# Management Blood Using Optimization Algorithm: A State of the Art Literature Review

Menur Wahyu Pangestika, Zalilah Abd Aziz and Razulaimi Bin Razali
*College of Computing Informatics and Media, Universiti Teknologi MARA (UiTM), Selangor Darul Ehsan, Malaysia*

Keywords: Blood Management, Optimization Algorithm, Blood Transportation.

Abstract: Blood is an important element that benefits every human being and is the most valuable resource in any health institutions. Blood transfusion service to patients is one of the health efforts for disease healing and health recovery which urgently requires the availability of blood and blood components. These blood components need to be sufficient, safe, easily accessible, and affordable by the community. Blood management is a series of activities that involves planning, organizing, coordinating, and controlling the provision of blood at the blood centre. The activities started from donating the blood, securing and processing the blood components, storing and distributing of blood to hospitals that requires the blood. In this paper, 45 articles published from 1973-2021 that discussed the problems that exist in the problem of blood management were reviewed. Optimization algorithms related to solving the blood problems were also observed. Discussion on other related topics such as blood organization, blood transportation, and factors for clinical blood loss were also included.

## 1 INTRODUCTION

The key to an effective health system is the provision of safe blood services and adequate blood product (Organization, 2009). Blood is a supplied resource, with unpredictable demand and blood that must always be fulfilled (Duan and Liao, 2014) because blood is an important element that benefits every human being (3, 2012) and is the most valuable resource in institutions any health (Baig and Javed, 2020). If blood is not managed properly, it will spoil quickly which will have an impact on the development of the supply chain (Karadag and Keskin, 2021).

Blood donation plays an important role in the blood supply chain because between donor motivation, optimization of location and capacity decisions, and control between reliability and resilience will be interdependent (Hosseini-Motlagh et al., 2020a). Blood is human blood which consists of cell components and a liquid component in the form of plasma. Transfusion blood is blood obtained from a donor who donates blood to a blood center. Blood centers and hospital blood banks are separate places with different blood management. The provision of blood at the blood center is a series of activities starting from donating blood, securing blood, processing blood components, storing blood and distributing blood to hospitals that need blood. Because the management of blood between the blood center and the blood bank is different, the service for giving blood to the recipient is carried out by the hospital through the hospital's blood bank which gets its supply from the blood center. A hospital blood bank is a work unit that receives and stores blood from a blood center, performs cross-match checks and delivers blood to be transfused to recipients according to applicable standards.

Management is the use of resources effectively and efficiently in the process of planning, organizing, coordinating, and controlling (Lloyd, 2020). One of the health efforts of blood transfusion services for healing disease and health restoration is the availability of sufficient blood or blood components that are affordable to the community.

Two indicators of network performance in the hospital's integrated inventory system are in terms of cross-matching units and obsolete units. This supply is called lateral supply which allows hospitals to meet their demand with other hospital supplies without the need for products in the blood center and excess in any hospital (Arani et al., 2021). National Safety and Quality Health Service (NSQHS) Standard 7, Systems must be in place for healthcare organizations to safely and effectively accept, store, transport, and monitor used blood and blood products (Commission and Care, 2012). But in reality, there are various problems that occur in this process for example ex-



Pangestika, M., Aziz, Z. and Razali, R.
Management Blood Using Optimization Algorithm: A State of the Art Literature Review.
DOI: 10.5220/0012444600003848

In *Proceedings of the 3rd International Conference on Advanced Information Scientific Development (ICAISD 2023)*, pages 107-117
ISBN: 978-989-758-678-1

pired blood (Heidari-Fathian and Pasandideh, 2018b) (Sapountzis, 1984).

The purpose of this paper is to find out specific problems in blood management problems and the algorithms used to solve problems in blood management. In this paper, several problems and issues will be presented to discuss blood management problems which are solved by optimization theory.

There are 6 points that will be discussed in this paper from the introduction to the conclusion. The first point is the introduction to the topic of this paper related to blood management. The second point that will be discussed is Background related to blood organisation, blood transportation, and clinical blood loss. The third point is Review methodology. The discussion of this point is an explanation of the article collection process as well as a critical review of the collected articles. The fourth point discusses the blood management problem. The fifth point discusses optimization algorithms that are applied to solve blood management problems. The final section is a conclusion that discusses all the work presented in this paper.

# 2 BACKGROUND

Patient Blood Management is a clinical and multidisciplinary approach to optimizing patient care requiring blood transfusions. Blood management is a long chain of processes so it can have problems that can disrupt the integrity of the process chain (Markowitz et al., 2014). The problem of blood management in the journal found is solved by optimization. The reason is that optimization is one of the disciplines in mathematics that is used to solve problems such as minimal costs, maximum profits, optimal design, optimal management, and minimal errors (Dijk et al., 2009).

Blood types are A, B, AB, and O blood. People who donate blood will go through a selection test process first to find out whether potential donors can donate blood or not. If the potential donor has met the criteria, then the prospective donor can donate blood. Lack of blood can occur due to several things. Sometimes there are many donors who want to donate blood but do not pass the selection test to be able to donate blood or request a blood type from the hospital to the blood center with the availability of the blood type in the blood center is not appropriate, while for other blood types there are large amounts.

