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Hemo-cloud: Revolutionizing Blood Bank Operations Through Cloud Technology

J. Hanveshith Reddy[1], NG. Karthikeya[2], B. Abhishek[3], Ms. T Jayasri Devi[4]
[1,2,3]UG Scholar, Dept. of CSE, Institute of Aeronautical Engineering, Hyderabad, Telangana, India.
[4]Associate professor, Dept. of CSE, Institute of Aeronautical Engineering, Hyderabad, Telangana, India.
Emails: *21951a0557@iare.ac.in[1], 21951a0545@iare.ac.in[2], 22955a0502@iare.ac.in[3], t.jayasridevi@iare.ac.in[4]*

Abstract
The online blood bank management web application is a useful tool which can be used in different areas of the healthcare setting such as laboratories, clinics and even emergency situations where there is a need for blood units. Because of streamlining all the operational procedures that are needed for blood donation as well as for its purchase, this system is in fact a one stop center for the management of blood operations. Important facts about the blood groups and their site cannot be missed out by users of our web. This grips up reflection ensures that in case of emergency any one even who is ready to donate or any representative of the authorized centers can quickly search and get the required blood groups. One of the main objectives of our system is also to minimize the concerns which people usually have when they are in need of blood due to its lack. Through focusing on blood systems that prevent breakdowns in ordering and using the blood, we will construct efficient systems that, together, eliminate the problems encountered in blood purchasing and usage.

Keywords: *Accessibility; Availability; Blood Donation; Blood Purchasing; Blood Shortages; Blood Units; Cloud Technology; Emergency Scenarios; Healthcare Environments; Online Blood Bank Management.*

1. Introduction
Blood is a necessary medical resource for surgical and trauma interventions, for the treatment of cancer, and also for caring of patients with chronic diseases. In a host of medical situations, time it takes to look for blood could even be the difference between life and death. Similarly, acquiring blood unit's is not always an easy task as there is often a shortage regardless of the availability of donors, distribution is poor, and there is a lack of awareness of all the available blood types. In this paper, we describe our website which is a web- based blood bank and management software developed to resolve and optimize the process of blood donations, storage and distribution. This should be applied to several areas including but not limited to emergency rooms, outpatient facilities and medical laboratories where blood units need to be readily available. Our site manages all the operations related to blood and the availability of many blood types at various donation sites makes it easier for users to get necessary information very fast. In addition to improving the efficiency of blood management, this centralized approach also alleviates the stress and panic resulting from emergency situations that call for the use of blood transfusion tanks [2]. Our web-based blood bank management system will help to enhance the blood supply information dependency and availability, eliminate the barriers in blood donation process and most importantly ensure that blood units are always in the right place at the right time. The primary purpose of using information thinking in such matters is to enhance the blood controlling system with a perspective of saving lives the further improvements in healthcare system energy efficiency are possible [1-3].

1.1. Problems and Challenges
The blood bank management process has some areas that impede the effectiveness and efficiency of the blood donation and blood distribution procedures. Most of the existing systems, which are mostly manual or depend on obsolete technological methods, create a few problems such as:

Lack of Integrated System: There is a quite common tendency of current systems to work in

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different logical units whose information is split among different sites. Healthcare providers are unable to know the stock status of blood leaving them as second guessed which can lead to wastage of precious time especially in situations where the urgency is critical [5].

Poor Utilization of Resources: Faulty inventory control could result in chronic blood unit's deficiency or excessive stocking. In the absence of an efficient tracking mechanism, blood banks may find it impossible to maintain the optimal levels of blood stocks, which would make the situation worse in an emergency [3].

Poor Information Availability: There are still some current systems where people who wish to donate blood or work in health care practice do not have enough information. This limitation may make it harder to rapidly locate certain blood types or organize donations, especially during urgent cases [8].

1.2. Key Features

1. A Brief Overview of User Registration and Profile Management.
2. A Blood Request and Tracking System.
3. Geocoding and Map Services.
4. Appointment Scheduling and Management.
5. Notifications and Alerts.

