Blood Supply Chain Management System Using Blockchain

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Abstract

Our project aims at improving the existing Blood supply chain management system. We propose an innovative blood collection chain system based on blockchain technology using a distributed ledger structure and transaction execution process of the situation where the collected blood reaches the final stage - hospitals. Existing centralized blood management systems have various drawbacks including lack of information on blood bags, inability to reflect real-time updates in details and the trust factor. In this respect, the blockchain technologies offer the possibility to maintain a transparent blood management system, especially since data cannot be counterfeited and tampered with. In addition, the system stores blood contracts between hospitals in the event of emergencies through the transaction and consensus flows. This approach is to allow hospitals that are far from the blood banks to accrue blood supply in emergency situations. Since blood has a certain storage period, it is expected that it will be possible to fulfill the demand of blood bags by supplying and using the bags that are nearing their expiration. Not only does it solve the primary purpose that is it helps to save lives, but it will also act as a waste management strategy for Blood by using near expiration bags first. Keywords: Blockchain, Blood, Supply Chain Management, Distributed Ledger.

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Chapter 1

Introduction

Blood is one of the most important essentials of human life. The journey of blood from a donor to a receiver is a complex landscape process. The blood after donated is tested, stored, transported and finally transfused. But when the blood is donated in many places the details of the sample are written using pen and paper. Bloodline helps conquer this issue using blockchain technology. This helps in tracking the blood from the time it is donated, till it is transfused When the blood is donated, the blood camp that takes the blood will create a new block that will store the blood. every transaction details are stored in the block chain which cannot be tampered.

1.1 Description

As a daily consumer ourselves, many a time we find ourselves in the wonderment, trying to figure out the entire lifecycle of a product when we purchase it. Right from its creation (manufacturing) process, until it is in our shopping cart. Every product that we purchase, is in turn connected to a chain of other products that are used as a basic set of ingredients in order to build the product we just purchased. Thus, emphasizing the fact that this intricate network of chain hierarchy is the basic building block for a product to be built and this is what we call Supply Chain. In order to ensure that the quality of the end product is up to the required mark, it depends on every single entity in the entire supply chain to be in place, in a timely manner whilst possessing good quality. It thus goes on to depict that proper management is required to handle the entire process, which is termed as Supply Chain Management (SCM). In our project, using the Blockchain (BC) implementation, we aim at providing rather simplified yet quality-assured support for maintaining and monitoring the data from the collection of the Blood from various different sources and tracking the physical conditions of those blood bags as well.

1.2 Problem Formulation

While the current traditional SCM is hampered by some fundamental flaws like uncertainty and distrust among the network, there are some factors that are difficult to handle despite the fact of them being recognized. Firstly, for example, the wastage of blood occurs due to less demand for blood bags and acquiring a higher supply of blood. An organization cannot take risk of reducing the collection of blood, based on the assumption that since the current requirement is low, it will stay low in the future as well. An emergency can occur anytime, hence it calls for a decisive measure of proper management which can be done using a few variations as mentioned in our proposed BC-based SCM solution. Secondly, the factor of mistrust amongst the entities in the entire network can be a major discomfort for their constituents to function smoothly. These posing challenges can be solved using our system. Our aim is to develop the BC implementation of the traditional SCM where traceability and efficient management is implied for the proper regulation of the entire distribution.

1.3 Motivation

Using traditional SCMs, when a product is launched into the market, the consumers are generally skeptical and may have some reservations with respect to the quality of the product. This factor of 'distrust' is a very common issue faced and is one of the major drawbacks of using traditional SCM. Moreover, this distrust factor is of primal importance when it is faced in the field of Blood donation and hence has to be rectified as early as possible. Thus there is a need of a system where a donor can satisfactorily get the whereabouts of the blood he donated and on the corollary, the recipient of the blood will also want to be assured that the blood that he is about to be injected with, is 100According to an article by the Times of India [3] , there is a tremendous amount of blood being tagged as 'waste', approximating to nearly six lakh litres of blood over five years of span, in Maharashtra itself and is disposed of due to 'improper coordination between the blood banks and hospitals' with given justification that they expired prior to their use. This shows a lack of management skills against the collection and disposition of the blood bags and is in desperate need of proper maintenance formulation.

1.4 Proposed Solution

In order to maintain transparency in the entire system/network, our solution proposes the use of Blockchain. That is, integrating BC in the SCM network where each and every entity can be tracked as per their movement.