Blood components whole blood, RBCs, Platelets, and Plasma (Gurevitz, 2010) have their respective ages and use. Whole blood has an age of up to 30 days which is used for trauma and surgery cases. RBCs have an age of up to 42 days and are used for cases of anemia, surgery, trauma, blood disorder, any blood loss, and such as sickle cell. Platelets have an age of up to 5 days and are used for cases of cancer treatments, organ transplants, and surgery. Plasma has a lifespan of up to 24 months for burn patients, shock, and bleeding disorders (Ahmadi et al., 2017). Blood components are used for various treatments (Shih and Rajendran, 2020).

At the hospital, each department will request blood based on blood components and type. Doctors will tend to ask for more blood bags for patient safety, causing uncertain blood needs. If later after the blood bag has been used and there are excess blood bags, the blood bag will be given or transferred to another patient with the same blood group and component. However, if the blood is not used by another patient until the expiration date, then the blood will be discarded

## 2.1 An Overview of Blood Organization

Implementation of the provision of national blood needs requires collaboration between blood transfusion services, government, hospitals, mass media, and the general public. Even in large countries, a regional distribution of blood needs is necessary. So there is a need for an effective national blood committee whose function is to formulate national blood policies including rules and regulations for storage, processing, collection, transportation, distribution of blood, and administration of blood transfusions to patients. National blood transfusion services require medical and managerial skills that are ideally led by a medically qualified director. A large blood transfusion service is also needed by the manager. Blood transfusion services can be centralized, regionally hospital-based or a combination. This system cannot be changed. Blood collections can be organized by a blood center, a hospital, or both. Large countries do it regionally where one center is responsible for the area A centralized organization that operates transfusion services throughout the country, with or without satellite regional centers. Regional organization can be carried out in two events, namely a strong national transfusion center with direct control of regional blood centers or national blood transfusion centers that have loose national coordination with regional centers. A hospital-based organization in which each hospital has its own blood collection program with or without central regulation and coordination. A mixed system is a hospital or blood service that can collect blood independently which can increase the independence of the institution (Gibbs and N, 1993).

### 2.2 An Overview of Blood Transportation

Blood transfusion services aim to fulfill patient demand by offering efficient, secure, and sufficient blood and blood products (Gibbs and N, 1993). Good blood storage management includes ordering, storing, handling, and administering blood products efficiently and optimally. Blood management consists of two key factors, such as product availability (blood storage plan, delivery time, and order volume) and product integrity (process and physical product control to ensure effective and efficient handling, thereby maintaining availability and reducing blood damage) (Authority, 2014). The blood supply chain network consists of donors, blood collection facilities, laboratories, hospitals, and blood centers (Arani et al., 2021) (Ghorashi et al., 2020). Two important properties are considered in the blood supply, namely the ABO-Rh factor and the shelf life of blood products (Arani et al., 2021). The problem with the blood supply chain (BSC) is price management, business decisions, and optimal design. In Turkey, the BSC management is carried out by the Turkish Red Cross Chain. The Turkish Red Cross is an important part of the Health system. The Turkish Red Cross blood chain structure is responsible for the supply of blood collected from donors via blood donation vehicles and mobile or blood donation centers which are then transported to the nearest regional blood center. The regional blood center will process various laboratory tests, produce and store blood products, and deliver the blood products to hospitals or health centers according to their needs (Karadag and Keskin, 2021).

### 2.3 An Overview of Clinical Blood Loss

Red blood cells will be transfused especially in symptomatic patients or when patients lose blood continuously (Allard and Contreras, 2015). Blood is used in hematological conditions such as thalassemia, hemophilia, leukemia, and aplastic anemia (Gibbs and N, 1993). In addition, blood is also used for complications of pregnancy, trauma, severe anemia in childhood, gynecology, cancer, surgery, hematological disorders, and chronic diseases (Shamshirian et al., 2018). Significant blood loss and relevant transfusions are important events in perioperative care (Bartoszko et al., 2017). Transfusion should also be guided by clinical signs and symptoms when the hemoglobin is between 7-10g/dL as in concomitant medical or surgical problems. For example in patients with age ¿65 years, cardiovascular disease, ongoing blood loss, respiratory disease, and coagulopathy. So in an incident like this, the blood bank must be able to ensure that blood and blood components are available or sufficient. When a patient is to undergo blood transfusion, the decision depends on estimates of how much blood loss, rate of blood loss, evidence of end-organ dysfunction, pre-bleeding hemoglobin level and whether there is a risk of coronary artery disease (Allard and Contreras, 2015).

## 3 REVIEW METHODOLOGY

In this paper, we synthesize a knowledge base that links the problems of blood management and optimization. We conducted a review in two stages, namely (1) Framing the research objective and (2) Study Selection.

### 3.1 Framing the Research Objective

There are 2 purposes of this writing, namely:

RO1: knowing the specific problems that exist in the problem of blood management;

RO2: find out what optimization algorithms are used to solve blood management problems.

### 3.2 Study Selection

Identification of articles that are suitable for analysis is carried out at the study selection stage. The steps taken are (1) determining search criteria and database, (2) inclusion and exclusion criteria, and (3) selecting the relevant studies and descriptive analysis. The flowchart of the study selection is shown in Figure 1.

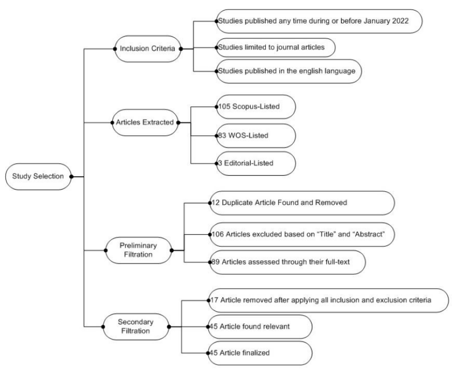


Figure 1: Flowchart Study Selection.