2. Literature Review

In recent years, there has been a notable focus on the implementation of cloud technology into blood banks management systems due to its advantages. This literature overview summarizes the results of several major studies that concentrate on various aspects of the cloud-based blood bank management. With an objective to increase efficiency, **Muppalla et al. (2023)** come up with a hybrid cloud mode of Blood Bank Management System through the use of Amazon Web Services (AWS). Such systems allow for the use of services such as RDS for database management and EC2 for computational processing making it possible to process recorded blood donation data in real time and show blood donation information to the public. The authors highlight the importance of the safe control of inventories in for-profit healthcare institutions and the need for coordinating blood storage systems among blood banks to ensure uninterrupted availability of blood products throughout all regions [1]. In addressing blood deficit, **Goel et al. (2023)** recommend an online program which runs on the cloud. With the system they developed, it enhances the process concerning blood donations, blood storage and blood distribution and equally helps blood donors locate blood banks within their locality. The authors reinforce the need for inventory control in real time, This technology simplifies the process of handling blood requests in hospitals and improves the optimal use of blood resources for specific patients [2]. **Abdullah and Younus (2021)** focus on the development of cloud technology based management system for the blood unit and convalescent plasma for COVID-19 patients in real time. The research discusses the automated system of blood unit allocation based on the units and urgency of demand and eliminating human effort in the process, promoting efficiency and reliability. This method reduces costs and also allows for quick response to changing health care needs [3]. **Ismail et al. (2022)** conduct research on the factors which influence the use of online capabilities and IoT based technologies to enhance management of blood banks in developing countries. Their study presents an integrated model that facilitates effective blood correlation and management of the blood stock in situations which call for improvement of the accessibility of safe blood in emergencies [4]. The authors also argue that such technologies are well placed in addressing the recurrent challenges faced by blood centres in resource strapped settings. **Rajendra and Bhalchanadra (2019)** describe a web-based blood bank management coordination support system that integrates blood donation sites with hospitals. With the help of this system, registered hospitals can check if their required blood types are in stock and send orders to the nearest blood donation centers. The authors emphasize the use of technology in minimizing the gap between the blood donor and recipient improving the general efficiency of blood donation processes [5].

3. Methodology

3.1. System Architecture

The system's architecture is constructed in a way that allows the efficient management of data storage, geographic information system, and communication

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in real time as shown in Figure 1. The critical aspects comprise:

1. **Client Side (Frontend)**
   - React.js App: A common interface of the users within the system.
   - Axios/Fetch API: That is, a component designed to perform HTTP calls to the backend server.
2. **Server Side (Backend)**
   - Node.js with Express.js: Receives the HTTP calls and delegates it to the right procedure while all the procedures dealing with the business logic is encapsulated.
   - API Gateway: Subsumes all the calls made to all the APIs and redirects them to respective backend services based on API hosted.
3. **Database**
   - PostgreSQL: Provides SQL capabilities for data storage and management tell the application.
4. **Security**
   - JWT: Used in protection of the API endpoints as well as managing the authentication of users [9&10].

