristics that set it apart from standard industrial supply chains and make it a particularly difficult research topic. (Osorio, 2017)

There have been two major periods of activity in the inventory management of blood supply chain:-

(1) 1970s, where regression models were first developed to identify optimal stock levels and order quantities (N. Yates, 2017)

(2) 2000s, which have been dominated by more advanced operations research techniques and simulation (N. Yates, 2017)

The literature from the first period asserts that the drivers for good inventory performance are the use of complex inventory models and algorithms (Stanger, 2012). However, the results of the case studies in this study reveal that these approaches are not applied in reality and that before implementing complex processes for the calculation of order quantities and target stock levels, wastage can be reduced by focusing on other factors (Stanger, 2012). Work done by (N. Yates, 2017) in the UK in recent years has found that the following are the key to good blood inventory management in hospitals:-

(1) Ensure to appoint experienced staff and train them appropriately.

(2) Find ideal target stock levels and order patterns.

(3) Build and sustain transparency of inventories.

(4) Maintain simple inventory procedures.

(5) Keep stock fresh and monitor remaining shelf-life.

(6) Collaboration throughout the business is key to success.

After a gap of nearly 20 years in research on this topic Owens et al. analyzed the impact of the average age of units on inventory performance (N. Yates, 2017). They found that the average age varied from blood group to blood group, concluding that an extension of shelf-life had the potential to yield significant reductions in wastage (N. Yates, 2017)

Over the years, researchers have also drawn several parallels between blood supply chain management and the inventory management practices of other supply chains. Although blood is an example of perishable product, some techniques used in industrial environments, for example just in time, are not suitable for the blood supply system due to the consequences of an inventory shortage; however, others are applicable says (N. Yates, 2017). Better stock management in hospital blood banks is achievable by implementing the rules that normally apply to manufacturing or common profit-driven companies; such as updating optimum stock levels, determining ordering intervals, specific ordering, delivery policies, etc. (Katsaliaki Korina, 2014). Additionally, an online, live-time stock control and ordering system for all blood banks will be beneficially for the supply chain (Katsaliaki Korina, 2014). Research has found that methods commonly used in commercial supply chain management can lead to efficiencies in the blood supply chain context and an example of this is sharing of stock or redistribution of blood units close to expiry between hospitals, reducing wastage across the supply chain (N. Yates, 2017).

The general goal of this study is to discover the elements that influence the National Blood Service (NBS) centre and the hospital it supplies to. The decision-making is done through a detailed analysis of a vertical segment of the blood supply chain. To accommodate future increases in demand and/or decreases in supply, which would result in better service levels, decreased shortages, and less wastage. The system incorporates material and information flows since they are crucial components of the supply chain. With the help of discrete event simulation, the issue is solved. (Brailsford, 2007)

Three factors have been determined to be essential for highly effective supply chains: timing, or the prompt delivery of the goods; transparency, or the visibility of all supply chain participants; and trust, which results from transparency. (Chapman, 2007)

The goal of an effective blood supply chain (BSC) is to meet demand while minimising losses and expenses. The system is burdened with costs in a variety of ways, including expenditures associated with collection, testing, segmentation (the division of whole blood into a variety of by-products), storage, and delivery. However, because demand is erratic and most blood products have a limited shelf life, achieving cost-effective operations for BSC poses a particularly difficult issue. (Valizadeh, 2021)

There is currently no substitute for human blood or the goods made from it because they are a limited resource that can only be generated by humans. In healthcare settings, it can be difficult to safely supply sufficient volumes of blood products for both elective and emergency procedures. Blood products and blood donors are always needed, but the supply of blood donors is unpredictable and the demand for blood products is stochastic. The task of efficiently matching supply and demand for this product is not straightforward. (Reza Ramezanian ⇑, 2017)

The rate of blood donation is a hazy variable that is challenging to forecast. In the UK, just 6% of the entire population donates blood, leaving around 60% of the population as potential donors. Even while blood is donated voluntarily and commercially in the United States, just 5% of the population does so, only 8% of donors give frequently, and roughly 62% never visit a blood centre again. In other nations, such as Japan, blood is even imported. The demand for blood products in some nations is rising significantly as the population ages and more blood components are required for new medical procedures. Additionally, the issues of the blood supply are made worse by the rising incidence of donor pool deferrals. (planning, 2018)

Poor data management results in the randomness of important decisions. Our understanding of the blood supply chain, refining blood inventory management procedures, and performance evaluations all depend on having access to crucial supply chain data. (Chapman, 2007).