### 3.3 Determining Search Criteria and Database

Before the article search, we identified several keywords that were used as literature for this writing related to the research topic. There are two groups of keywords used for literature searches:

A. Words related to blood management: “Blood”; ”Management”; ”Blood Management”; ”Blood Organization”; “Blood Transportation”; “Clinical Blood Loss”; “Blood Management Problems”; “Blood Transfusion”; “Blood Donors”; “Type of Blood Products”; ”Blood Supply Chain”.

B. Words related to optimization: “Optimization”; “advantages and disadvantages of optimization”; ”algorithm optimization”; ”Heuristics”; “Metaheuristics”; ”Optimization of Blood”.

The search carried out is to find several journals that discuss blood management issues. Next, do a search on optimization studies. Finally, do a search related to optimization to solve various blood management problems. So we found various problems in blood management and methods for solving them. To search this journal, we used 2 widely recognized databases, namely Scopus and Web of Science (WoS).

### 3.4 Inclusion and Exclusion Criteria

In Table I below, The author analyzed by determining the inclusion criteria and exclusion criteria in selecting the relevant studies

Table 1: Inclusion Criteria and Exclusion Criteria.

| No. | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| 1 | Studies related to; blood management | Review articles; |
| 2 | Studies related to optimization are used to solve blood management problems. | Studies that have a theoretical or conceptual framework. |

### 3.5 Selecting the Relevant Studies

In writing this paper, several screenings were carried out for the study selection stage. These stages are starting from the selection of titles and abstracts, followed by reading the entire text, and selecting journals for screening several journals that are in accordance with the objectives of the research.

The first stage is the selection of titles and abstracts based on the purpose of this research and seen from several keywords that are appropriate to the research. Next, we apply journal selection based on inclusion and exclusion criteria. Followed by reading the full-text version used as literature in this study. The papers used are papers published in 1973-2021.

### 3.6 Descriptive Analysis

The number of papers published in this field is an ever-increasing number of blood management problems from distribution to storage. Figure 2 shows that there are various solutions or algorithms used to solve blood management problems and including optimization algorithms. From this graph, it can be seen that from 1973 until 2021 the resolution of this problem for several studies is still being carried out.

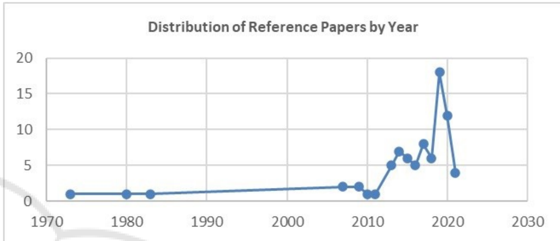


Figure 2: Distribution of Reference Papers by Year.

### 3.7 An Overview of Optimization Algorithm

Optimization is an act or process of making the best of something; (also) the optimal rendering action or process; optimal state or condition (oxford dictionary). Optimization is to help human activities in solving problems such as creating, and processing an optimal product design, but optimization can also be used for problems such as mathematics in calculating minimal costs, and maximum profits, making an optimal design, and optimal management (Kulkarni, 2017). In optimization, there are two categories, such as Approximate which can provide the right solution or not provide the right solution. The second is Exact which can provide exact solutions (Dréo and Siarry, 2003).

## 4 BLOOD MANAGEMENT PROBLEM

Several management problems, including blood distribution, can be seen.

1. Citation: (Haijema et al., 2007)
   Method: “Combined Markov Dynamic Programming (MDP) And Simulation” Type of Blood Product: Platelet

Issue: Demand is highly variable and uncertain; Cost production; Stock time ex- pired.
Objective: Presenting dynamic program- ming formulations for blood platelet problems; Provides optimal numerical computation and policy structures for small-sized situations; The "nearptimality" of singlelevel and double-level order-up-to policies should be demonstrated; Offers a simulation based search algo- rithm; Make sure it's okay to ignore different blood types.

