A BLOCKCHAIN-BASED MODEL FOR PROVISION OF INCENTIVES TO RARE BLOOD GROUP DONORS

CHEBET LEAH BUNEI

A Thesis Submitted to the Institute of Postgraduate Studies of Kabarak University for Partial Fulfillment of the Requirements for the Award of Master of Science in Information Technology Degree

KABARAK UNIVERSITY

NOVEMBER, 2025

DECLARATION

1. I do hereby declare that:

    i. This thesis is my original work prepared with no other than the indicated sources and to the best of my knowledge; it has not been presented for the award of a degree in any university or college.

    ii. The work has not incorporated material from other works or a paraphrase of such material without due and appropriate acknowledgement.

    iii. The work has been subjected to processes of anti-plagiarism and has met Kabarak University's 15 percent similarity index threshold.

2. I do understand that issues of academic integrity are paramount, and therefore, I may be suspended or expelled from the University or my degree may be recalled for academic dishonesty or any other related academic malpractices.

Signed: ________________________ Date: _________________

Chebet Leah Bunei

GMI/NE/0217/01/18

RECOMMENDATION

To the Institute of Postgraduate Studies:

The Thesis entitled **"A Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors,"** and written by **Chebet Leah Bunei,** is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed this thesis and recommend its acceptance in partial fulfillment of the requirements for the award of the Master of Science in Information Technology from Kabarak University.

Signed: ________________________ Date: _________________

Prof. Simon Maina Karume

Department of Computer Science and Information Technology

Kabarak University.

Signed: ________________________ Date: _________________

Dr. Ruth Anyango Oginga

Department of Computer Science and Information Technology

Kabarak University.

COPYRIGHT

ACKNOWLEDGMENTS

First and foremost, I am grateful to God for, through His grace, completing this research study. My heartfelt acknowledgement goes to my tireless supervisors, Prof. Simon Maina. Karume and Dr. Ruth Anyango Oginga, whose invaluable guidance helped me shape this work, and for their patience throughout the research process. Special appreciation also goes to my dear parents and my uncles for being a great source of inspiration; to my child, my brothers, my sister, and my friends for their encouragement and moral support.

DEDICATION

This thesis is dedicated to my lovely family for their support. It is also dedicated to my friends: Mathew Kimeli, Tecla Sirma, Fred Chelule, Francis Komen, Alex Kibet, and Jared Nyakamba, who have always been a source of support and encouragement during the challenges of my academic life.

ABSTRACT

A critical requirement in achieving universal healthcare in Kenya is to maintain a consistent and adequate blood supply in the blood bank. Rare blood group donors, specifically those with AB-negative, B-negative, A-negative, and O-negative blood types, played a vital role in providing life-saving support to patients with special medical needs. However, the scarcity of these blood types posed a significant challenge, especially during emergencies or periods of high demand. Donor motivation remained low due to ineffective incentive systems, as traditional blood donation management platforms often lacked transparency, poor donor identification, and delayed or inadequate reward mechanisms. To address these challenges, the researcher developed a blockchain-based model prototype designed to provide secure, transparent, and trustworthy incentives for rare blood group donors. The study focused on the design, development, and evaluation of a model that integrated Solidity smart contracts and was implemented using React.js, accessible at https://grandmullah.github.io/donor. The model featured a token reward module that automatically generated and distributed digital tokens to verified donors, allocating 250 tokens for AB−, 230 for O−, 200 for B−, and 150 for A−, which could be redeemed for benefits such as subsidized medical care, free checkups, preferential services, and T-shirts. To ensure data protection and regulatory compliance, the model employed encryption, access controls, and adherence to data privacy laws. The research adopted a systematic literature review to examine existing models and used the agile methodology in prototype development. Testing with dummy data was conducted at the Nakuru County Referral and Teaching Hospital blood donor unit. In conclusion, the blockchain-based model for provision of incentives to rare blood group donors demonstrated a viable and secure solution to the challenges in blood donation management, enhancing trust, transparency, and donor motivation, particularly among rare blood group donors.

Keywords: *Blockchain, Model, Smart Contract, Confidentiality, Donors*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

API	Application Programming Interface
DAPPs	Decentralized Applications
DB	Database
DLT	Distributed Ledger Technologies
EVM	Ethereum Virtual Machine
FGD	Focus Group Discussion
FLHWs	Frontline Healthcare Workers
GDPR	General Data Protection Regulation
HIPAA	Health Insurance Portability and Accountability Act
ICT	Information Communication Technology
IDE	Integrated Development Environment
IPFS	Interplanetary File System
KNBTS	Kenya National Blood Transfusion Service
KTTA	Kenya Tissue and Transplant Authority
NACOSTI	National Commission for Science Innovation and Technology
NCRTH	Nakuru County Referral and Teaching Hospital
NPM	Node Package Manager
P2P	Peer-to-Peer
POC	Proof of Concept
RBTC	Regional Blood Transfusion Center
SLR	Systematic Literature Review
VNRBD	Voluntary Non-Remunerated Blood Donors
WHO	World Health Organization

CONCEPTUAL OPERATIONAL DEFINITION OF TERMS

Blockchain: This refers to a decentralized, distributed ledger that records transactions across a network of computers without the need for central recordkeeping.

Blockchain-as-a-Service (BaaS): A cloud-based service that enables organizations to build, host, and use blockchain applications, smart contracts, and functions without setting up and managing their own blockchain infrastructure.

Blood: This is a liquid substance that flows through human veins and arteries and carrying and transporting oxygen, nutrients, and other necessary elements to tissues.

Donors: These are individuals who donate blood, particularly those with rare blood types

Blood Donation: This is the process by which a willing individual donates blood, which is then received by another individual in need of a transfusion to manage a health condition.

Blood Donor Units: These are organizations that collect and manage blood donations.

Healthcare Providers: These refer to healthcare institutions, such as hospitals, clinics, and long-term care facilities, that deliver medical services, treatments, and care to patients.

Distributed Ledger: This refers to a digital database that is shared across multiple sites and is managed by a central authority.

Ethereum: This refers to an open-source blockchain platform that helps developers build and deploy decentralized applications using smart contracts, as well as allowing peer-to-peer transactions without relying on a central authority.

Incentives: These are rewards or factors that encourage individuals or groups to continue engaging in a specific action.

Model: Refer to a program that runs on a computer that creates a prototypical, or simulation, of a real-world feature, phenomenon, or event.