- The inclusion of Blockchain solves the disadvantage of 'distrust'. By providing total transparency to its users, the entities involved in the network that are not be acquainted with one another and may become a potential cause for dissension during the phase of payment transactions. Our system resolves this problem, with the help of Smart Contracts, a feature of BC, that helps take control of the security aspect of these transactions. Only when a certain criterion is satisfied, the Smart Contract is fired, releasing the due payment.

- Secondly, all the data on a blockchain is stored securely through cryptographic hash function and the ledger is owned by each node in the network. This makes it very difficult for any intruder to manipulate the ledger data, ensuring protection against any possible mutations or fraudulent manipulation of the data stored insofar, thus establishing a common base of trust and immutability Also by exposing the supply chain ledger publicly, it helps gain the trust of blood donors.

- Our solution also provides a remedial strategy for improper waste management, which is one of the factors that deter donors away from this system. Using the data uploaded on the BC network, the internal entities can have access to the transparent data and consequently prioritize the process of dispatching the blood bags that are nearing its expiry. The bags which are nearing their expiry are flagged and are placed as ready to be dispatched in a case when an urgent call from a hospital is received.

1.5 Scope of the project

With respect to the donor, our system will take various parameters as input like the amount of blood donated, health conditions of the candidate, and blood group. This input obtained will then get hashed for the block creation process and get updated on the BC network. Simultaneously, the Certificate module will get initialized with the corresponding input values. However, the system does not limit itself to the block generation and updating it on the network. Upon further transportation of the blood bags, required entities will generate invoices and update the details on to the network as well.

- Once the bag has arrived at the T and P, after the testing and processing at this stage the system will output the new UID's of the split bags (if any), and update the expiry value for each and every bag received or generated, on to the Database as well as the BC network.
- After reaching the SCT, all the physical regulatory measures such as expiry check, temperature conditions, preservation and anticoagulation parameters, are updated on to the Database as well as the Network.
- Now as and when the requirement for the blood arises from the hospital, an appropriate urgency request is broadcasted to the nearby SCT and Hospitals, stating the precise values for the requirements. The system then calculates the cost structure and handles the payment of the transaction according to the various urgency-based scenarios. After the business is completed the details are updated on the Database and Network.

Chapter 2

Review of Literature

We have divided this literature review into two sections wherein first we review the previous work accomplished on the use of BlockChain in general supply chain management and then move on to review the literature on the use of BlockChain in blood SCM.

2.1 Blockchain in SCM

BlockChain is an ideal platform that can solve a number of problems related to centralized SCM's such as provenance tracking, cost reduction and the most important of all, establishing trust. The paper proposed by el Maouchi et al. [2] justifies the application of BlockChain in SCM and its feasibility. Their work is generalized for a standard SCM where a product travels from the initial actor to the final actor through the entire cycle and at each exchange, a transaction is validated through consensus and authentication which is then added to the blockchain. The paper provides standard architecture and algorithms to be executed when two actors exchange the product. Many other blockchain-based SCM papers include the one proposed by Patrick Sylim et al. [6]. This paper focuses on solving one of the major problems faced by the existing SCM in the medical field i.e. drug counterfeiting, using BlockChain to track the supply chain of medicines using Ethereum and proof-of-stake algorithm for consensus. In the field of medicine, blockchain contributes to increased safety and reduced costs which is ensured by identifying changes in ownership of drugs between different participants of the chain such as manufacturers, distributors, packers, and end-users. In another paper, Feng Tian proposed the use of RFID which allows the users to scan the product and validate its supply chain history, along with BlockChain to track the agri-food Supply Chain [7]. Tian supported the idea that a decentralized approach for tracking products could solve the issues in a centralized approach, such as trust, tampering, etc.

2.2 Blood SCM

Research on the blood cold chain system has been conducted by several approaches. Davis et al. proposed an RFID based system which dynamically manages the information related to blood [1]. Quite a few problems faced by the currently existing system for blood information management were pointed out in [5]. For example, the amount of information that can be contained in the bar code is limited, and the information is not reflected in the blood source in real-time, trusting the respective actors on updating legit information on the system, etc. Jabbarzadeh et al. proposed a robust network design model for the blood supply chain in the event of a disaster [4]. They took into consideration a set of decision parameters such as the number of blood centers nearby etc in order to manage blood allocation, blood collection, and other such critical decisions during a disaster. Kim et al. proposed a model that modifies the standard models proposed before that minimizes transportation time of blood during emergencies by not only allowing the blood storage centers to distribute blood but also authorizing specific hospitals as blood distribution institutions [5]. Despite efforts to track real-time information on the blood boxes or transport vehicles, there is a limitation to how closely each medical institution conducts blood transfusions and disposal. Besides, in the event of an emergency, there is a possibility that placing temporary facilities or designating a new base for blood supply, does not take realistic complex factors into account. They proposed a system wherein an actor in need of blood can view the nearest hospitals or blood centers that have the available blood for distribution thus helping the end-users avoid delays during emergencies.