2. Citation: (Dijk et al., 2009)
   Method: "A Mathematical Technique Called Stochastic Dynamic Programming (SDP) And Computer Simulation"
   Type of Blood Product: Platelet
   Issue: Shortages; Overproduction; Outdating; Cost Production.
   Objective: Presents an approach based on operations research techniques on blood management; Provides formal support for the existence of nearoptimal upto order rules and a structural and replicable approach to computing them; Apply an operations research approach to actual inventory data to obtain a number of interesting conclusions for blood management
3. Citation:(Ghandforoush and Sen, 2010)
   Method: DSS, Integer Nonlinear Programming
   Type of Blood Product:Platelet
   Issue: Platelets have a very short shelf life
   Objective: "Determine the minimum cost platelet production schedule at the regional blood center with the time that is every day of the week"
4. Citation: (Osorio et al., 2017)
   Method: "Combines Discrete-Event Simulation (DES) With Integer Linear Programming (ILP)"
   Type of Blood Product: Platelet
   Issue: Uncertain supply and demand; Shelf life constraints.
   Objective: Calculating temporary production costs
5. Citation: (Jabbarzadeh et al., 2014)
   Method: Supply Chain Network,Robust Optimization
   Type of Blood Product: Blood Product
   Minimize the total cost of the network; The uncertain and dynamic nature of blood demand
   Minimize total network cost
6. Citation: (Duan and Liao, 2014)
   Method: A Simulation Optimization (SO), TA-TS (Threshold accepting- Tabu search)
   Type of Blood Product: Red blood cell, Blood ABO
   Issue: Outdating
   Objective: Minimize the expected system expiry rate below the maximum pre-determined allowable deficiency level
7. Citation: (Dillon et al., 2017b)
   Method:"Two-Stage Stochastic Programming Model"
   Type of Blood Product: Blood Product
   Issue: Uncertainty in the demand; Perishable blood; Minimize operational costs; Lack and waste of blood due to expiration.
   Objective: Minimize operational costs, as well as shortages and wastage of blood due to obsolescence, taking into account durability and uncertainty of demand.
8. Citation: (Attari et al., 2019)
   Method: "Blood Supply Chain; Stochastic Programming; e-Constraint; Robust Optimization"
   Type of Blood Product: Blood Product
   Issue: Minimize the expected costs; Uncertainty
   Objective: Developing a novel hybrid approach.
9. Citation: (Heidari-Fathian and Pasandideh, 2018b)
   Method: "Multi-Objective Optimization, Robust Optimization, Bounded Objective Function, Lagrangian Relaxation"
   Type of Blood Product: Blood Product
   Issue: Minimize the total cost; Demand for the blood product are uncertain.
   Objective: Minimize the total costs of the supply chain network; Proposed for minimizing the total number of shortages and perished blood products; minimize the total amount of GHG emissions caused by transportation activities in the chain.
10. Citation: (HosseiniFard and Abbasi, 2016)
    Method: Two Echelon Inventory,Stochastic Replenishment
    Type of Blood Product: Blood Product
    Issue: Perishable items.
    Objective: "shows how centralizing hospital inventory in the second echelon of the blood supply chain and two echelons with perishable goods to improve supply chain performance when replenishment is stochastic".
11. Citation: (Heidari-Fathian and Pasandideh, 2018a)
    Method: Mixed-Integer Linear Mathematical, MultiObjective Decision Making, Augmented eConstraint Method And LP-Metric Method, ELECTRA
    Type of Blood Product: Blood Product
    Issue: Minimize the total cost
    Objective: Minimizes total chain costs and maximizes the reliability of local and primary

blood centers by maximizing the total average amount of blood products delivered to the point of demand.

12. Citation: (Liu and Song, 2019)
    Method: "A discrete-time mixed integer linear program- ming (MILP)"
    Type of Blood Product: Red blood cells
    Issue: Total operational cost; Uncertainty; Perishable product.
    Objective: Minimize the total time for central blood collection, and blood transport; Minimize the total cost of setting up a blood collection center, and transporting blood.
13. Citation: (Hamdan and Diabat, 2018)
    Method: "Combined Markov Dynamic Programming (MDP) And Simulation"
    Type of Blood Product: Red Blood Cells
    Issue: Inventory; Location decisions; Reduce the number of outdates; Simultaneous blood delivery time and system fees Uncertainty demand.
    Objective: Reduce the number of expirations, system costs and blood delivery times simultaneously.
14. Citation: (Hosseini-Motlagh et al., 2020b)
    Method: "Multi-Objective Optimization, Robust Fuzzy Stochastic Programming"
    Type of Blood Product: Blood Product
    Issue: Minimizing the shortage and wastages; Uncertainty; The perishability of blood; The age-based characteristic of blood.
    Objective: Minimize the expected value of the total shortage including the shortage of fresh blood in the hospital blood bank (HBB), the shortage of ordinary blood in the HBB, the shortage of fresh blood in the area, and the short- age of ordinary blood in the area during all periods; Minimize the total cost of SC which consists of the fixed costs of opening TES in the regions, the cost of purchasing fresh blood and ordinary blood at HBB, the cost of purchasing fresh blood and ordinary blood sent to the regions, and the cost of waste and storage at HBB.
15. Citation: (Rajendran and Ravindran, 2019)
    Method: Modified Stochastic Genetic Algorithm (MSGA)
    Type of Blood Product: Platelet
    Issue: Wastage; Shortage.
    Objective: Minimize Wastage and Shortage

    In general, the blood management problems that occur are related to three points in Jennings' journal in 1973. The paper that will be discussed is various obstacles related to blood management problems in 1973-2021. One of the problems in supply chain management is the management of perishable blood products, because the blood center is responsible for receiving, transfusing, and finally delivering blood products to the point of demand (Heidari-Fathian and Pasandideh, 2018b). Many complex factors occur in the blood supply such as uncertain supply and demand, the proportion of blood groups, shelf life limitations, and different collection and production methods (Heidari-Fathian and Pasandideh, 2018b; Osorio et al., 2017; HosseiniFard and Abbasi, 2016). Because the nature of blood is perishable, it is necessary to consider the time required to process the received blood and minimize the amount of wasted blood (Alizadeh et al., 2020).
16. Citation: (Larimi and Yaghoubi, 2019)
    Method: Robust-Stochastic Optimization
    Type of Blood Product: Platelet
    Issue: Demand fluctuation; Short lifespan of platelets; Efficiency as suppliers and costs
    Formulate the cost of placing BET in the hospital plus the cost of setting up fixed produc- tion in the laboratory center.
17. Citation: (Alizadeh et al., 2020)
    Method: Bi-Objective
    Type of Blood Product: Blood Product
    Issue: Highly perishable; Time Processing; Minimizing the amount of wasted blood.
    Objective: Consider the economic dimension of the supply chain; Minimize blood transfusion times from portable facilities to hospitals.
18. Citation: (Ahmadimanesh et al., 2020)
    Method: Deep Neural Network
    Type of Blood Product: Blood Product
    Issue: Expired blood; Blood perishability; Uncertainty of blood demand; Reducing blood return and blood loss
    Objective: Designing an optimal blood transfusion network manage- ment model and deep neural network that is used so that the cost of blood waste, return and shortage can be reduced by several recursive layers in the supply chain
19. Citation: (Shih and Rajendran, 2020)
    Method: Possibilistic Programming; P-Robustness
    Type of Blood Product: Blood Product
    Issue: Maintaining sufficient blood supply; Blood Wastage
    Objective: Develop a novel mixed possibilistic-stochastic flexible robust programming
20. Citation: (Abdulwahab and Wahab, 2014)
    Method: Approximate dynamic programming
    Type of Blood Product: Platelet