There is a roughly 20-year hiatus before the effect of unit age on inventory performance was examined. They discovered that the average age varied depending on the blood group, coming to the conclusion that large Table I Blood components Component Shelf-life waste reductions could result from extending the shelf life. Therefore, there are other factors that affect wastage outside inventory management. There is no specific literature accessible on the blood supply chain between the two periods, with the exception of general perishable inventory theory, such as Raafat (1991), who classifies blood as goods with a defined shelf life.. (Stanger, 2012)

Along with the erratic nature of the supply and the perishable nature of blood, demand for blood products is also erratic and changes day to day, usually being higher on workdays. Additionally, since there are typically numerous hospitals in a network, the need for blood happens in hospitals, which adds to the complexity of the issue. These data show that a detailed planning process that takes into account various viewpoints and hazy variables is necessary to efficiently balance the supply and demand of blood. (Dehghani, 2021)

“The blood stocks in hospitals are generally classified into two categories, i.e. assigned and unassigned inventories (Jennings, 1973). Assigned inventory consists of units that are reserved for specific individuals and the unassigned inventory is open for use by absolutely any patient. Before being allocated, blood units are cross-matched against a sample of blood from the named patient to avoid transfusion reactions and to confirm compatibility. Once cross-matched, units from the assigned inventory are reserved for the specific patient for between 24 and 72 hours, ready for transfusion to avoid wasting time in cross-matching in case of urgent demand. This leads to a loss of valuable shelf life if units are not required and are consequently returned into the general unassigned inventory.” (Sebastian H.W. Stanger, 2012)
(Sebastian H.W. Stanger, 2012) targeted transfusion laboratories that have minimized their wastage, and identifies the associated key drivers for good performance and states that a strict focus on shelf life and a consistent First In, First Out/ Oldest Unit First Out policy is applied in all hospitals. In addition, (Sebastian H.W. Stanger, 2012) found that target stock levels, hence classic periodic review inventory theory (Waters, 2003), have been applied in all hospitals.

(Katsaliaki Korina, 2014)’s contribution to theory of the Blood Supply Chain Game is the game’s ability to facilitate students and professionals to acquire knowledge of the push–pull and cycle process view of a supply chain [i.e. push process: blood collection system and stocking both in the NBS and hospitals’ banks, pull process: doctors’ ordering; cycle process: information (orders) from doctors to hospital bank, etc.]

Another finding has been that Centralized systems are more efficient than decentralized systems (Andres F. Osorio, 2018). The benefits of centralization in the blood supply chain are fairly evident in extant literature. Economies of scale are an essential factor in driving centralization. Building and maintaining the infrastructure for a blood supply chain is expensive; therefore, location decisions are viewed as strategic ones; many authors have studied the correlation of location and allocation decisions in blood supply chains. (Andres F. Osorio, 2018). The same paper also elaborates on the fact that developed countries follow a more centralised approach which has also been proven by other research papers that form part of this review.

Many writers utilised a range of analysis techniques to their research on the blood supply network. Numerous publications could be grouped under simulation and statistical analysis categories. Some of these could be classified as operations research publications, while others focus on cost analysis. (Ma, 2013)

One of the major stakeholders in the healthcare system is the blood supply chain. As a result, any advancement in blood management has the potential to significantly affect how well the healthcare system functions. The factors that affect blood supply chain improvement include taking into account multi-period planning horizons, perishability of blood, uncertainty in demands and supplies, blood transfusion, and blood delivery system framework. (Emadi, 2021)

The price of the blood supply was evaluated by Custer et al. [9]. In terms of direct blood supply production costs, they made distinctions between four categories: donor recruiting and selection, donation collection, donor screening and processing, and donation distribution. They used a spreadsheet application to compute both the overall and per-unit prices. (Ma, EOQ-based inventory control policies for perishable items: The case of blood plasma inventory management, 2013)

In the beginning, the blood bank supply chain's overstocks and stocks of various suppliers are represented by zero or non-zero values. Zero indicates that the Blood Inventory does not need to be controlled by the contributor, whereas non-zero data necessitates such supervision. Data that is non-zero implies an inventory and a bottleneck. The excess is expressed as a positive number, whereas the shortfall is expressed as a negative number. (Yadav A. S., Blood bank supply chain inventory model for blood collection sites and hospital using genetic algorithm Ajay, 2019)

Since blood is a perishable product, there is little literature on the blood supply chain, which presents particular and unusual issues. The literature on blood management primarily focuses on the effectiveness and efficiency of managing the blood inventory. (Hsieh, 2014)

Blood inventory demands a great deal of control. This is the fundamental prerequisite for any kind of blood inventory control to be successful. K-Means clustering serves as a tool in this. In reality, the blood bank supply chain is made up of n players, such as a factory, distribution centres, suppliers, retailers, etc., and has a length of n. (Yadav A. S., 2019)

The Covid-19 pandemic's effects on the blood supply system Several businesses that offer goods or services to the consumer or end user make up the inventory management industry. In other words, the network (made up of suppliers, intermediaries, transport and logistics service providers) that depicts the flow of raw, semi-finished, and final materials represents the influence of the Covid-19 epidemic on the inventory management of the blood supply chain. (Yadav, 2021) .

There are 2700 licenced blood banks in India, out of which the government owns 40%, NGOs hold 20–25%, and the private sector owns the majority of the remaining blood banks (Choudhury [2011]). Indian blood banks are only able to collect 9 million units of blood per year, despite the nation's estimated 12 million unit yearly blood requirement (Indiastat [2012]). This shows that India suffers from a severe annual blood shortage of 3 million units (Balan [2014]). There may be a 90% blood scarcity in some Indian states (Indiastat [2012]) (Lowalekar, 2017)

It is crucial to evaluate the national blood programme in order to identify the strategies and tactics that have worked and comprehend the causes of those successes. It is equally crucial to identify the stages or actions that failed so that the concepts can be abandoned or changed and future effort can be improved. This gives knowledge that can be applied to future collaboration with other nations.