Chapter 3

System Analysis

3.1 Functional Requirements

The System will contain 5 users as follows. The donor will be registered on to the network on donating for the first time and he/she can then login to the application and see/track his donations through a certificate on the web/app UI. The Donor will only be able to view the necessary details about his donated blood on the app. Blood collection centers (BCC) receive donations and for every new blood bag donated it creates a new blood bag (with initial information) and updates it on the BC which will be the genesis block. BCC can make a transaction of blood bags to testing and processing center (T And P). Testing and processing centers (T And P) accept transactions from BCC and adds necessary information about tests performed on the blood and then make a transaction to the Storage center (SCT). Storage center (SCT) receives bags from T And P thus claiming the ownership of the bag for storing it under proper conditions until a request has been placed for the supply of blood by any hospital. On receiving a request to send blood, SCT then performs a transaction to hand over the ownership of the blood bag to the hospital and on a successful transaction, SCT gets paid for the same through Smart contracts (SCs). Hospitals receive bags from SC and/or other hospitals that also act as suppliers on having excess blood at their disposal, on putting up a request for it. Hospitals can also get requests for blood from nearby hospitals. Finally, hospitals update the information of blood bags depending on whether they were used for any patients or are stored for future use, etc.

3.2 Non-Functional Requirements

Below are discussed some non-functional attributes of blockchain.

- Openness: The nodes in the blockchain show interoperability that means that the nodes in the Blockchain have the ability to exchange and use information during a transaction.

- Concurrency: Nodes process concurrently to enhance the performance of the blockchain.

- Scalability: Nodes can be added or removed to make the Blockchain flexible. Scalability considers three things:–Size: Mores nodes can be added easily in the Blockchain network.–Distribution/Transaction Processing rate: Geographical dispersion of the nodes does not degrade the performance of the Blockchain.–Manageability/latency: The Blockchain should be manageable as no. of nodes in the Blockchain increases and the different nodes are located in different parts of the world.

- Fault tolerance: The transactions in the Blockchain are immutable and any fault at any node will be transparent to all other nodes in the Blockchain.

- Transparency: Every transaction in the Blockchain is visible to each node in the blockchain network.

- Security: The Blockchain uses strong Cryptographic protocols such as SHA-256for securing the data in the Blockchain.

Non-functional requirements for the Users

- A web supporting device with an internet connection to use the application is preferred so that the devices can be used by the blockchain for consensus protocol and to ensure smooth working of the system.

SWOT analysis of blockchain technology	
Strength	Weakness
Network Decentralization Data Transparency Robust Architecture Autonomous network Speedy data access Availability of data on Distributed Ledger	Lack of Scalability Poor user interface Interoperability issues Storage Capacity Costly

Table 3.1: A Comprehensive survey on Blockchain

3.3 Specific Requirements

3.3.1 Software Requirements -

- An application that encapsulates the BC and the entire system for users to use for making transactions and tracking their blood bags.
- Ethereum - Blockchain
- Ganache - a personal blockchain for Ethereum development
- Truffle - a development environment for Ethereum decentralized applications