Issue: Blood platelet shortage; Outdating; Inventory level
Objective: Minimizes deficiency and wastage of blood platelets while maximizing the total reward; Keep inventory levels to a minimum by meeting various types of demand using appropriate policies.

21. Citation: (Sapountzis, 1984)
Method: Integer Programming Model
Type of Blood Product: Blood Product
Issue: Expired Blood
Objective: Minimize the number of units of blood that will be sent back to the blood transfusion service when the blood expires.
22. Citation: (Shih and Rajendran, 2020)
Method: A Stochastic Mixed-Integer Linear Programming (MILP)
Type of Blood Product: Platelet
Issue: easily damaged elements; Age limit of platelets and red blood cells; Uncertainty of supply; supply costs; Lack of blood and; Expired wastage of blood
Objective: Minimize the total costs incurred throughout the blood supply chain.

Is responsible for receiving, transfusing, and finally delivering blood products to the point of demand (Heidari-Fathian and Pasandideh, 2018a). Many complex factors occur in the blood supply such as uncertain supply and demand, the proportion of blood groups, shelf life limitations, and different collection and production methods (Heidari-Fathian and Pasandideh, 2018b) (Osorio et al., 2017) (HosseiniFard and Abbasi, 2016). Because the nature of blood is perishable, it is necessary to consider the time required to process the received blood and minimize the amount of wasted blood (Alizadeh et al., 2020).

Several papers discuss blood problems with blood patelets components. Platelets are components of blood that are easily damaged they have a very short shelf life (Abdulwahab and Wahab, 2014) and need to pay attention to the amount of demand and supply (Ghandforoush and Sen, 2010) with a shelf life of 5-7 days. The demand for platelet blood is uncertain and its production is periodic in one week, so efforts need to be made so that there is no shortage or excess (Haijema et al., 2007). If there is uncertainty in the demand for blood platelets, it will cause a significant waste of the total blood collected by donors (Rajendran and Ravindran, 2019). Uncertain blood demand needs to be minimized in order to avoid overproduction which can lead to expiration (Dijk et al., 2009). In addition, it is necessary to develop an appropriate inventory model in order to minimize the shortage and waste of blood (Rajendran and Ravindran, 2019). In addition, from the transportation side, the following paper discusses transportation schedule for the delivery of platelets from the production center to the transfusion center, which is usually a hospital (Ghandforoush and Sen, 2010).

The number of donor platelets in the supply chain can be affected by four main issues namely the presence of different types of donors as polycythemiadonors for the first time, the number of donors ordered and the number of donors not ordered during and after, allocation of blood extraction technology to hospitals, and sending announcements. social media such as social media, newspapers and banners (Larimi and Yaghoubi, 2019).

One of the properties of blood is that blood has a shelf life and if it exceeds the production limit it will expire. So that several papers have discussed about minimizing the expiry rate. Blood supply managers in the blood supply always try to keep blood products sufficient and to reduce the number of deaths due to expired blood (Ahmadimanesh et al., 2020). This paper uses RBC blood components which have a shelf life of up to 42 days. RBC is useful for patients with chronic anemia, kidney failure, gastrointestinal bleeding, and acute blood loss due to trauma and surgery (Duan and Liao, 2014). Reducing the number of expiry dates, system costs, and the time of sending blood simultaneously are also discussed in the paper (Hamdan and Diabat, 2018). The blood component used in this study is red blood cells. This research accounts for the production, inventory, and location decisions. Due to the perishable nature of blood products, the storage of large quantities of blood products is limited and the quality of blood products decreases with transportation time. Blood is also needed in times of disaster. The following paper discusses the determination of the allocation and location of blood facilities for several post-disaster periods (Dillon et al., 2017b). In addition, during a disaster, the need for an efficient blood supply is more important. This occurs when there is no coordination between distribution and inventory management.

Blood supply planning can help inventory to make decisions under uncertainty, to minimize blood shortages and waste (Hosseini-Motlagh et al., 2020b). In addition, when a disaster occurs, it is necessary to manage the blood supply chain system optimally in terms of determining the amount of blood collection, location, transportation, and storage in order to minimize the total response time and total operational costs (Liu and Song, 2019).

Other papers discuss the various characteristics of blood requests, i,e, the existence of uncertain blood requests that cause blood shortages and wastage. perishable nature of blood, strong subjective bias towards criteria other than cost minimization and Minimizing operational costs (Dillon et al., 2017a).