12. (McCullough, 2013)

The accompanying Clinical Series in The Lancet is appropriate and timely given the recent development of quality-performance indicators for patient blood management by healthcare institutions and accreditation organizations3 and examines the impact of patient blood management on three areas of transfusion medicine: blood utilization, alternatives to blood, and inventory management of the blood supply. (Goodnough, 2013)

It is crucial to evaluate the national blood programme in order to identify the strategies and tactics that have worked and comprehend the causes of those successes. It is equally crucial to identify the stages or actions that failed so that the concepts can be abandoned or changed and future effort can be improved. This gives knowledge that can be applied to future collaboration with other nations. (McCullough, Strengthening blood programs in developing countries, 2013)

In the 1970s and 1980s, the blood product supply networks attracted a lot of attention (WP, 2012). The blood supply chains have altered dramatically as a result of technological advancement and stricter regulation, and there is increasing interest in this field. To control the platelet inventory level, a simulation model was created. The performance measurements are the out-of-date and shortfall rates as a function of base stock levels (V & E, 2012). A computer simulation model of the Finnish blood supply chain was provided by (JS & Spens, 2012).A discrete-event simulation was used to determine ordering policies in order to reduce shortages, wastage, and costs as well as to improve service levels and safety procedures (K & Brailsford, 2012). The case study examined the management of the blood inventory of a UK hospital that was supplied by a regional blood centre.

(V, Doerner, Hartl, & Savelsbergh, 2012) took into account an issue faced by the Austrian Red Cross blood bank for Eastern Austria and proposed integer programming-based approaches to investigate the potential value of changing from the current vendor-managed inventory set up to a vendor-managed inventory system.

The technical structure of blood collecting systems is generally ignored in investigations of blood product supply chains, and there is little literature on these systems. Various authors presented their unique models on the topic. A computer simulation model was given by (ML & Grindon, 2012) to investigate the work flow and queue issues in blood collection. To assess the system's performance, donor scheduling techniques were examined with random arrivals occurring at a fixed hourly rate .In order to investigate customer satisfaction and productivity difficulties for American Red Cross bloodmobiles in the collection of whole blood, (JE, Golden, & Rappoport, 2012) presented a computer simulation model based on a six-bed benchmark clinic. To improve the system, several setup, staffing, and work-rule tactics were employed. A simulation study to assess approaches for planning the arrival of blood donors to a Red Cross blood drive was given by (JD, Brennan, Golden, & Fu, 2012). To estimate the number of servers needed for a mission based on expected donors, (P, Hutchins, & Lewis, 2012) provided a computer simulation model for mobile blood banks in the U.S. Navy. (V, Felici, & Impelluso, 2012) provided an approach for calculating and validating the best server configuration for a transfusion centre in Rome by combining simulation and optimization. A modelling method to enhance whole blood donor flow in Canadian blood clinics was presented by (J, Lipton, & Sangster, 2012).

In conclusion, despite the abundance of research on blood supply chains, little is known about blood collecting methods. Other existing research on blood collection primarily concentrate on strategic choices, and operational efficiency of blood collection systems has not been examined in a thorough manner, with the exception of (V, Felici, & Impelluso, 2012) and (J, Lipton, & Sangster, 2012). The study of blood collection systems with various types of blood donation was not done because only whole blood collection was discussed.

This essay is also connected to the extensive body of literature on clinic appointment scheduling (Gupta & Denton, 2012). In particular, a simulation-based approach for designing a family practise healthcare clinic was given by Swisher & Jacobson (2012). Both booked patients and walk-in patients are taken into account. Strategic choices like the number of check rooms and the makeup of the medical team are included in design selections. The definition of a "clinic effectiveness metric" includes clinic profit, patient satisfaction, and staff satisfaction. The clinical design possibilities are sorted using ranking and selection procedures.

Due to the fact that we also use a simulation-based methodology and take into account walk-in donors as well as scheduled donors, our approach is somewhat comparable to that of Swisher & Jacobson (2012). Our method, however, differs from that of Swisher and Jacobson (2012) because it takes into account unique characteristics of blood collecting methods, which are very different from customary clinics and hospitals. To be more explicit, we

provide a Petri net-based model of blood collection procedures that enables us to precisely characterise the blood collection activities, resource requirements, donor behaviours, and resource capacity planning.
Last but not least, operational choices are made using the simulation in order to coordinate daily human resource capacity planning with planned and walk-in contributors. In our paper, donor appointments are specifically optimised, whereas in (Swisher & Jacobson, 2012).