Kenya National Blood Transfusion Service: This is the government agency responsible for ensuring the safety, quality, and availability of blood in Kenya.

Solidity: Refers to a high-level programming language that is designed specifically for writing smart contracts on blockchain platforms, particularly Ethereum, which enables developers to create secure and efficient decentralized applications.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Blood donation is essential in healthcare worldwide, yet many blood donor units face persistent challenges in maintaining adequate supplies, especially for rare blood types. Blood transfusion supports surgeries, emergency care, and chronic illness treatment, and benefit patients facing life-threatening conditions, such as leukemia and hemophilia, to live longer and with a higher quality of life. The World Health Organization emphasizes the need for safe blood and blood products, particularly for individuals with rare blood types that are critical yet often in short supply (World Health Organization, 2021).

Blood mainly comes from voluntary non-remunerative donors, including students and patients' family members (World Health Organization, 2023). The number of emergencies requiring blood donation is always on the rise, but lifesaving donors are not available to meet the need. Blood plays a significant role in human life and delivers essential substances, such as nutrients and oxygen, to cells (Sadri *et al*., 2021). For medical treatment, blood availability is vital, as the need for blood is growing each year (Kumar, 2020).

Despite many awareness campaigns, it is still hard to keep enough blood reserves available at all times, which makes it even worse for rare blood groups. The rare blood types include AB negative (AB-) which is the rarest blood types found in less than 1% of the population, B negative (B-) is another relatively rare blood type which 2% of the population has, A negative (A-) present in about 6% of the population and O negative (O-) which is the universal donor type found in about 7% of the population (Debele et al., 2023). However, finding and encouraging donors with these rare blood types is difficult, especially when their blood is needed quickly. Therefore, it is important to have a reliable, motivated group of rare blood group donors to meet demand (American Red Cross, 2023).

Ensuring the availability of blood is very important for saving human lives; thus, every drop of blood counts. In a country like Kenya, seven people need a blood transfusion every ten minutes (World Bank, 2022). The COVID-19 (coronavirus) pandemic in 2020 worsened the situation, as only 16% of the 1 million blood units required were collected (World Bank, 2022).

However, in Kenya, the supply and demand for blood are continuously widening as the population increases. Timely access to blood transfusions helps save lives, thus eliminating deaths. Current models, such as the blood donation network managed by blockchain technologies, are used to support blood consumption and disposal. Blood information is kept securely (Trieu Le *et al., 2022*). The blockchain-based management of blood donations is another existing system developed to trace blood units. This system enhances the reliability and performance of tracking blood donations from their origin to the receiving patient (Hawashin *et al*., 2021).

Blockchain in blood bank supply management was also among the developed systems, based on private blockchain technology to secure information visibility and reduce blood supply time. The system supports blood exchanges between clinical institutions after agreement is reached on earnest interest and is important for avoiding delays in blood supply, which is legitimately associated with saving the lives of patients in crisis (Sanyukta *et al*., 2021).

Moreover, another existing system is the implementation of a blood cold chain using blockchain technology. The system, which is designed to share information as blood is moved, consumed, and discarded in real time, also assists in verifying temperature-related transactions. Timestamps were recorded to specify when the temperature was confirmed and to indicate the state of storage for the blood units, and participants in the blood cold supply chain updated the reason for the status change (Kim *et al*., 2020). A Blockchain-Based Blood Donation Framework has been proposed and implemented using the Hyperledger Fabric platform. This system enhances transparency in blood donation by tracking blood units and providing a platform for secure, transparent exchanges between blood suppliers (Lakshminarayanan et al., 2020).

The current system in Kenya is Damu-Sasa, which uses digital technology to assist in resolving health challenges through a cloud-based, end-to-end blood services information management platform. The platform provides information that enables stakeholders, especially frontline healthcare workers (FLHWs), to collaborate effectively to save patients' lives. This aids in real-time sourcing of blood products, blood donor relationship management, blood product screening, transfusion management, inventory management, hemovigilance reporting, and e-learning. Damu-Sasa matches potential blood donors with opportunities to donate blood (Fakiya, 2023). In addition, it helps prevent wastage due to blood unit expiries by providing fair advance notice to relevant FLHWs. Furthermore, using information from the system, FLHWs can also distribute blood products from areas of high supply and low demand to those of high demand and low supply. This allows access to blood products in the blood services ecosystem.

Globally, the policies that govern blood donation are typically guided by a combination of international guidelines, national regulations, and local health standards. These include the World Health Organization, which provides global guidelines and standards for safe blood donation practices (WHO, 2010). We also have the American Association of Blood Donor Units (AABB), which is responsible for setting standards for blood donor units and transfusion services in the United States (AABB, 2021). Furthermore, the United States Food and Drug Administration (FDA) regulates blood and blood products to establish quality standards and safety (FDA, 2020).

In addition, the European Blood Alliance is responsible for providing support and guidance to blood services across Europe (European Blood Alliance, 2020). Moreover, the National Blood Transfusion Service (NBTS) may have its own governing body responsible for setting specific policies regarding blood donation, safety protocols, and donor eligibility criteria (National Health Service Blood and Transplant, 2021).

However, the policies and guidelines that govern rare blood donations in Kenya are set by the Kenya National Blood Transfusion Service (KNBTS). This policy is responsible for coordinating blood donation and transfusion services, as well as establishing policies for safe and effective blood collection, testing, processing, and distribution to healthcare facilities (Kenya National Blood Transfusion Service, 2013). The Kenya Health Act is another policy that provides a legal framework for health services to help ensure blood safety and management (Republic of Kenya, 2017).

In addition, there is the Kenya National Blood Policy 2019, which outlines strategies for blood collection that lead to increased donations of rare blood types (Ministry of Health, Kenya, 2019). Moreover, the National Emergency Response Policy for Blood Transfusion outlines procedures to mobilize rare blood group donors during emergency situations (Kenya National Blood Transfusion Service, 2020).

However, in the year 1994, Kenya recognized the benefits of establishing a national blood service in line with World Health Organization (WHO) proposals and World Health Assembly (WHA) declarations and recommendations, with the aim of establishing a regional system of transfusion centers managed by central coordination.

In 2001, Kenya’s initial blood policy plan was put in place, and it opened its first Regional Blood Transfusion Center (RBTC) and national management office in Nairobi. Currently, the Kenya Tissue and Transplant Authority (KTTA) was established in August 2022 under the Ministry of Health. KTTA's mandate is to oversee, supervise and coordinate the collection and distribution of secure blood in Kenya (Kenya Tissue and Transplant Authority, 2023).