In addition, another paper discusses the problem of blood management, called Perishable element, Platelets having a limited lifetime of five days and red blood cells lasting 42 days, Supply uncertainty, Supply cost, Shortage of blood and Expired wastage of blood (Shih and Rajendran, 2020).

Some of the papers that have been described, until 2021 are still discussing some blood problems from storage, organization to distribution of the blood itself.

# 5 OPTIMIZATION ALGORITHM ON BLOOD MANAGEMENT PROBLEM

Several studies use optimization to solve blood problems. Ghorashi et al, used mathematical models to solve problems related to minimizing the total cost and supply chain time to make decisions regarding location-allocation, blood flow, inventory levels, and optimal routes. The problem is solved by optimization using the Multi-Objective Gray Wolf Optimizer algorithm which is compared with two algorithms, such as Multi-Objective Particle Swarm Optimization and Non-dominated Sorting Genetic Algorithm-II. After conducted statistical tests, it was found that the Multi-Objective Gray Wolf Optimizer can solve problems efficiently and can outperform other approaches (Ghorashi et al., 2020).

Blood management system related to the entry and exit of blood, related to planning, implementation, and control. Another study uses mathematical models and metaheuristic optimization methods that offer a better solution approach for blood allocation in a dynamic environment. This study uses red blood cells. The optimization method used is to combine symbiotic organisms search, genetic algorithm, and particle swarm optimization (Ezugwu et al., 2020).

The next research, implements the particle swarm optimization algorithm, the results of which show the ability to minimize the import of blood units, and there is no form of waste (Adewumi et al., 2012).

W. Liu et al (2020) found blood has an easy expiration date and blood distribution problems, this paper optimizes the blood product scheduling scheme using the concept of a vendor-managed inventory routing problem (VMIRP).

The concept is used to balance supply and demand to minimize operational costs. The decomposition algorithm is also used to solve the proposed mathematical model. By using this concept, it is found that the VMIRP concept can reduce the operational costs of the blood supply chain.

To overcome the problem of perishable blood, this paper designs a two-stage approach, the strategic stage and the tactical stage, which create two models to obtain location-allocation decisions and to obtain inventory control decisions from the optimal quantity of blood filling. To solve this problem, the optimization algorithm used is the Genetic Sorting II (NSGA-II) algorithm which is not dominated to find Pareto sets (Hsieh, 2014).

The uncertain demand for blood products has also been investigated and solved using a multi-objective mixed integer mathematical programming model. The model aims to minimize the total cost of the supply chain network. Optimization algorithms used to solve this problem are bounded objective function, robust optimization, and Lagrangian relaxation (Heidari-Fathian and Pasandideh, 2018b).

The existence of various kinds of demand for blood becomes a strategic problem in choosing the best combination of technology. Many factors are encountered in blood problems whose solutions utilize optimization to optimize the total cost and the number of donors needed. The existence of stochastic demand, blood type compatibility, blood availability, and blood group proportions result in uncertainty. To solve this problem, a multi-objective stochastic integer linear programming model is used and a new combination of the Average Approximation and the Augmented Epsilon-Constraint algorithm is used (Muriel et al., 2017).

Storing an excessive number of units of blood in the blood storage can result in the wastage of blood products. This is due to the perishable nature of blood. A dynamic mathematical model is applied to this problem which aims to increase the efficiency of blood-related activities that occur in the blood center. if there is a failure in the blood supply, it will result in the cancellation of the operation and some worst-case scenarios. An optimization algorithm is proposed to solve this problem which aims to identify the optimal routing for each blood group. These algorithms are symbiotic organisms search, symbiotic organisms search genetic algorithm, and symbiotic organisms search simulated annealing algorithms (Ezugwu et al., 2019).

So that blood can be distributed properly and the quality of blood products can also be maintained, it is necessary to manage distribution to various locations that need blood properly. Several papers have discussed these problems which can be solved by optimization.

During a disaster, some locations require blood facilities and distribution of blood products after a natural disaster. At the same time, uncertainty becomes an inseparable part of the uncertainty of the need for blood and location during and after the disaster. The researcher compares the P-robust optimization and robust optimization approaches. In this paper, two models are made, a model for determining the location and a model for determining distribution decisions in an uncertain environment. Distribution decisions take into account how much blood should be brought to the disaster site (Fereiduni and Shahanaghi, 2016).

The planning of transportation operations in the blood sample supply chain, which includes clinics and laboratories, is the emphasis of this article. This study objective is to determine the optimal number of vehicles to deploy and to plan the pick-up procedure. The step is to develop a mixed-integer programming issue first (MIP), then to scheme two heuristic algorithms and numerical search as part of a heuristic scheme. Potential new heuristic approaches are given in a comprehensive numerical research that is based on information from techniques used to collect blood samples in the real world (Elalouf et al., 2016).

The multiple knapsack optimization algorithm includes the following algorithms for example “Genetic Algorithm, Adaptive Genetic Algorithm, Simulated Annealing Genetic Algorithm, Adaptive Simulated Annealing Genetic Algorithm, and Hill Climbing” Algorithm which is also used for solving the problem of red blood cell assignment which aims to minimize the number of units of blood imported from outside the system. From some of these algorithms, it is said that Hill Climbing has a good performance in solving these problems (Adewumi et al., 2012).

Until 2021, various optimization algorithms have been developed to optimize the problems that occur in the storage and distribution of blood

# 6 CONCLUSION

This paper discusses 45 papers from 1973 to 2021 which provide an overview of blood management problems that are solved by various algorithms including optimization algorithms. Several papers have discussed the development of the optimization algorithm itself to solve blood management problems.