(Suchithra Rajendran, 2017)Developed a mixed integer stochastic programming model under demand uncertainty in which, due to the computational complexity of the problem, three heuristic rules are proposed for determining the platelet ordering policy at the hospital. The performance of these three ordering policies was compared against that of the periodic review order-up-to policy proposed in the literature using real-life data obtained from a medical center (ALOK SINGH, 2018)

Blood Screening

In 2017, the blood screening process was also addressed. The blood screening process has two phases. The first phase, involves blood units being screened together in pooled groups of a certain size by the Enzyme Linked Immuno-Sorbent Assay (ELISA) test to detect various virus-specific antibodies. In the second phase, the Polymerase Chain Reaction (PCR) conducts a testing of the individual blood units found clean by the former phase. Undeniably, the shorter the testing time, the longer the residual lifetime the blood unit has left for future use. The controller, thus, faces a well-motivated operations management problem. (Shaul K. Bar-Lev, 2017) proposed a new testing procedure that termed Recycled Incomplete Identification Procedure (RIIP).

Capitalism in Blood Bank System

Recently, there has been notable discussion about private organizations disrupting the blood bank sector and providing financial compensations for donating blood. Several studies come to show that financial compensation incentivizes people to donate and is actually effective at increasing donation rates. Most of the plasma products of a Canadian province’s hospitals used to come from the U.S. To counteract this, one clinic in Saskatchewan started paying their donors $25 per donation (Rienzi, 2013). Many Canadians disagree with the idea of giving out such financial incentives due to ethical concerns about exploiting their poorer citizens, as well as the increased costs involved in performing more thorough tests since paid donors could be lying about their health history in order to gain the money, which poses risks to transfusion patients (Jung-Joo Maeng, 2018)

Process Mining

Process mining is an analytical method that is already being applied in other industries, like financial auditing, telephony and manufacturing. It can and should also be applied to blood bank inventory management. Process mining lends itself well to blood bank inventories' analysis, since each blood product entering blood banks becomes part of the inventory "process," wherein it is received as inventory and disposed from it via transfer, transfusion, or discard. Process mining helps in understanding the processes in three main ways. Firstly, "discovery," where a process map is created using logs, generally without prior knowledge of the process. Next is "conformance," wherein a previously determined process from an understood practice is measured against the map created, the latter being the ideal standard. Lastly, "enhancement," whereby a pre-existing process map can be magnified with calculated time-stamp data in the event log to depict throughout time and highlight potential bottlenecks (Jason G. Quinn, 2017)

Disaster Management

Disasters are inevitable in nature and an unprecedented event. Dealing with a disaster can be tough for businesses, but it is more arduous and laborious for hospitals. What do these hospitals need to treat their patients: BLOOD. In the aftermath of a disaster, it is crucial to obtain and fulfil the demand for blood. As a result, the idea of designing a blood supply chain for disaster relief has become extremely important in recent years. (Jamal Nahofti Kohneh, 2021).

The wildest issue for the blood banks for inventory management is not to distribute the blood and its products, but to actually interpret the adequate amount of inventory required amid the pandemic situation.

The optimal management of blood supply chains (BSCs) is difficult due to their high complexity,a variety of coll ection techniques, supply and demand volatility, blood perishability, blood groupdistinction, and compatible subs titutions. (Kees, 2022)

Due to the perishability of RBCs and platelets, excessive blood collection in some periods cannot effectively maintain the balance between supply and demand in subsequent periods of rising demand or falling supply. Due to incomplete or ambiguous information about the nature of the catastrophe, donors frequently provide more than is necessary, and as a result, the supply may be considerably higher than the actual demand. For instance, an urgent request for more blood during the Black Saturday bushfires in Victoria, Australia, significantly increased the number of donations. A whopping 40,000 people registered online in just 10 days, far exceeding the usual 2,200 registrations per month on average. However, the actual demand for blood was much lower than anticipated, resulting in many units going out of date. Only 18% of the blood that was collected was given to people who had burns, and more than 30% was used for needs unrelated to disasters (Australian Red Cross, 2009). This implies that approximately 50% of the blood collected in response to this disaster was discarded, even though this was not specifically reported

"The cost of waste is correlated to the workforce involved in the production of each blood product, such as donor collection, transportation, testing, and processing, as well as the disposal of the used product." (Mohammad Shokouhifar, 2021).

Since the World Health Organization (WHO)'s declaration of a pandemic in March 2021, the coronavirus disease-19 (COVID-19) has profoundly disrupted the global landscape, having an effect on regular affairs of business, education, healthcare, and society. (Linda S. Barnes1, 2021)

At times of the lockdown, all the blood donation drives and NGOs which collect, store and pass on blood to hospitals were put on hold to restrict the spread of the virus, as a result the voluntary supply of Blood and its products reduced drastically. The number of blood donations gradually decreased as COVID-19 spread from early 2020, as most people opted to spend more time at home and practise social distancing. (Mohammad Shokouhifar, 2021) To illustrate the same, we would take a 10 month analysis from February 2020 to October 2020, the

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lockdown period in India (Raghuwanshi1, Blood supply management amid COVID 19 pandemic: Challenges and

Raghuwanshi, *et al.*: COVID-19 pandemic and its impact on blood transfusion services in India

Table 1: Number of Donations in District Blood Banks in Madhya Pradesh (M.P.)