3.3.2 Hardware Requirements -

- Laptop / Computer
- RAM: 8GB
- Hard Disk: 256 GB

3.4 Use-Case Diagram And Sequence Diagram

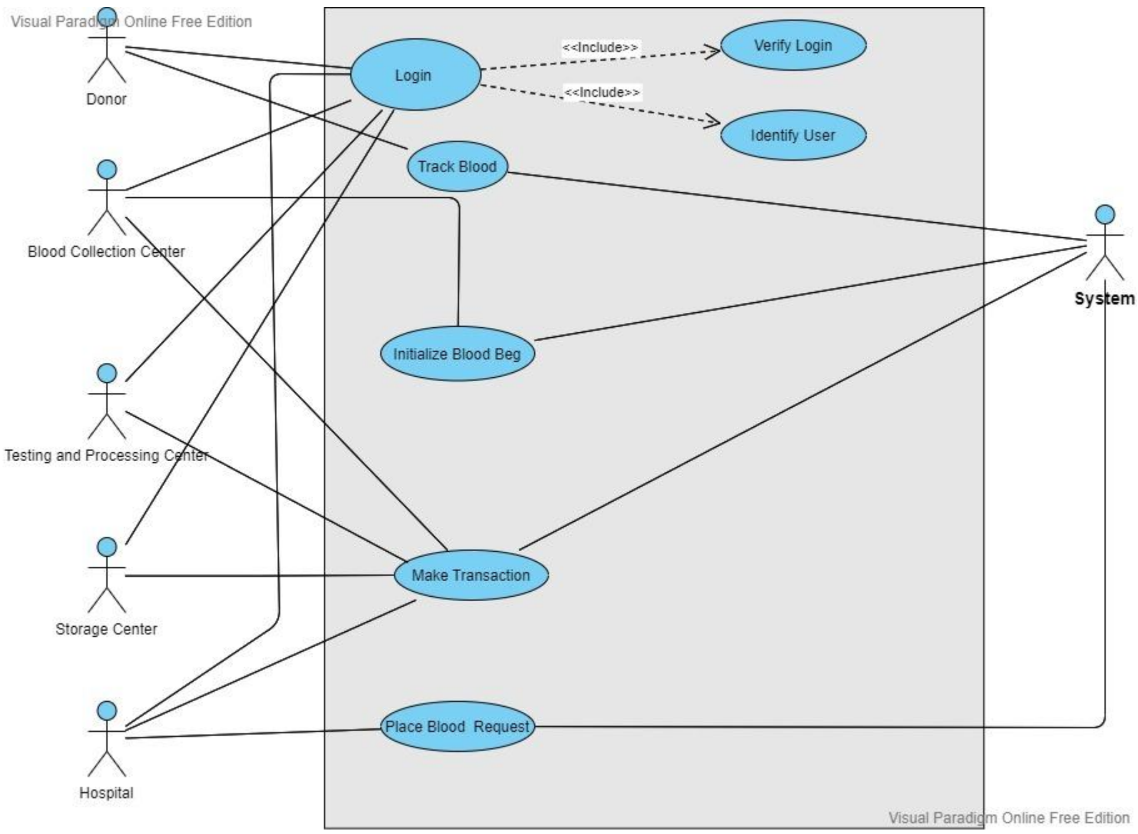

Figure 3.1: Use-Case Diagram.