This writing aims to find out specific problems in blood management problems and what algorithms are used to solve problems in blood management. Several papers discuss blood products, and are specific to one of the blood products, namely platelets and red blood cells. Platelets are widely discussed in several studies because of the nature of platelets themselves, that is having a short shelf life, while the nature of the use of blood is uncertain. So that the management of the blood itself must be optimized so that the distribution and use of the blood becomes more optimal. Optimization has many uses that can help human activities to solve complex problems. Optimization problems are solved such as to create optimal product and system designs, solve mathematical problems to get minimal costs, maximum profits, optimal management and minimal errors.

There are several issues of blood management that are discussed in several papers, namely related to Cost production, Stock time expired, Overproduction, Platelets have a concise shelf life, Uncertain supply and demand for blood, Shelf life constraints, The perishable nature of the blood, Minimizing operational costs , Blood shortage and wastage due to outdating, Minimize the total cost, Inventory, Location decisions, System costs and blood delivery time simultaneously, Time Processing, Reducing blood return and blood loss, Maintaining sufficient blood supply. With the issue of blood management and the uncertainty of the blood itself, this optimization algorithm is collaborated or compared with other algorithms. The Multi-Objective Gray Wolf Optimizer is used to make decisions about optimal location allocation, blood flow, inventory levels, and routes by minimizing total cost and supply chain time. The particle swarm optimization algorithm, whose results show the ability to minimize the import of blood units while producing no waste. The vendor-managed inventory routing problem (VMIRP) is a method of balancing supply and demand in order to reduce operational costs. It has been discovered that using this concept, the VMIRP concept can reduce the operational costs of the blood supply chain. To solve the problem of perishable blood, the Genetic Sorting II (NSGA-II) algorithm is used. Bounded objective function, robust optimization, and Lagrangian relaxation to solve The uncertain demand for blood products has also been investigated and solved using a multi-objective mixed integer mathematical programming model. To solve the problem, a multi-objective stochastic integer linear programming model is used, along with a new combination of the Average Approximation and the Augmented Epsilon-Constraint algorithm. Uncertainty is caused by stochastic demand, blood type compatibility, blood availability, and blood group proportions. Symbiotic organisms search, genetic algorithms search, and simulated annealing algorithms search are used to solve to identify the optimal routing for each blood group. Hill Climbing was used to solve the problem of reducing the number of units of blood imported from outside the system.

## REFERENCES


(2012). The multi-period location-allocation problem of engineering emergency blood supply systems. *Systems Engineering Procedia*, 5:21–28.

Abdulwahab, U. and Wahab, M. (2014). Approximate dynamic programming modeling for a typical blood platelet bank. *Computers Industrial Engineering*, 78:259–270.

Adewumi, A., Budlender, N., and Olusanya, M. (2012). Optimizing the assignment of blood in a blood banking system: Some initial results.

Ahmadi, A., Najafi, M., and Zolfagharinia, H. (2017). Blood inventory management in hospitals: Considering supply and demand uncertainty and blood transshipment possibility. *Operations Research for Health Care*, 15:10 1016 2017 08 006.

Ahmadimanesh, M., Tavakoli, A., Pooya, A., and Dehghanian, F. (2020). Designing an optimal inventory management model for the blood supply chain: Synthesis of reusable simulation and neural network. *Medicine*, 99:21208.

Alizadeh, M., Sharbafi, F., and Paydar, M. (2020). A bi-objective natural disaster blood supply chain network considering blood transfusion: A case study in babol.

Allard, S. and Contreras, M. (2015). Clinical blood transfusion (postgraduate haematology.

Arani, M., Chan, Y., Liu, X., and Momenitabar, M. (2021). A lateral resupply blood supply chain network design under uncertainties. *Applied Mathematical Modelling*, 93:165–187.

Attari, M. N., Pasandideh, S., and Niaki, S. (2019). A hybrid robust stochastic programming for a bi-objective blood collection facilities problem (case study: Iranian blood transfusion network.

Authority, N. (2014). *Managing Blood and Blood Product Inventory*.

Baig, M. I. and Javed, A. (2020). Wastage of blood units at tertiary care hospitals of lahore. *cureus*, page 1–6.

Bartoszko, J., Vorobeichik, L., Jayarajah, M., Karkouti, K., Klein, A., Lamy, A., Mazer, C., Murphy, M., Richards, T., Englesakis, M., Myles, P., and Wijeysundera, D. (2017). Defining clinically important perioperative blood loss and transfusion for the standardised endpoints for perioperative medicine (step) collaborative: A protocol for a scoping review. *BMJ Open*, 7, e016743.

Commission, A. and Care, H. (2012). Safety and quality improvement guide standard 7: Blood and blood products.

Dijk, N., Haijema, R., Wal, J., and Sibinga, C. (2009). Blood platelet production: A novel approach for practical optimization. *Transfusion*, 49:411–20.

Dillon, E., Oliveira, F., and Abbasi, B. (2017a). A two-stage stochastic programming model for inventory management in the blood supply chain. *International Journal of Production Economics*, 187:10 1016 2017 02 006.

Dillon, M., Oliveira, F., and Abbasi, B. (2017b). A two-stage stochastic programming model for inventory management in the blood supply chain. *International Journal of Production Economics*, 187:27–41.

Dréo, A. and Siarry, P. (2003). Metaheuristics for hard optimization, methods and case studies.