One way to encourage blood donation is by offering incentives or rewards. In countries like the United States and Australia, monetary payments are used to motivate donors. While this method has been effective in attracting some donors, it has also raised ethical concerns about treating blood donation like a commercial transaction (Murray et al., 2019). In Canada, blood donor units often provide gift cards or vouchers for local businesses to encourage donations (Harrison et al., 2018). In the United Kingdom, non-monetary incentives such as awards and public recognition are commonly used to acknowledge donors (Gonzalez et al., 2020).

Although traditional incentive methods have benefits, they also have problems. These include a lack of clear processes, the risk of misuse, and difficulty accurately tracking donations. Managing donor information and rewards in a single central location can also lead to privacy issues and delays, reducing the program’s effectiveness and trust. Furthermore, the current models used for blood donation and management include bank management systems, blood donation management systems, LifeBlood, the Digital Blood Donation Management Platform, BloodConnect, Red Cross Blood Services, and Damu Sasa. However, these systems lack important features such as security, decentralization, transparency, and trust, especially for donors with rare blood types.

Blockchain technology offers a promising solution to these problems. Blockchain is a secure, transparent, and decentralized system that can keep donation records safe and unchangeable. It protects donor privacy while allowing quick verification and tracking of blood donations (Li et al., 2021).

Therefore, the development of a blockchain-based model prototype for the provision of incentives to rare blood group donors helps secure records, allows donors to track their blood donation history, and builds trust. Donors receive tokens for each blood donation, which must be redeemed for various incentives, including, but not limited to, subsidized medical care, preferential medical services, free medical check-ups, and T-shirts. This helps to increase donor participation and improve the supply of rare blood types in the blood banks.

To address regulatory challenges, the study implements data protection measures such as encryption and access controls to secure donor information and ensure privacy compliance, while also developing a non-monetary incentives model aligned with regulations (World Health Organization, 2023).

1.2 Statement of the Problem

Rare blood group donors play a critical role in the healthcare sector by providing life-saving support to patients with specific medical needs to live longer and with a higher quality of life. However, the scarcity of these rare blood types, namely AB-, B-, A- and O-, poses a significant challenge, especially in emergency or high-demand situations. Despite the crucial need for blood donations, donors may be less motivated to donate regularly due to a lack of incentives.

The traditional blood donation management systems are often not transparent, secure, trustworthy, or efficient. The existing system does not provide any motivation or incentives for blood donors. This discourages them from donating blood, particularly those individuals with rare blood types. However, due to these challenges, a transparent, secure, and decentralized solution was needed to improve donor engagement. Therefore, a blockchain-based model for the provision of incentives to rare blood group donors offered significant potential, providing immutable records, enhanced traceability, and ensuring that donors received incentives based on their donation history and blood type demand. This assisted in fostering a culture of appreciation and recognition for donors, thereby leading to better healthcare outcomes and saving lives.

1.3 Objectives of the Study

1.3.1 General Objective of the Study

The general objective of the study was to develop a blockchain-based model for provision of incentives to rare blood group donors that offers trust, transparency, and security, tailored to increase blood donation.

1.3.2 Specific Objectives of the Study

i. To explore the weaknesses of existing models used in blood donation and management

ii. To design a blockchain-based model for the provision of incentives to rare blood group donors.

iii. To implement a blockchain-based prototype for the provision of incentives to rare blood group donors.

iv. To evaluate the blockchain-based model prototype for the provision of incentives to rare blood group donors.

1.4 Research Questions

This study was guided by the following research questions;

i. What are the weaknesses of existing models used in blood donation and management?

ii. How can a blockchain-based model for the provision of incentives to rare blood group donors be designed?
iii. How can a blockchain-based Prototype for the provision of incentives to rare blood group donors be implemented?
iv. How can the blockchain-based model prototype for the provision of incentives to rare blood group donors be evaluated?

1.5 Research Contribution of the Study

The expected output of this study includes the following deliverables;

i. A report of existing models used in blood donation and management
ii. A model design for the provision of incentives to rare blood group donors
iii. A model prototype for the provision of incentives to rare blood group donors
iv. A report of the model prototype functionality for the provision of incentives to rare blood group donors.

1.6 Justification of the Study

Individuals who donate blood play a vital role in saving others' lives. Rare blood types are especially crucial for treating patients with specific medical conditions and during emergency situations. However, many healthcare systems struggle to maintain an adequate supply of rare blood. As a result, relatives and friends of patients often appeal for donations by phone or on social media to help save lives.

The blockchain-based model enhances transparency by recording rare blood donations and rewards on a permanent, tamper-proof ledger, thereby building trust among donors of rare blood groups. Token-based incentives allow donors to receive immediate, tangible rewards for their contributions, motivating especially those with rare blood types to donate more frequently. Consequently, hospitals can maintain sufficient blood supplies for patients in need.

Furthermore, the decentralized nature of blockchain technology minimizes misuse of donor data and ensures rewards are distributed fairly, thereby further strengthening donor confidence and participation.

1.7 Significance of the Study

The blockchain-based model for incentivizing donors of rare blood groups aims to improve donation rates for rare blood types by rewarding donors for donating blood. This motivates and encourages more people to participate in blood donation, thereby helping save many lives. The use of blockchain technology provides transparency and security for tracking blood donations and also ensures the reliability and accuracy of donor records, particularly for rare blood group donors. This helps build trust, leading to higher donor loyalty. In addition, donors have a high chance of controlling their personal information and donation history; this promotes a sense of ownership and inspires persistent participation.

Furthermore, donor information is securely encrypted, and only authorized personnel are permitted to access it. In addition, the use of smart contracts reduces administrative overhead and ensures there are timely rewards for rare blood group donors. The model complies with health regulations and data privacy requirements to ensure the rights of rare blood donors are protected. Lastly, this study has a significant impact on the healthcare sector, especially in the emergency and trauma sector, blood-related ailments such as Leukemia, and general surgeries that often require rare blood in blood banks.