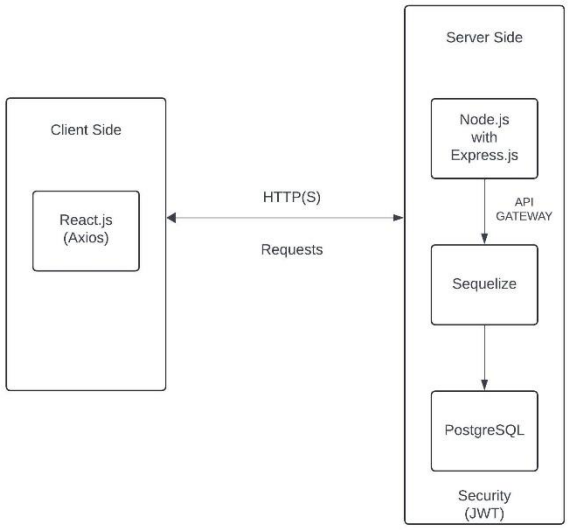

Figure 1 System Architecture

3.2. AWS Architecture

1. **Users:** The users are at the upper part of the diagram and they can access the AWS cloud via the internet.
2. **Amazon Route 53:** This application can also be referred to as a DNS web service and it ensures users are routed to the required resources within the AWS cloud that have been provisioned, for instance, load balancers [11].
3. **VPC:** This encompasses the whole of the infrastructure meaning it is a virtual network dedicated to the AWS Cloud in which resources are hosted.
4. **Public Subnet:** As shown in the diagram, the green shaded areas are known as public subnets where resources are allowed to access the internet through NAT Gateway.
5. **Private Subnet:** The blue shaded areas highlighted in the diagram are called the private subnets which although resources do not have direct access to the internet through NAT Gateway, they can still access the public internet in a restricted manner.
6. **Amazon EC2 (Elastic Compute Cloud):** Within each subnet, the orange icons are the EC2 instances which are the rented servers running the application [12].
7. **Auto Scaling:** The auto-scaling feature is attached to the EC2 instances. It helps ensure proper load of the different instances hence the EC2 instances increases or decreases in number when demand requires it.
8. **Application Load Balancer:** Application load balancer performs an important function in the architecture as it directs application traffic from clients across multiple EC2 instances in the backend to prevent overloading of a single EC2 instance and this enhances fault tolerance while improving the availability of the application.
9. **Internet Gateway:** The internet gateway is the means of connecting the VPC with the internet and helps in the communication of your instances and the users.
10. **NAT Gateway:** Located in the public subnet, the NAT gateway allows instances located in private subnets to make connections to the internet for update functional purposes or other operations without taking any incoming connections from the internet [13]. (Refer Figure 2)

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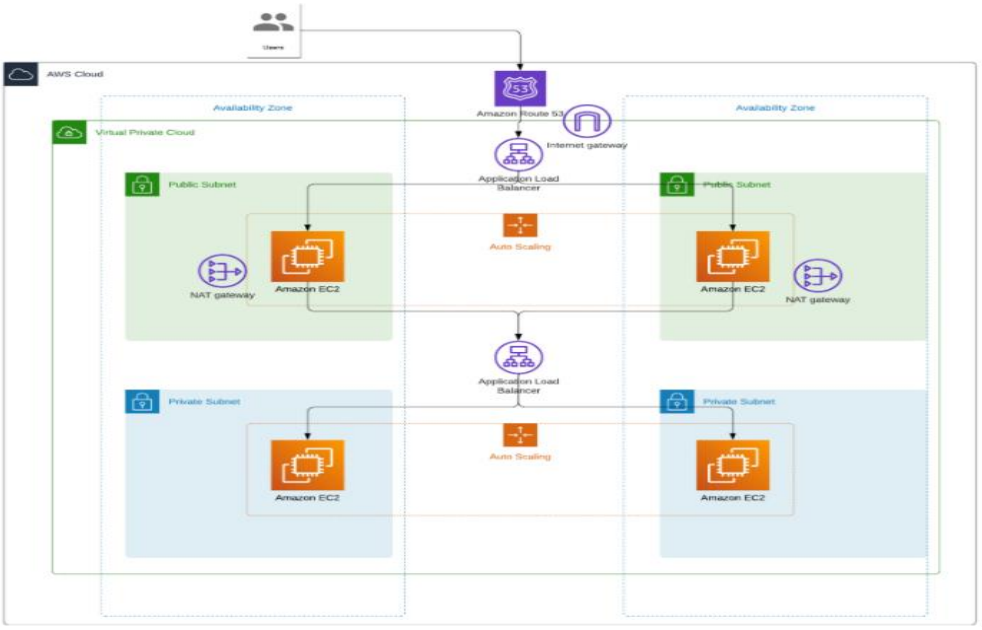

Figure 2 AWS Architecture

4. Proposed System

Utilizing an online blood bank management system is hoped to solve the primary issues existing within the current systems of blood donation and distribution. Their understanding is that since anesthetic management may be considered peripheral to a surgical procedure within the operating room, their engagement with and use of AWS might be rather limited in certain procedures or surgeries [7].

Centralized Data Management: With Amazon RDS for PostgreSQL, the application centralizes data by incorporating additional web services. There is a reduction in multiple requests in which users have to go in search of donor details and blood stock available at various blood down stations and healthcare centers [5].

User-friendly Interface: Creation of a scatter graph lets the user visualize the status of the vessel from the point of start towards the endpoint." Responsive, simple and reliable interface created in React and Java Script gives the users ability to interact with the application without any difficulties, including even healthcare professionals and donors. A scheduling system for the blood donors is included, and a specific blood type can be ordered instantly by call when needed by medical staff.