Month	Total No. of Donations in District Blood Banks (M.P.), *n* (%)	Voluntary Donations in District Hospital Blood Banks (M.P.), *n* (%)	Replacement Donations in District Blood Banks (M.P.), *n* (%)
February	148,741 (61.5%)	127,133 (63.74%)	21,608 (50.8%)
March	8,580 (3.54%)	7,030 (3.52%)	1,550 (3.64%)
April	8,037 (3.32%)	1926 (0.96%)	6,111 (14.37%)
May	12,353 (5.10%)	10,040 (5.03%)	2,313 (5.44%)
June	12,941 (5.34%)	10,602 (5.31%)	2,339 (5.50%)
July	13,196 (5.45%)	10,831 (5.43%)	2,365 (5.56%)
August	11,971 (4.94%)	10,482 (5.25%)	1,489 (3.50%)
September	13,748 (5.68%)	11,294 (5.66%)	2,454 (5.77%)
October	12,375 (5.11%)	10,103 (5.06%)	2,272 (5.34%)
Total	241,942	199,441	42,501

strategies, 2022)

From the above chart, we can the see the massive fall in blood donation in the 33 districts in Madhya Pradesh, India starting from February 2020 (sample taken by the authors of that paper).

Lockdown had hit India on the 24th March, 2020, but the fear of Covid-19 was seen from the beginning of the month of March. "Unfortunately, blood donation has considerably reduced during the COVID-19 epidemic as a result of fear of the coronavirus, the implementation of lockdown has resulted in the low level of donor participation." (Hossein Shirazi a, 2021)

As in the case of Madhya Pradesh's district hospitals, the percentage of people who donate blood drastically decreased from 61.5% in February 2020 (before the pandemic) to 3.35% in April 2020 (during the COVID-19 pandemic).

Section 144 was implemented at many places across the state, which led to restrictions on the number of people at gatherings, and this jeopardized the voluntary blood donation drives, thus straining the blood bank stock and blood supply. (Raghuwanshi1)

Blood donation declines peaked in February 2020 during the pre-pandemic period and reached their lowest point in April 2020 (phase 1 of COVID-19 pandemic lockdown). In April, when the country was under its strictest lockdown, there were a minimum of 8,037 donations (3.32%) in all 33 of Madhya Pradesh's districts.

We can also observe that during the COVID lockdown, voluntary donations significantly decreased in a nation like India.

The number of voluntary and replacement blood donations significantly decreased, and April saw the fewest donations. With the unlock phases from phase 1 to phase 5, the quantity of blood donations slightly increased.

People who volunteered to donate blood were questioned about their interactions with COVID 19 patients, and those who had an abnormal temperature or symptoms of a dry cough were not permitted to give blood. Medical personnel who had close contact with COVID 19 patients or infected donors were subject to a quarantine policy. Donors were advised to get in touch with blood banks if they experienced a temperature increase, a cough, or other signs of nCoV infection.

Blood supply issues for chronic transfusion-dependent patients, victims of motor vehicle accidents, people undergoing chemotherapy, people receiving dialysis, and critically ill COVID 19 patients with multiple organ failure were created by the decline in blood donations and resulting decrease in blood stocks.
Due to the significant costs of over/under collection during an emergency and consequent negative impacts on the balance of blood supply chain, further study to determine better estimates of the quantity of blood donations needed in emergencies are necessary (Zahra Hosseinifard, 2020)

RESEARCH METHODOLOGY

This section presents the research methodology utilised to evaluate the inventory management in the blood supply chain. A total of 250 papers were evaluated out of which 212 were shortlisted and thoroughly studied for our research. The number of articles published till 2022 are represented graphically in 4-year increments as seen in the figure.
During the research, we were able to find the years of publication for 208 research papers out of the 212 selected ones. The histogram considers seven time periods namely 2019-22, 2015-18, 2011-14, 2007-10, 2003-06, before 2003. The highest number of research papers pertinent to our topic of research were 78 found in the time period 2019-2022. This was followed by 2011-2014 wherein 50 research papers were published regarding the topic. In the 2015-2018 increment, 42 papers were published related to the topic at hand whereas the 2007-2010 increment saw 22 research papers relevant to our research area. 9 research papers were taken in the "before 2003" increment to carry out research. Finally, the least number of papers which were 7, found belonging to the 2003-2006 increment.