1.8 Scope of the Study

This research primarily focused on developing a blockchain-based model to incentivize donors with rare blood types. A review of existing models in blood donation and management was conducted, after which a new blockchain-based model was designed, implemented, and evaluated with the involvement of rare blood donors to assess its suitability. The model was developed using Hardhat, Node.js, and Web3 JSON-RPCs to support interactive features. It was specifically designed to protect donor privacy and ensure that all transaction records remain secure and immutable. To minimize research costs and ensure a safe testing environment, the model was deployed to Ethereum test networks, and smart contracts automated the distribution of rewards. The prototype serves as a proof-of-concept for incentivized rare blood donation. Furthermore, this study recognizes the potential for bias in incentive allocation. To address this, the model includes mechanisms to ensure fair distribution of rewards regardless of donor frequency, location, or accessibility. The incentive structure is non-monetary and designed to promote inclusivity, transparency, and equity among all donors. This study was conducted at the Nakuru County Referral and Teaching Hospital blood donor unit between January and August 2025.

1.9 Assumption of the Study

The study assumed that the government hospital's blood donor unit, located at Nakuru County Referral and Teaching Hospital, provided access to its facilities and the necessary data required for the research. Furthermore, it was assumed that offering incentives, particularly to rare blood group donors, would effectively motivate them to donate blood and that donors would perceive such incentives, such as tokens, as valuable and rewarding. It was also assumed that the data entered into the blockchain system was accurate and reflected the actual incentives and donation records. Additionally, the study assumed that respondents provided truthful and accurate information as required by the researcher. Lastly, it was assumed that participants had not received any training prior to the study and that all questions were answered honestly and truthfully.

1.10 Limitation of the Study

This study uses only the Ethereum Virtual Machine (EVM); however, future research could explore other platforms, such as Hyperledger or Corda, to enhance interoperability and scalability. The prototype also required a constant internet connection and could not function offline, a limitation that might have been addressed through hybrid models with local data caching and later synchronization. Furthermore, blockchain development demands significant technical expertise and resources, but this can be mitigated by adopting APIs, middleware, training programs, or Blockchain-as-a-Service (BaaS). Donor incentives that rely on token rewards also require additional funding, which could be supported through partnerships with government, NGOs, or private sponsors, alongside non-monetary rewards such as recognition badges. Finally, setting up blockchain infrastructure in blood donor units can be costly, but this expense may be minimized by adopting cloud-based solutions or consortium blockchains that enable cost-sharing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents existing models for blood donation and management. It also reviews the literature based on the objectives and draws on relevant knowledge to develop the model. The conceptual framework used to design the blockchain-based model prototype will also be presented in this chapter.

2.2 Overview of Rare Blood Donations Worldwide

Blood donation is a vital component of healthcare systems worldwide. Rare types are crucial for patients with specific medical conditions, such as those requiring frequent transfusions, and are also used during emergencies. The availability of these rare blood types can be a significant challenge in regions with diverse populations, where certain blood groups may be underrepresented (D'Almeida, A., & Varela, P., 2020).

The individuals with rare blood include AB negative which is the rarest blood types found in less than 1% of the population, B negative is another relatively rare blood type which 2% of the population have, A negative present in about 6% of the population and O negative which is the universal donor type found in about 7% of the population (American Red Cross, 2023).

2.2.1 Blood Donation in Kenya

Currently, Kenya's annual demand for blood stands at 500,000 units, against an average of 175,000 units collected by KNBTS. Kenya is facing a shortage of blood supplies in hospitals, where relatives and friends of patients have to appeal to people to donate blood via phone or social media to save lives. Every ten minutes, about seven Kenyans need a blood transfusion and are at risk of dying when blood is not available. Every month, at least 30,000 people require blood transfusions (KNBTS, 2023).

The population in Kenya is 47.5 million people, and according to World Health Organization (WHO) guidelines, Kenya should be collecting a minimum of one per cent of the population, which is 470,000 units of blood a year. Due to increased demand for blood supplies, there is an urgent need to ensure the continuous availability of blood and its products. The adequacy of blood supply depends on blood donation rates and the number of blood donors. Recruiting and retaining rare blood group donors always remain key challenges for blood agencies (Kenya News Agency, 2022).

However, ensuring the availability of blood is very important for saving human lives; thus, every drop of blood counts. In a country like Kenya, seven people need a blood transfusion every ten minutes. The COVID-19 (coronavirus) pandemic in 2020 worsened the situation, as only 16% of the 1 million blood units required were collected (World Bank, 2022).

2.3 Existing Models used in Blood Donation and Management

The models that currently exist to curb some of the concerns in blood donation and management are stated below:

2.3.1 Blood Bank Management System

A Blood Bank Management System is designed to streamline the collection, storage, management, and distribution of blood and its components. This system plays an important role in managing the blood donation process, tracking blood inventory, and ensuring the safe delivery of blood to patients in need, especially in hospitals and clinics. It also integrates key blood banking processes, including donor registration, blood collection, testing, and distribution (Khan *et al.*, 2024).

2.3.2 Blood Donation Management System

A blood donation management system is a software platform that streamlines the entire blood donation process from donor registration to blood distribution. It manages donor data while ensuring efficient distribution of blood to hospitals and clinics based on demand. Furthermore, the system is developed to optimize blood collection, minimize wastage, and enhance traceability and transparency throughout the blood donation process. Such systems can also be implemented as web or mobile applications, allowing both donors and healthcare providers to interact and effectively manage blood donation operations (Gollapelly *et al.*, 2023).

2.3.3 Life Blood

Life Blood is an emerging system that aims to address the critical challenges surrounding blood donation, particularly those related to rare blood types. The idea behind Lifeblood was to create a technology-driven platform, typically a mobile app or web-based platform, that helps to connect donors and recipients for rare blood types. This assists in ensuring that the donation process is as efficient**,** transparent**,** and accessible as possible. Moreover, this system focused on improving the management and distribution of rare blood types that are in high demand (Futura Technologies, 2020).

2.3.4 Blood Connect

Blood Connect is a digital platform that aims to enhance the blood donation process by facilitating connections between blood donors and patients or healthcare providers in need of blood. The platform leverages technology to bridge the gap between blood demand and supply, focusing on building a community-driven solution to address critical blood shortages. It helps find suitable blood donors, schedule appointments, and track donation history. Furthermore, it helps ensure that blood is readily available whenever patients need it (Verma et al., 2025).

2.3.5 Digital Blood Donation Management Platform (DigiBlood)

This platform is designed to bridge the gap between blood donors and those in need by leveraging technology to streamline the donation process. Its main aim is to facilitate the availability of safe, timely blood donations, especially in regions experiencing blood shortages. Furthermore, DigiBlood helps connect hospitals, blood donor units, and donors through a mobile or web platform that enables real-time blood requests, geolocation-based donor-recipient matching, and donation history tracking. This system also increases donor awareness, improves supply chain efficiency, and enhances transparency by digitizing the process (Kühnert et al., 2024).