Real-Time Data Access: Allowing only authorized healthcare personnel to access the system ensures that there is real-time data access that is hinged on the quantity of blood units available. Cloud technology has made this possible. This is especially important when things need to be done fast since there is an emergency.

Optimised inventory control: reduces the chances of understock situations and wasting blood units by securing the appropriate level of inventory on crucial blood components through an automated inventory system [4&6].

Enhanced Security Measures: In order to avoid unauthorized access to crucial information, the application implements robust security measures with regard to the access control using CLIENT-SIDE technologies such as JWT (JSON Web Token).

4.1. Technologies Used

a. Hardware Requirements:

1. **Processor:** Intel core i3 or any higher processor
2. **Hard Disk Drive:** 64GB
3. **Memory:** 4 GB RAM or more

b. Software Requirements:

1. Html, CSS, JS, EJS, Bootstrap
2. ReactJS
3. Node.js
4. PostgreSQL
5. pgAdmin

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6. Express
7. Google Maps API

5. Results and Discussion

5.1. Results

Table 1 addresses itself to juxtaposing the differences in the potential and actual technological infra between the present system and the proposed one. It gives importance to programming languages used, integration tools, data management systems, security, real-time capabilities, the up-scaling f the systems as well as interface enhancements.

Table 1 Difference Between Existing and Proposed System.

Feature	Existing System	Proposed System
Programming Languages	Java, SQL	ReactJS, Node.js, PostgreSQL
Integration Platforms	Manual Integration	Automated API Gateway
Database Management	SQL-Based (Traditional)	Cloud-Based (Amazon RDS for PostgreSQL)
Security Measures	Basic Authentication	Advanced (JWT Authentication)
Real-Time Capabilities	Limited Real-Time Data Access	Enhanced Real-Time Access
Scalability	Limited Scalability	High Scalability (Auto-Scaling on AWS)
User Interface	Basic UI	Responsive and User-Friendly UI

In our blood bank management system, the database design follows relational models. Here, we demonstrate common relational algebra and relational calculus operations for data retrieval and management within the system.

1. Relational Algebra Operations:

- To select donors with a specific blood type, for example, blood type 'O+':

$$\sigma_{blood\_type= \ 'O+'}(Donor)$$

- To project only the donor's name and blood type:

$$\pi_{name,blood\_type}(Donor)$$

- To join the Donor and Receiver tables based on the blood type for matching donations:

$$Donor \bowtie_{Donor.blood\_type=Receiver.blood\_type} Receiver$$

2. Tuple Relational Calculus (TRC):

- To retrieve the details of donors who have blood type 'O+':

$$\{t \mid t \in Donor \wedge t.blood\_type = \ 'O+'\}$$

- To retrieve tuples of donors and receivers who have the same blood type:

$$\{t \mid \exists d \in Donor, r \in Receiver \wedge d.blood\_type = r.blood\_type \wedge d.name = t.name \wedge r.name = t.name\}$$

- To find donors who are not receivers:

$$\{t \mid t \in Donor \wedge \neg(\exists r \in Receiver \wedge r.name = t.name)\}$$

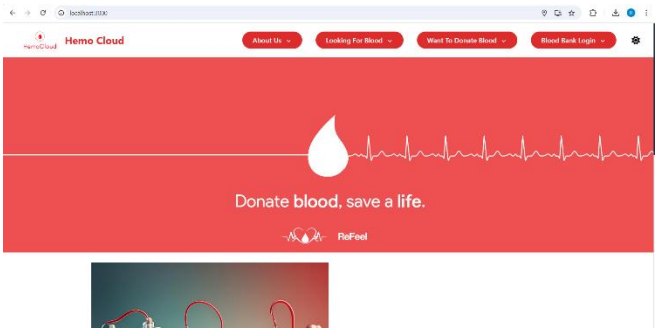

Figure 3 A Homepage with A Navigation Bar for Patient, Donor, And Blood Bank Logins