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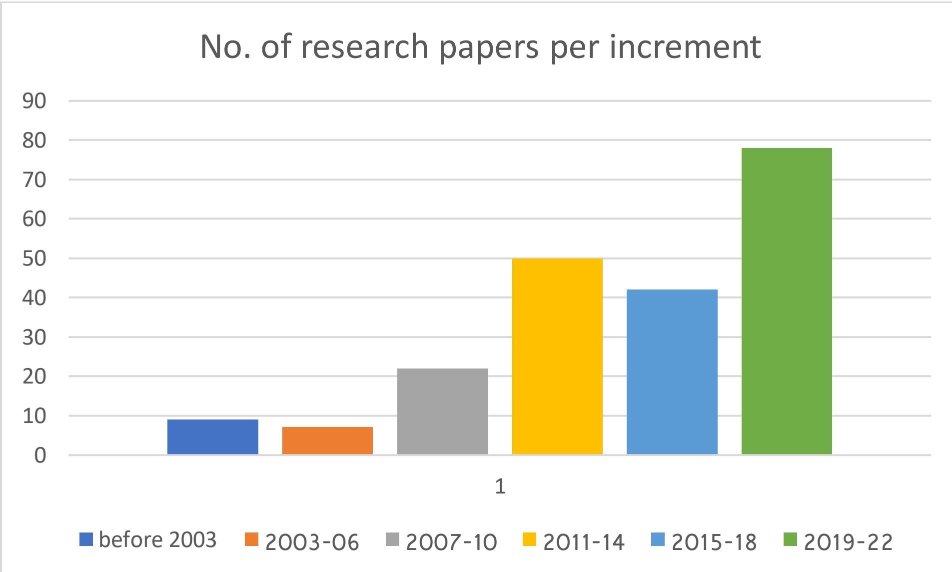

FIG 1- Research papers over the years

ANALYSIS

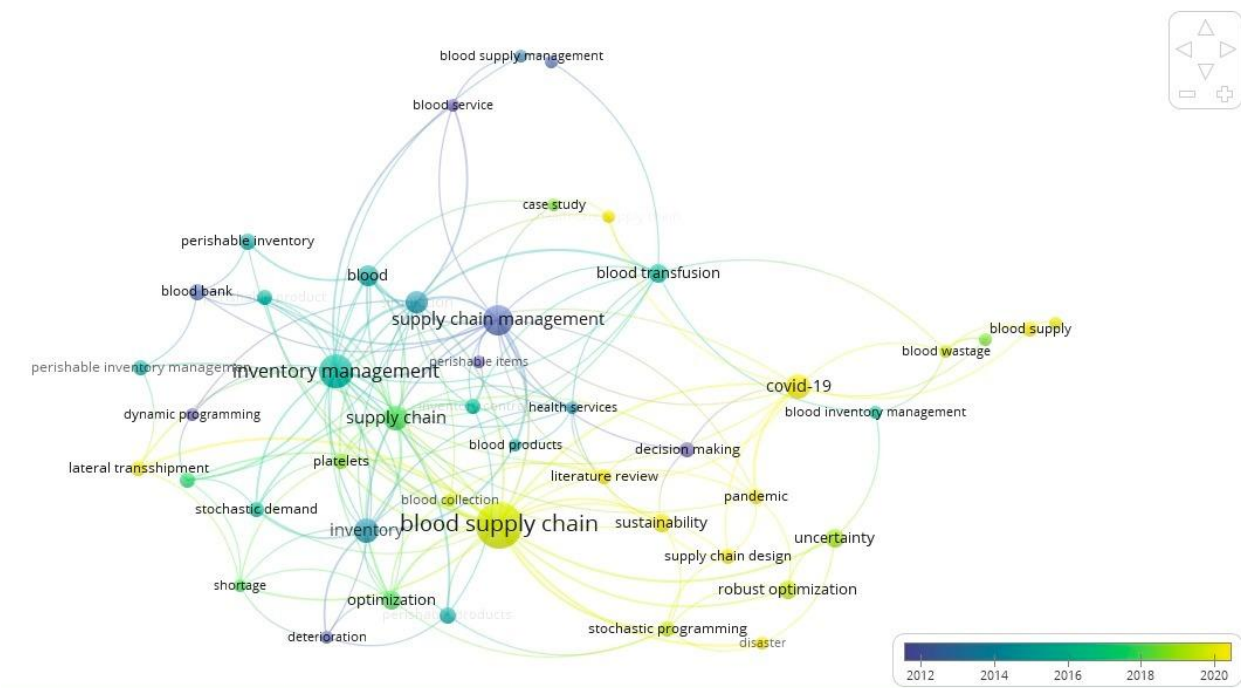

FIG 2- Key words

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Here in this graph you can see the keywords used in the research papers used to create the paper, blood supply chain is the word being used the most along with inventory management and supply chain management. The blood supply chain activities include collecting, testing, processing, and distributing blood (and its derivatives) from donors to patients for emergencies, surgical or routine medical treatments. The blood supply chain activities include collecting, testing, processing, and distributing blood (and its derivatives) from donors to patients for emergencies, surgical or routine medical treatments. Inventory management here means the supervision of non capitalized assets -- or inventory -- and stock items. Supply chain is the series of processes in the production and distribution of goods, from when they are first made, grown, etc. until they are bought or used. Other words used are blood transfusion , covid-19, platelets, blood supply management, lateral transshipments.