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

Elalouf, A., Tsadikovich, D., and Hovav, S. (2016). Optimization of blood sample collection with timing and quality constraints. *International Transactions in Operational Research*, 25:10 1111 12354.

Ezugwu, A., Olusanya, M., and Govender, P. (2019). Mathematical model formulation and hybrid metaheuristic optimization approach for near-optimal blood assignment in a blood bank system. *Expert Systems with Applications*, page 10 1016 2019 06 059.

Ezugwu, A., Otegbeye, O., Govender, P., and Odo, J. (2020). Computational intelligence approach to dynamic blood allocation with abo-rhesus factor compatibility under real-world scenario. *IEEE Access PP*, 1–1.

Fereiduni, M. and Shahanaghi, K. (2016). A robust optimization model for blood supply chain in emergency situations. *International Journal of Industrial Engineering Computations*, 7:535–554.

Ghandforoush, P. and Sen, T. (2010). A dss to manage platelet production supply chain for regional blood centers. *Decision Support Systems*, 50:32–42.

Ghorashi, S., Hamedi, M., and Sadeghian, R. (2020). Modeling and optimization of a reliable blood supply chain network in crisis considering blood compatibility using mogwo. *Neural Computing and Applications*, 32:10 1007 00521–019–04343–1.

Gibbs, B. and N, W. (1993). *Guidelines for the organization of a blood transfusion service*. World Health Organization.

Gurevitz, S. (2010). Update and utilization of component therapy in blood transfusions. *Laboratory Medicine*, 41:739–744.

Haijema, R., Wal, J., and Dijk, N. (2007). Blood platelet production: Optimization by dynamic programming and simulation. *Computers Operations Research*, 34:760–779. logistics of Health Care Management.

Hamdan, B. and Diabat, A. (2018). A two-stage multi-echelon stochastic blood supply chain problem. *Computers Operations Research*, 101:10 1016 2018 09 001.

Heidari-Fathian, H. and Pasandideh, S. (2018a). Bi-objective optimization of a blood supply chain network with reliability of blood centers.

Heidari-Fathian, H. and Pasandideh, S. (2018b). Green-blood supply chain network design: Robust optimization, bounded objective function lagrangian relaxation. *Computers Industrial Engineering*, 122:95–105.

Hosseini-Motlagh, S.-M., Samani, M., and Cheraghi, S. (2020a). Robust and stable flexible blood supply chain network design under motivational initiatives. *Socio-Economic Planning Sciences*, 70:100725.

Hosseini-Motlagh, S.-M., Samani, M., and Homaei, S. (2020b). Toward a coordination of inventory and distribution schedules for blood in disasters. *Socio-Economic Planning Sciences*, 72:100897.

HosseiniFard, Z. and Abbasi, B. (2016). The inventory centralization impacts on sustainability of the blood supply chain. *Computers Operations Research*, 89:10 1016 2016 08 014.

Hsieh, C.-L. (2014). An evolutionary-based optimization for a multi-objective blood banking supply chain model.

Jabbarzadeh, A., Fahimnia, B., and Seuring, S. (2014). Dynamic supply chain network design for the supply of blood in disasters: A robust model with real world application. *Transportation Research Part E: Logistics and Transportation Review*, 70:225–244.

Karadag, V. and Keskin, M. E. (2021). Re-design of a blood supply chain organization with mobile units. *soft computing*, page 6311–6327.

Kulkarni, G. J. (2017). *Ajith Abraham, Introduction to Optimization*. Springer International Publishing Switzerland.

Larimi, N. and Yaghoubi, S. (2019). A robust mathematical model for platelet supply chain considering social announcements and blood extraction technologies. *Computers Industrial Engineering*, 137:106014.

Liu, X. and Song, X. (2019). Emergency operations scheduling for a blood supply network in disaster reliefs. *IFAC-PapersOnLine*, 52:778–783.

Lloyd, W. (2020). *The Four Functions of Management - An essential guide to Management Principles*. Management Open Educational Resources.

Markowitz, M., Waters, J., and Ness, P. (2014). Patient blood management: A primary theme in transfusion medicine. *Transfusion*, 54:10 1111 12862.

Muriel, A., Brailsford, S., and Smith, H. (2017). Whole blood or apheresis donations? a multi-objective stochastic optimization approach. *European Journal of Operational Research*, 266:10 1016 2017 09 005.

Organization, W. (2009). Safe blood and blood products (world health organization.

Osorio, A., Brailsford, S., Smith, H., Forero-Matiz, S., and Camacho-Rodríguez, B. (2017). Simulation-optimization model for production planning in the blood supply chain. *Health Care Management Science*, 20:548–564.

Rajendran, S. and Ravindran, A. (2019). Inventory management of platelets along blood supply chain to minimize wastage and shortage. *Computers Industrial Engineering*, 130:10 1016 2019 03 010.

Sapountzis, C. (1984). Allocating blood to hospitals from a central blood bank. *European Journal of Operational Research*, 16:157–162.

Shamshirian, A., Mohseni, A., Pourfathollah, A., Mehdipour, S., Azizi, S., Hosseini, S., and Ghorbanpour, A. (2018). A review of blood usage and wastage in a tertiary heart center. *Acta Clinica Belgica*, 75:1–8.

Shih, H. and Rajendran, S. (2020). Stochastic inventory model for minimizing blood shortage and outdating in a blood supply chain under supply and demand uncertainty. *Journal of Healthcare Engineering*, page 1–14.