2.3.6 Red Cross Blood Services Application

This is a mobile application developed by the American Red Cross to enhance and streamline the experience of individuals who donate blood. The application is designed to make the blood donation process more convenient, accessible, and efficient by allowing users to track their donation history, schedule appointments, find nearby blood drives, and receive updates when blood is urgently needed. In addition, the application provides a user-friendly interface that encourages regular blood donations and improves donor engagement (American Red Cross, 2020).

2.3.7 Damu Sasa

This mobile application was developed to address challenges encountered during blood donation in Kenya. The application is designed to connect blood donors with recipients to facilitate blood donation management and improve the efficiency of blood transfusion services. The term "Damu Sasa" is derived from Kiswahili, meaning "Blood Now" or "Instant Blood." The platform aims to streamline the blood donation process by making it easier for individuals to donate and enabling hospitals to quickly find compatible donors during emergencies (Mbuthia & Mutua, 2020).

2.3.8 Blood Chain: A Blood Donation Network Managed by Blockchain Technologies

This system is developed to assist in the secure management of blood information, including blood consumption and disposal. It is designed to ensure the quality of blood for both donors and recipients. In addition, the system supports blood transactions among medical institutions, allowing donors and recipients to feel confident that blood quality is maintained. At the same time, donors can also access information about their health status. Finally, the system enhances transparency in blood information management (Trieu Le et al., 2022).

2.3.9 Blockchain-Based Management of Blood Donation

This system is developed to trace the blood origin in a transparent, secure, trustworthy, auditable, private, and decentralized manner. The system uses the smart contract feature of the private Ethereum blockchain to automatically record and log events. They integrated the private Ethereum blockchain with the Interplanetary File System (IPFS) to deal with the limited storage issue. Testing and validation were done using the Remix Integrated Development Environment (IDE). In the future, the system is intended to be tested on the real Ethereum network and to build an end-to-end decentralized application (Hawashin et al., 2021).

2.3.10 Blockchain in Blood Bank Supply Management

The blockchain for blood bank supply management is built on private blockchain technology to ensure information visibility and reduce blood supply time. Furthermore, this system provides support for blood exchange among clinical institutions after agreement is reached on earnest interest; it is also important to avoid delays in blood that is legitimately identified as life-saving for patients in crisis (Sanyukta et al., 2021).

2.3.11 Implementation of a Blood Cold Chain System using Blockchain Technology

The implementation of a blood cold chain system using blockchain technology is based on Hyperledger Fabric. However, this system is designed to share information in real time as blood is moved, consumed, and discarded. It also helps verify temperature-related transactions and timestamps, which are used to confirm temperature. Moreover, it indicates the storage status of blood units, where participants update the reason for the status change (Kim et al., 2020).

2.3.12 Implementation of Blockchain-Based Blood Donation Framework

A Blockchain-Based Blood Donation Framework was proposed using the Hyperledger Fabric. The system ensures transparency of donated blood by tracking blood units and providing a secure platform for exchange between blood suppliers (Lakshminarayanan et al., 2020).

2.4 Design of a Blockchain-Based Model Prototype for Provision of Incentives to Rare Blood Group Donors

This section discusses the constituent parts of a blockchain-based model, including existing designs, an overview of blockchain, a distributed ledger, a consensus algorithm, and smart contracts.

2.4.1 Existing Designs of Blockchain Models

Existing research highlights blockchain's growing application in healthcare, particularly in areas of data security, traceability, and donor management. Several studies have demonstrated the potential of blockchain in managing blood donation systems. For instance, Chakraborty et al. (2020) proposed a blockchain-enabled blood bank system that ensures transparency in donor-recipient matching and secure recordkeeping. Similarly, Shahnaz et al. (2019) designed a blockchain-based electronic health record system that improved trust and accountability, features equally critical to blood donation management.

Incentive-driven models have also been explored, although not specifically targeting rare blood groups. (Liu et al., 2021). Discussed token-based rewards for healthcare data sharing, showing how blockchain can encourage participation through financial and non-financial incentives. In the context of blood donation, Bhatia & Sood (2021) suggested using smart contracts to automate donor recognition and reward distribution, thereby reducing administrative overhead and ensuring fairness. These designs demonstrate how blockchain can be adapted to motivate participation in sensitive and resource-critical areas.

However, literature specifically focused on rare blood group donors remains limited. Rare blood groups (such as AB−, B−, A−, and O−) face chronic shortages globally, making donor motivation critical (WHO, 2020). Existing blockchain models address general blood donation, but they rarely incorporate tailored incentive mechanisms for rare blood groups. This gap underscores the need for a blockchain-based prototype that integrates donor incentives such as token rewards, recognition badges, or priority access to healthcare services specifically for rare blood donors.

Thus, while blockchain has been successfully applied to donor management, healthcare data sharing, and incentive distribution, there is limited research on the unique challenges faced by rare blood group donors. Designing a prototype model for this niche area would bridge an important gap in both blockchain and healthcare innovation literature (World Health Organization, 2020).

2.4.2 Blockchain Technology

Blockchain is a decentralized public ledger that supports the creation of permanent, unchangeable records. This ensures transparency and trust among stakeholders by providing real-time access to donor information and donation histories. Smart contracts, which are executable on blockchain platforms, automate the verification and distribution of incentives and enhance operational efficiency (Guo *et al*., 2021).

2.4.3 How Blockchain Works

The technology that has emerged nowadays is the blockchain, which is defined as a list of records that are normally linked using cryptography, allowing industry participants to keep track of digital currency transactions without central recordkeeping. Blockchain is a decentralized public ledger on peer-to-peer networks that allows real-time tracking and verification of blood donations and ensures donor records are transparent and accurate (Li *et al*., 2021).

2.4.4 Blockchain Smart Contracts

A smart contract is a self-executing program in which the terms of an agreement between two or more parties are directly written into code and executed on a blockchain network. This contract enables trusted transactions and agreements to be carried out without a central intermediary. Smart contracts offer transparency, security, and cost-effectiveness by eliminating intermediaries and enabling automatic execution when certain conditions are met, all without manual intervention (Taherdoost, 2023).

The blockchain smart contracts provide a health-centered system in which the rare blood donor owns the records, decides who can access the information, and cannot delete it, thereby solving trust issues. Interoperability can also be provided where blockchain acts as a catalogue listing all donors' records and histories.