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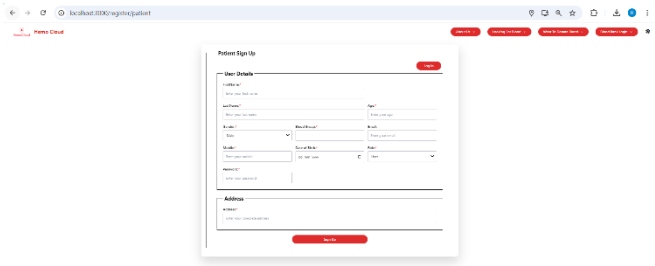

Figure 4 A Patient Signup Page

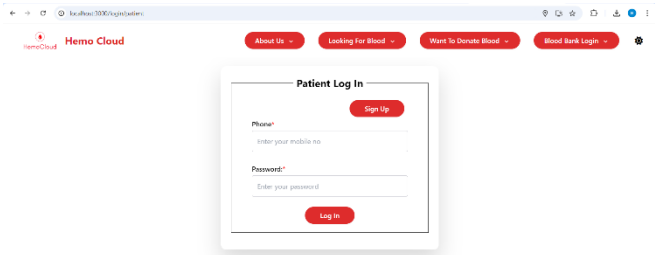

Figure 5 A Patient Login Page

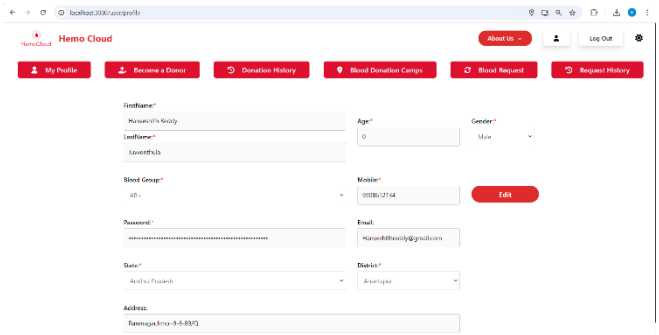

Figure 6 This Is the Patient Profile Page Where the User Update Their Details

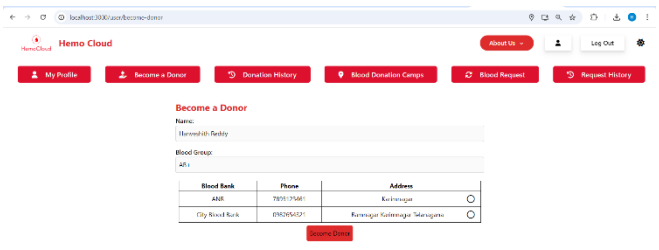

Figure 7. This Page Is for Becoming a Donor to The Nearest Blood Banks

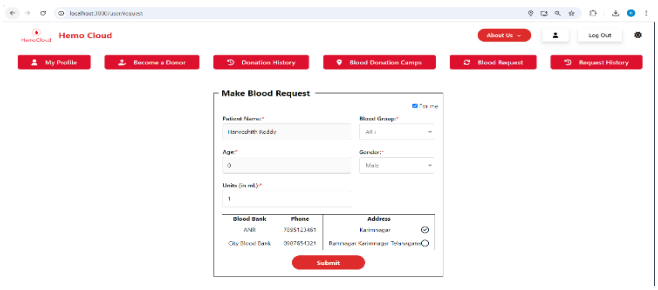

Figure 8 This Page Allows Users to Request Blood by Specifying the Number of Units Needed and Selecting the Nearest Matching Blood Group

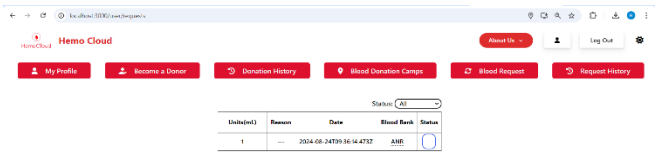

Figure 9 This Page Shows the History of the Patient's Previous Blood Requests

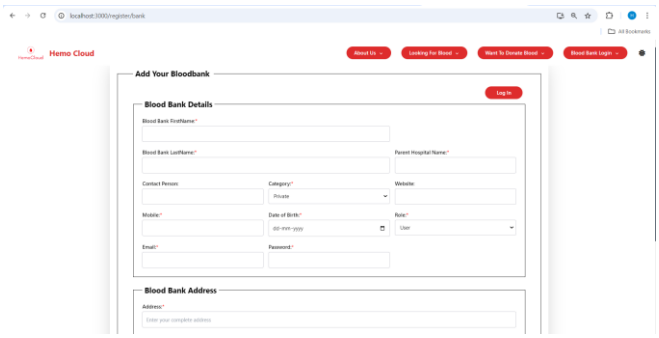

Figure 10 This Is the Signup Page for The Blood Bank, Where The Latitude and Longitude Are Fetched