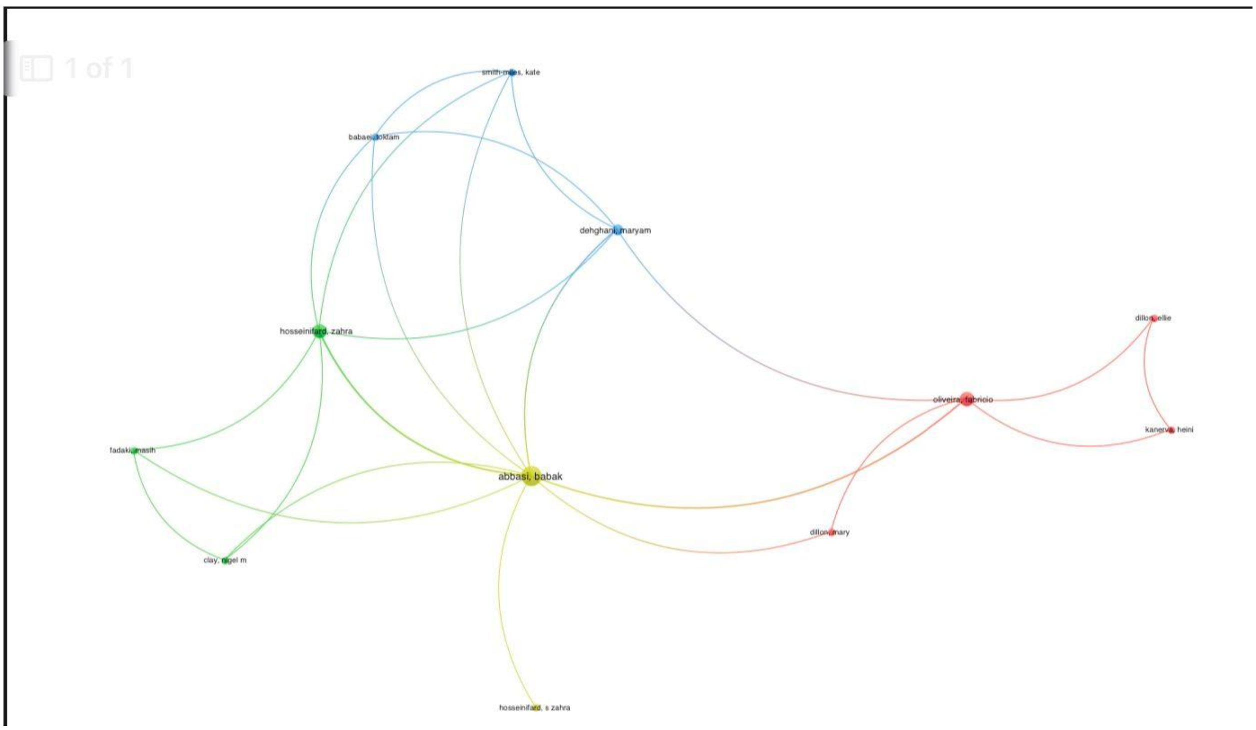

FIG 3- COAUTHORS

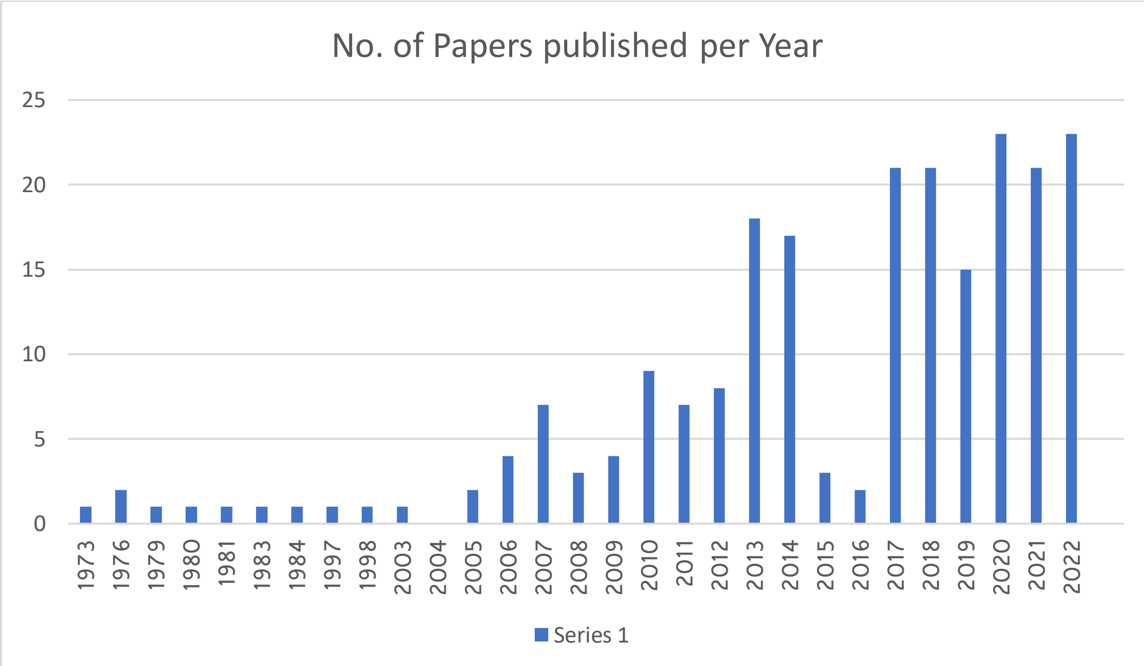

FIG 4- Number of papers published per year

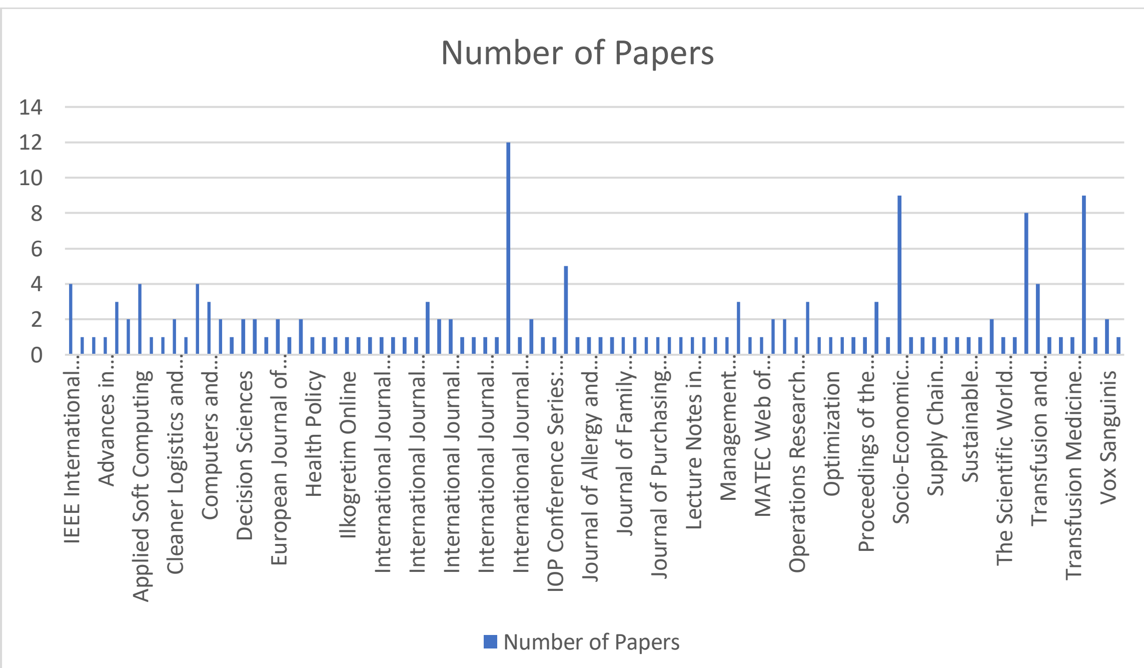

FIG 5- Number of papers

CONCLUSION

The supply chain for blood products was examined in the paper that was given; this is one of the main areas that researchers of healthcare systems have recently looked into. A literature research revealed a gap in the design of a comprehensive network by taking the movement of transportation equipment into account. This research's decision to switch to a closed-loop supply chain and propose a more effective structure was driven by the distinctive characteristics of the equipment.

The management of blood inventory is a crucial component of blood bank supply chain management. In order to reduce the total cost of the blood supply chain, we concentrate on how to identify the most likely reserves and the absence of reserves.

It can be shown that the practice of gathering the entire supply of blood during a camp may not always be the best for blood banks. It results in high operating costs and causes a great deal of system waste. Additionally, it was demonstrated how halting supply above a particular point does not worsen the shortage but unquestionably lowers system waste. The operations of Indian blood banks differ from those of western blood banks in terms of collecting, storage, componentizing, and usage and transfusion. The literature has published a number of models and analyses that are scientifically sound.

One can draw the following conclusions:

i) Inventory levels ought to be correlated with actual demand. Due to the unpredictable demand facing healthcare operations, probabilistic models must be used in the computations.

ii) Instead of categorizing objects according to their functions, classify them according to annual dollar usage values that are determined by annual consumption and the average unit price of each item (e.g., supplies related to Ophthalmology, Emergency, Rheumatology, and Gynaecology). Additionally, it's important to identify shelves and aisles properly. The picking time is facilitated and decreased by this method.

iii) In order to maintain the improvements, top-management participation and employee training must be continuously practiced.

In terms of future study, a simulation model should be further constructed to thoroughly test the suggested solutions, particularly in terms of other components of blood inventory management that were not taken into account in this model, such as cross match and assigned and unassigned inventory. Additionally, various demand categories (such as urgent and non-urgent demands) that may necessitate ABO-substitutions or emergency delivery should be taken into account. The literature has not yet fully analysed either subject. The unpredictability around the shelf life of the supplies obtained by the hospitals would be an additional intriguing feature to the model. Assuming a constant value for this parameter could affect the outcomes. One the one hand, if the arriving units' average age turns out to be greater than assumed, the model's predicted target inventory level might not be enough, which would lower service levels and exacerbate shortages. The desired inventory level may be higher than necessary if the average age of the blood units is lower than the average age taken into account, which could result in unanticipated wastage.

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