2.4.5 Types of Blockchain

There are three main types of blockchain, which are described below:

i) Public Blockchain

A public blockchain is open to anyone with internet access, allowing participants to conduct transactions and validate blocks without restrictions. Decision-making in public blockchains is achieved through decentralized consensus mechanisms such as Proof of Work (PoW) or Proof of Stake (PoS). Examples of public blockchains include Bitcoin, Ethereum, and Litecoin (Financestrategists, 2025).

ii) Private Blockchain

A private blockchain restricts access to authorized participants only. It is controlled by a single organization or designated administrator who manages permissions and oversees communication within the network. This type of blockchain is commonly used in enterprises to manage internal operations that require confidentiality and efficiency (Paxos, 2025).

iii) Consortium (or Federated) Blockchain

A consortium blockchain is a semi-decentralized network managed by a selected group of organizations rather than a single entity. It is often used in industries such as banking and supply chain management, where multiple stakeholders collaborate to securely share data. Consortium blockchains offer higher scalability, faster transactions, and greater privacy than public blockchains (Techopedia, 2024).

2.4.6 Benefits of Blockchain

According to Patel and Sharma (2023), blockchain technology offers several significant benefits, making it well-suited for applications that require transparency, security, and efficiency.

i) Enhanced Security

Blockchain transactions use cryptographic techniques such as hashing to secure data. Each transaction is verified by multiple nodes through consensus mechanisms (e.g., Proof of Work or Proof of Stake) before being added to the chain. Once recorded on the blockchain, data becomes immutable, making it extremely difficult to alter without the consensus of the network. Additionally, because information is stored across a distributed network rather than a single central server, it is more resistant to hacking and data breaches.

ii) Greater Transparency

Blockchain operates as a distributed ledger that ensures all transactions within a public network are visible to authorized participants. This transparency helps build trust among users, as every transaction, such as blood donations or incentive distributions, can be independently verified without intermediaries.

iii) Increased Efficiency and Incentive Tracking

Blockchain technology simplifies the tracking of donor incentives, particularly through smart contracts. These contracts automatically execute transactions such as distributing rewards once predefined conditions are met, ensuring timely and accurate delivery of incentives while minimizing administrative workload.

iv) Improved Traceability

Blockchain enables hospitals and blood donor units to create verifiable audit trails for all historical transactions. This capability improves traceability, prevents data manipulation, and reduces the risk of fraud in sensitive operations like blood management.

v) Decentralization

The decentralized nature of blockchain enables multiple stakeholders, such as hospitals, blood banks, and health authorities, to securely share information without relying on a central authority. This ensures collaboration while maintaining autonomy and data integrity.

vi) Cost Reduction

By eliminating the need for third-party intermediaries and establishing trust through data verification on the blockchain, organizations can significantly reduce operational costs for recordkeeping, auditing, and coordination.

2.5 Research Gaps

The researcher noted that there exists a gap in the already existing models from the literature review, as illustrated in the table below;

Table 1

Research Gaps

S/No.	Author	Description	Research Gap
1.	Blood Bank Management System (Khan *et al.*, 2024).	This is a centralized system used for managing blood donation, storage, testing, and distribution within blood donor units and hospitals.	There are issues of data privacy and security where sensitive donor and patient data were not protected as well as database decentralization is not addressed.
2	Blood Donation Management System (Gollapelly et al., 2023).	Facilitates management and tracking of blood donations, donor histories, as well as distributions of blood in hospitals or clinics. This system is designed using mobile application in order to connect blood donors with recipients of rare blood types This is crowdsourcing platform used to connect blood donors with hospitals and patients who require blood via mobile.	Data privacy, transparency, and database decentralization are not addressed. There is also a lack of real-time tracking. There was a lack of privacy in this system, as storing health data of donors on mobile applications posed a security risk.
3	Life Blood (Futura Technologies, 2020)	Facilitates management and tracking of blood donations, donor histories, as well as distributions of blood in hospitals or clinics. This system is designed using mobile application in order to connect blood donors with recipients of rare blood types This is crowdsourcing platform used to connect blood donors with hospitals and patients who require blood via mobile.	Data privacy, transparency, and database decentralization are not addressed. There is also a lack of real-time tracking. There was a lack of privacy in this system, as storing health data of donors on mobile applications posed a security risk.
4	Blood Connect (Verma et al., 2025	This is a mobile platform used to connect blood donors with recipients who need blood in real-time by use of geolocation and notification features	Issues of data privacy and security as well as DB decentralization, are not addressed.
5	DigiBlood (Kühnert et al., 2024).	This is a mobile application used in	Data privacy, transparency and database decentralization are not