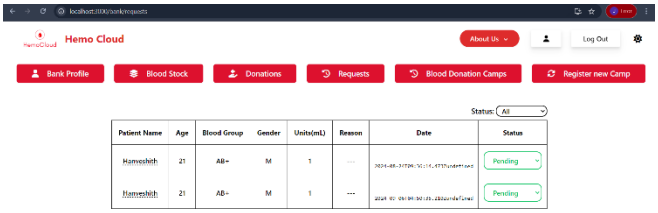

Figure 11 This Page Shows the Blood Requests Received by The Blood Bank

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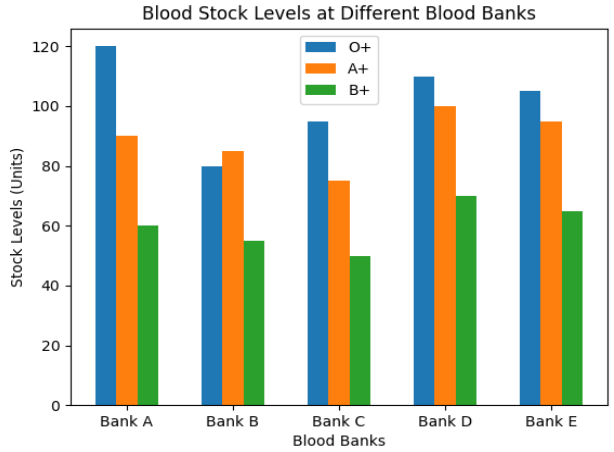

Figure 12 Blood Stock Levels at Different Blood Banks

5.2. Discussion

The introduction of our cloud-based blood bank management system has however cut down efficiency and accessibility barriers that are typically seen in the blood donation and distribution procedures. Owing to the integration of real-time data changes and AWS cloud facilities, we achieved a more effective blood inventory control through regionally balanced blood distributions. Such capability of estimating restocking needs and inventory management in a do it yourself way has depressed dormant and active stock outs, particularly for blood types necessary in rush ambience. The scalability of AWS mitigated costs and guaranteed high availability of services because resources could be increased during high usage periods, and low latency services delivered regardless of the location of the users. Therefore, there are high levels of flexibility offered in this solution which is however very useful especially in resource limited settings. The reliability of the system, which is almost 100% available, also supports the argument for the use of cloud-based solutions in healthcare. Data security was another key strength, as the system employed strong encryption and authentication mechanisms to protect sensitive medical information. This meant that the critical information could only be accessed by those who had been given permission to do so and thus the security and accessibility of health care practitioners' information was maintained. Though effective, the system is dependent on data entry and data that is delivered in a timely manner and accurately, something that could be improved by the use of IoT sensors. Future enhancements could be the use of machine learning to improve demand forecasting and the distribution of resources further efficiently. In general, such a system demonstrates The effectiveness of this solution cloud technologies in transforming healthcare logistics. (Figure 3 – 12 Shows the Results).

Conclusion

Our online blood bank management web Application not only meets the core functionality and needs of a blood donation programme, but it also revolutionizes the blood donation and distribution processes within healthcare structures. Hence with the help of recent web technologies such as React and Node.js, we developed a system which is flexible, scalable and easy to use hence fulfilling the urgent need of proper blood management. This web application manages all the activities of blood donation and blood inventory and makes the process effortless with live feeds, excellent search, and response to blood requests. Various administrative functions are automated making them free from errors, efficient, and ensuring blood is present when required as best as possible. In essence, our web application alleviates the worries and difficulties in a blood crisis by assuring that there is a steady supply chain and accelerating the response time to emergencies. The project shows how technology has the capacity to enhance the management of health care supply chains and make essential supplies more accessible to those who require it [14&15].

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