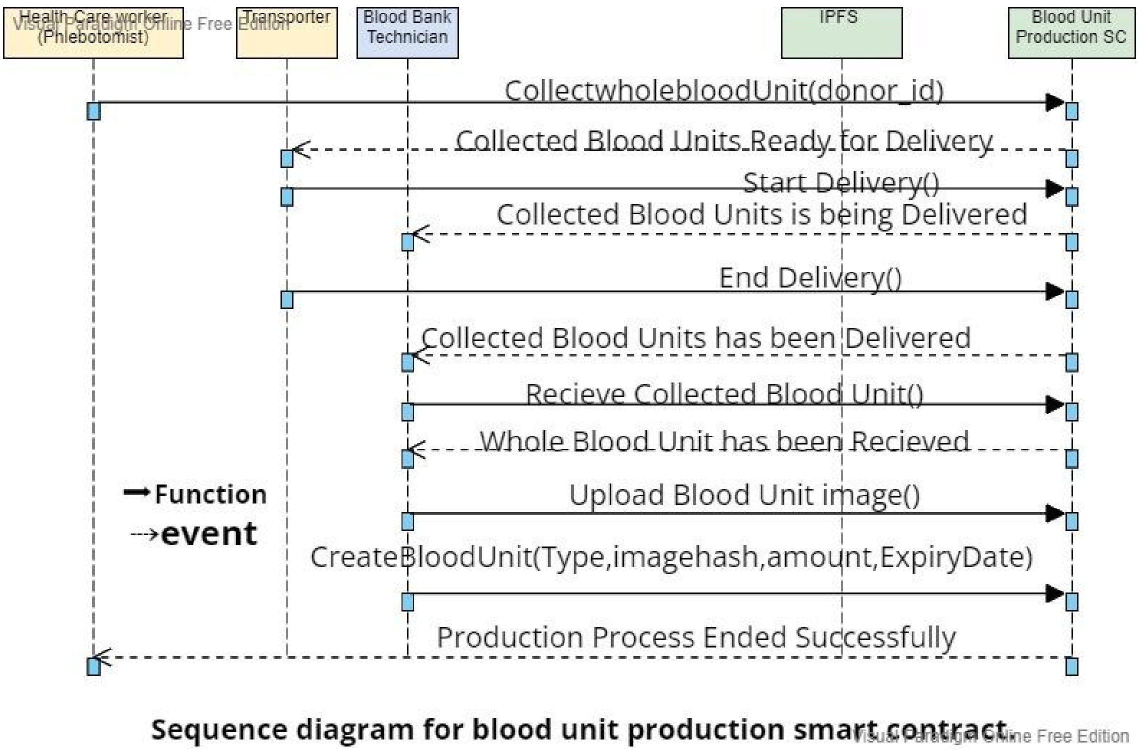

Figure 3.2: Sequence Diagram.

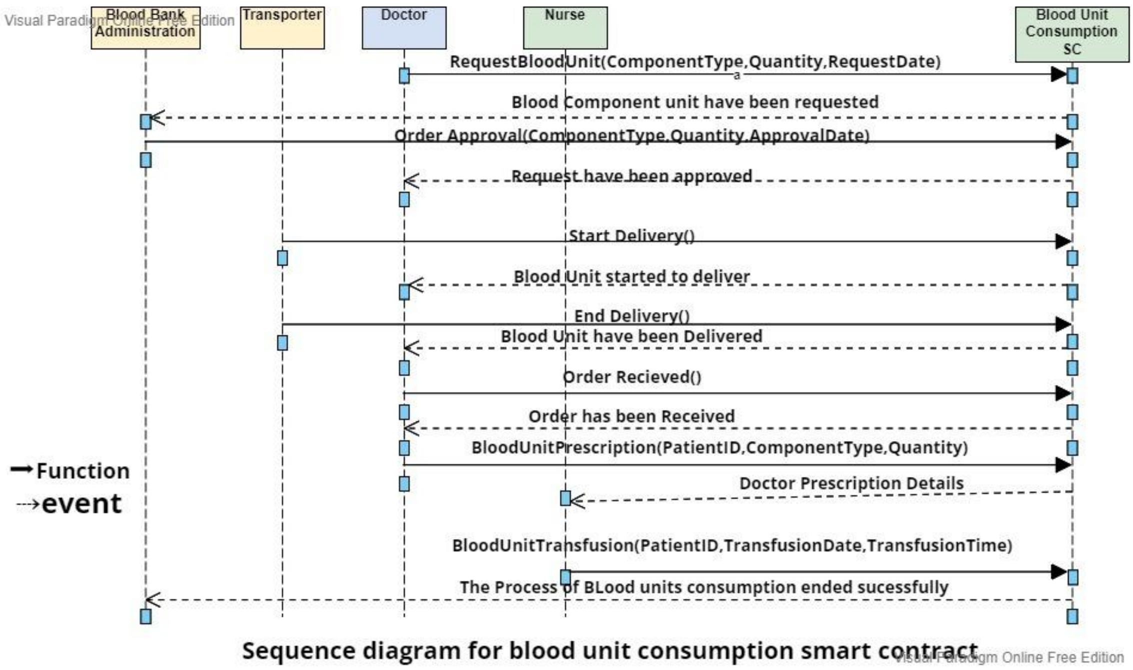

Figure 3.3: Sequence Diagram2

Chapter 4

Implementation

4.1 Methods Used

Our algorithm, as previously stated is heavily dependent on the specific features of solidity, such as the ‘Smart Contracts’. Shown below are the snippets of our main contract – ‘BloodManagement.sol’.

```
mapping(uint => Bloodbag) public bloodbags;
mapping(address => uint[]) public donors;
mapping(address => uint[]) public hospitals;
mapping(address => User) public usertype;
mapping(address => uint[]) public notification;
mapping(uint => User) public users;
```

Figure 4.1: mapping

Mappings: Mappings can be seen as hash tables which are virtually initialized such that every possible key exists and is mapped to a value. Here we have 5 prime mappings:

- **Bloodbags** – This is a very general list of bloodbags. It stores and returns the entire structure(object) of a Bloodbag, whose ‘id’ will be equal to the uint (integer) provided to the mapping.