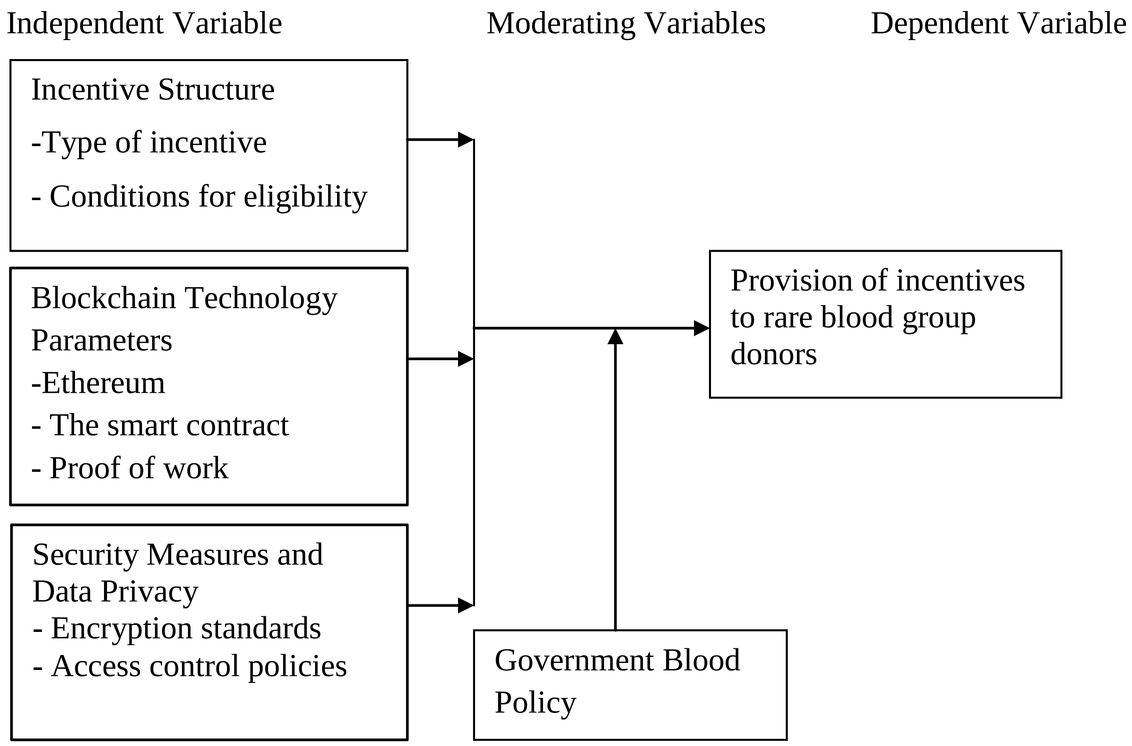
		managing blood donations, tracking donor history, scheduling donations, and also facilitating emergency blood requests.	addressed.
6	Red Cross Blood Donor App (American Red Cross, 2020).	This is a mobile application that is used to allow users to track their donations and earn points that can be redeemed for rewards.	
7	Damu Sasa (Mbuthia, *et al*., 2020). Blood chain: a blood donation network managed by blockchain technologies (Trieu Le, *et al., 2022*)	The system is developed to assist management of blood information in a secure way such as blood consumption and disposal, and was also used to guarantee the quality of blood for donors and receivers.	This application lacks privacy, where blood donors were reluctant to share their personal information, and database decentralization is not addressed. This system does not offer incentives to rare blood group donors. Data privacy, transparency, and . database decentralization are not addressed
8	Implementation of a blood cold chain system using blockchain technology (Kim *et al*., 2020). Implementation of Blockchain-Based Blood Donation Framework (Lakshminarayanan *et al*., 2020).	The system is developed for blood units' traceability in order to improve performance and reliability of tracking donated blood units.	They did not deploy and test their solution on the real Ethereum network and also did not build an end –to-end Dapp.
9	Blockchain based management of blood donation (Hawashin, *et al*., 2021)	The system is developed based on the private blockchain technology for securing information visibility and reducing blood supply time. The system is designed to share information as blood is moved, consumed, and discarded in real-time	They did not deploy and test their solution on the real Ethereum network and also did not build an end –to-end Dapp.
10	Blockchain in Blood Bank Supply Management (Sanyukta, *et al*., 2021).	Proposed a system using the Hyperledger Fabric framework. The system ensures transparency of donated blood by tracking blood units and providing a secure platform for exchange between blood suppliers	Their system did not satisfy the donor, they only deal with securing information visibility, reducing the supply time and supports blood exchanges.

2.6 Conceptual Framework

A conceptual framework is a research tool that helps a researcher facilitate relationships among variables or concepts in the real world, as shown in Figure 1 below.

Figure 1

Conceptual Framework



Source: Authour, (2025)

The following are the Independent variables;

1. Incentive Structure

i) Type of incentive: Tokens were used to present various types of rewards to rare blood group donors, namely, subsidized medical care, preferential services, free medical check-ups, as well as T-shirts. These tokens can be accumulated over time as a blood donor makes regular donations and can be redeemed.

ii) Conditions for eligibility: This was a criterion used to show the frequency of donation and the specific blood type needed.

2. Blockchain Technology Parameters

i) Blockchain platform: Ethereum was used to provide a secure, transparent, and efficient mechanism for rewarding rare blood group donors as well as tracking donations.

ii) The smart contract: This was used to ensure that rewards were automatically triggered once a rare blood group donor met a certain criterion for donating a certain amount of blood or a certain number of times blood had been donated.

iii) Consensus mechanism: Proof of work was used to validate transactions as well as maintain blockchain integrity.

3. Security Measures and Data Privacy

i) Encryption standards: The encryption was used to protect rare blood group donor information and transactional data.

ii) Access Control Policies: Rules and protocols for controlling access to sensitive information stored on the blockchain were used.

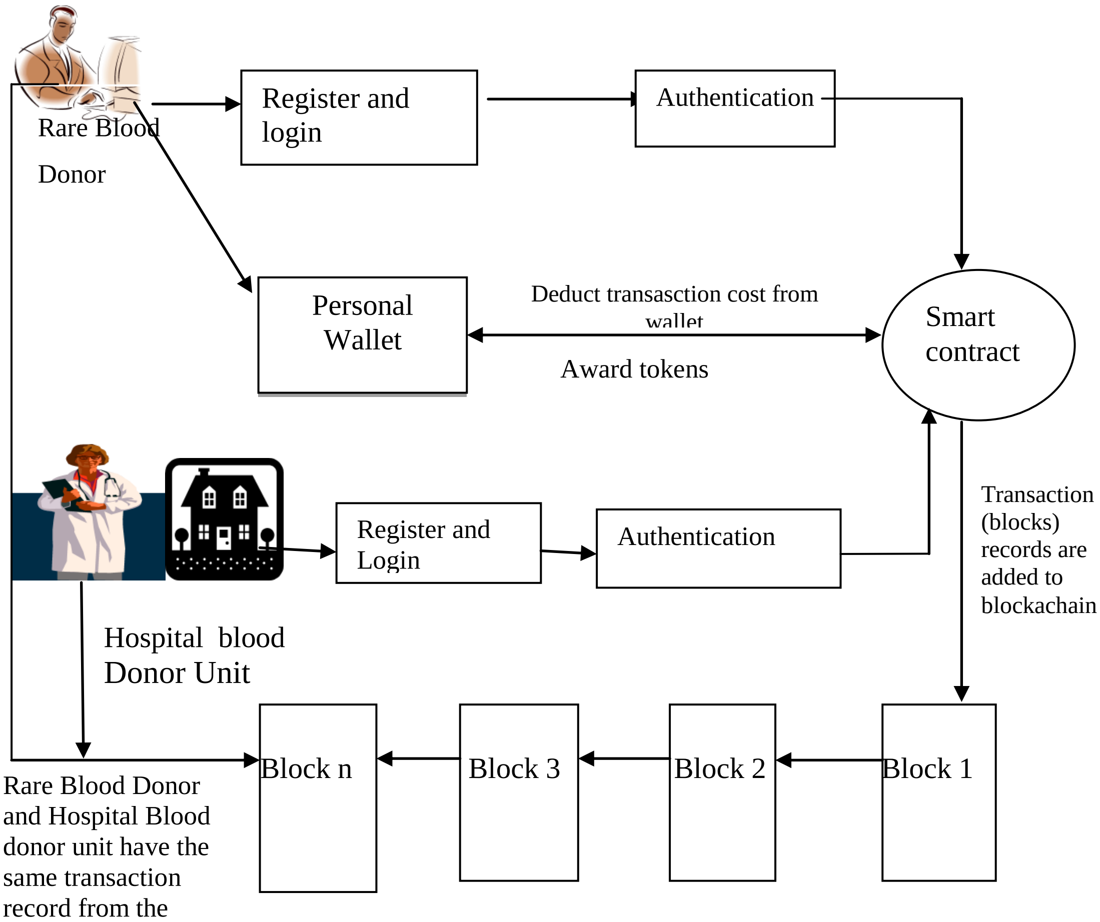
Government blood policy was the moderating variable, a set of laws, guidelines, and strategies established by the government to regulate and manage blood donation and the overall blood supply system. This policy specifically ensures that the medical information of rare blood group donors is kept secure and private by adhering to data protection and confidentiality standards.