- **Donors** – The Donors mapping will store and return an array, consisting of the bloodbag id(s) corresponding to each and every donor for a particular Blood Collection Center. Based on the address of the Bank provided, the list of donors for that center will be retrieved.

- **Hospitals** – – This mapping stores and returns an array, consisting of the bloodbag id(s) that are currently in possession and owned by the given address's hospital.

- **Usertype** – This is the type of mapping used for administrative purposes. It is used specifically to provide the client's information, such as the type of user. **For example** – '1' is for Donor '2' is for Blood Bank '3' is for Hospitals

  This 'usertype' mapping helps the system to dynamically recognize the type of client, who is visiting the webpage. Based on the usertype and the address of the client, we can provide a fluent access to the data belonging to the user/client.

- **Notification** – This mapping stores and returns an array, consisting of the bloodbag id(s) that have been used by the hospital(s). It is then used to notify respective donors about their donated blood. It is initially set to false by Blood Bank admin and updated to true by Hospital Admin.

- **Notification** – This mapping stores and returns an array, consisting of the bloodbag id(s) that have been used by the hospital(s). It is then used to notify respective donors about their donated blood. It is initially set to false by Blood Bank admin and updated to true by Hospital Admin.

```
struct User {
    uint id;
    uint user_type;
    string user;
    address payable user_address;
    string name;
}

struct Bloodbag {
    uint id;
    bool used;
    bool first;
    uint donation_date;
    address payable donor;
    address payable bank;
    string blood_group;
    uint expiry;
    string owner_name;
    address payable owner;
    // uint price;
}
```

Figure 4.2: Struct in our Smart Contract

Chapter 5

Results And Discussions

5.1 Results

Our proposed system will track the Blood throughout the supply chain process. It achieves secure and reliable blood supply in following way:

- Firstly, it authorizes the data collection and updating process by validating the users and the data entered by them.
- Secondly, the data integrity is maintained as the transactions on network are immutable. There is no database structure to manipulate the data even after the user has been authorized, which provides additional security from attackers.
- Blood wastage can be reduced by supplying near expiration blood first.

The web application will provide the following features for four entities viz. Admin, Donor, Blood bank and Hospital :

- Admin will add blood banks and hospitals to the system.
- Blood bank on collecting the blood will enter blood bag details along with donor details and submit the data on the Blockchain. Banks will have access to the list of all the bags collected by it.

- Hospitals will get a list of all the blood bags available at blood banks as well as other hospitals and will have an option to buy them.
- Donors will be able to track the ownership along with other details of all his/her donated blood bags.

5.2 Discussions

Previous papers [1] and [5] propose a traceability system but do not show the implementation of the same. We are developing "Blood Cycle", an Ethereum based system which keeps tracks of the blood bags and allows the actors to make transactions on the website with the help of a smart contract. Results can be seen as the relevant info of the blood bag gets updated after each authentic transaction and is visible to every actor including the donor. We have presented a new system for blood supply process based on Ethereum technology. In our sample use cases, we have demonstrated the process from the Blood Collection phase at BCC to the hospital storing the Blood bags. Implementation of this system would require the existing blood management systems to be linked on the network. Also, all the required actors as per the business logic would be needed to set-up machines and install Ethereum. These shall complement the system to make sure it works accordingly.

Chapter 6

Conclusions and Future Scope

6.1 Conclusion

By applying required checks at every stage in the Blockchain-based SCM, we have ensured that a scarce and perishable resource like blood is properly collected, stored and dispatched according to their priority for patients. Since the whole process is transparent with the help of the shared ledger maintained, the donors can easily track their donations. It would make a great impact on increasing the trust factor and consequently, the donation rate. The existing cold blood chain system lacks reliability, proper waste management system, and immutable transactions. With the addition of Blockchain to Supply Chains, it now records the transactions which bolster reliability, maintain logs and provide traceability. The security of payments and waste management factors have been considered by including smart contracts.

6.2 Future Scope

With respect to moving this project in the future, we would aim to implement two key aspects that might further enhancing the entire chain. Firstly, we would design the system to handle the splitting of blood in to different key components such as plasma, WBC's and RBC's are medically recommended. Secondly, in order to generate a better view against waste management, we would design a data visualizer. This visualizer would track the details regarding where each blood bag is stored and for how long, thus analyzing the cause of unexpected expiration, if any. It would also track the nominal data, such as how regular is a donor donating, how much blood is present in zones that are more prone to accidents and disasters.

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