2.7 Prototype Implementation Conceptual Framework

Figure 2 below shows the conceptual framework for the prototype implementation of the interaction between the involved parties.

Figure 2

Prototype Implementation Conceptual Framework



Source: Researcher, (2025)

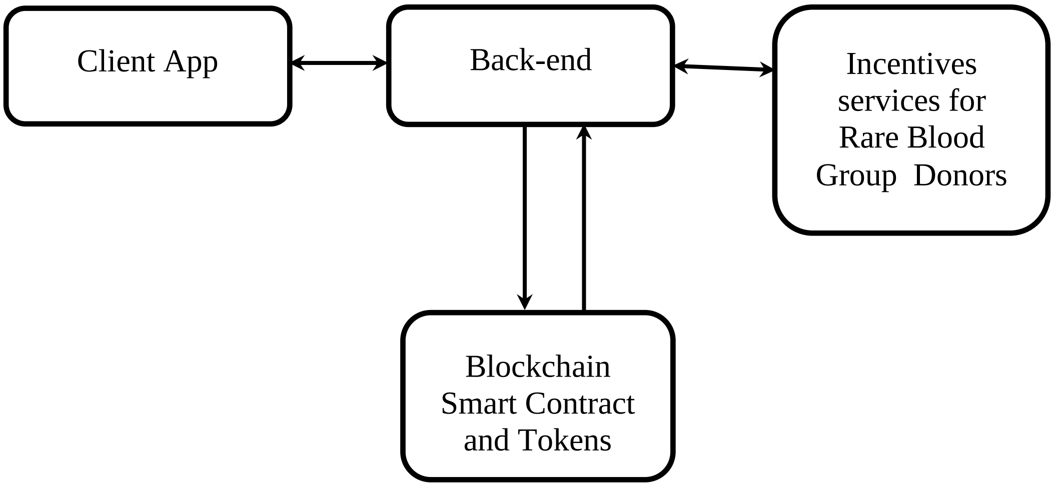
The model has the following modules: A User Registration module for the blood donor and the hospital staff, a User login and authentication module was used in regulating access to authorized users only, personal wallet on the other hand was used to securely stores reward tokens after successful rare blood donations., the smart contract was responsible for generating a token and create immutable transaction blocks of records. Finally, blockchain was used to update all the information. The model was very robust, as it handled rare blood and did not reveal any authentication details, since the donor's records were a private matter.

2.8 Model Design and Operation

Figure 3 below shows the model design and operation.

Figure 3

Model Design and Operation



Source: Researcher, (2025)

i) Client APP: A client application makes a call to the back-end API that is responsible for authorization and authentication. The request is then passed to the blockchain smart contract, and a unique request ID is generated. After the donor's successful donation, the backend receives the donation notification and forwards it to the smart contract for execution. If the donation is successful, the user receives the tokens, and the hospital is responsible for updating the blood donation record, for example, by one unit of blood. The admin/ hospital then updates the model.

ii) Back-end: This module manages the communication between the application and the blockchain, including interactions with smart contracts that track blood donations and incentives. It handles donor and hospital account creation, transfers tokens as rewards for donations, and facilitates exchanges or update between participants. Essentially, it ensures that all donor information, donation history, and reward transactions are securely stored, verified, and processed in real time.

iii) Incentive services for rare blood group donors: This provided incentives for rare blood group donors by notifying the backend whenever a donation was made.

iv) *Blockchain smart contract and tokens*: upon receiving a verified blood donation update from a donor, a smart contract is executed to generate a token that facilitates the provision of incentives to rare blood group donors.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter discusses the methodology and research design followed in developing a blockchain-based model for the provision of incentives to rare blood group donors. The model was first designed and then implemented to provide a working prototype.

3.2 Research Design

A research design was the overall plan or blueprint that guided a study, outlining how data were collected, measured, and analyzed to answer research questions. It ensured that the research was systematic, valid, and reliable by providing structure and direction throughout the process (Creswell et al., 2018).

This study adopted a mixed-methods research design, combining quantitative and qualitative approaches to provide a well-rounded evaluation of the blockchain-based model for the provision of incentives to rare blood group donors. On the quantitative side, the study relied on measurable indicators, such as donor participation rates and data integrity, captured through blockchain transaction logs. These numerical measures enabled accurate, transparent tracking of the system's performance.

At the same time, the qualitative dimension of the study focused on understanding the human side of the model. By examining patterns, behaviours, and contextual insights around donor engagement and trust, the research highlighted the motivations and perceptions that numbers alone could not capture. Integrating both approaches ensured that the findings not only demonstrated how effectively the model worked in practice but also explained why it worked and where improvements were needed. In this way, the mixed-methods design provided a balanced, holistic picture of the model's effectiveness and reliability. The methods used to answer each research question are explained in Sections 3.2.1-3.2.4 below.

3.2.1 Exploring the Weaknesses of Existing Models used in Blood Donation and Management

A systematic literature review was used to analyze the effectiveness of existing models. This study was conducted through a structured, methodical investigation using pre-existing data, known as secondary or desk research. This approach involved gathering, organizing, and analyzing information from various sources such as peer-reviewed journals, academic textbooks, the internet, government reports, and library archives. By conducting a comprehensive literature review, the study critically assessed the effectiveness and limitations of the current blood donation and management system, as shown in Section 4.1.

3.2.2 Design a Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

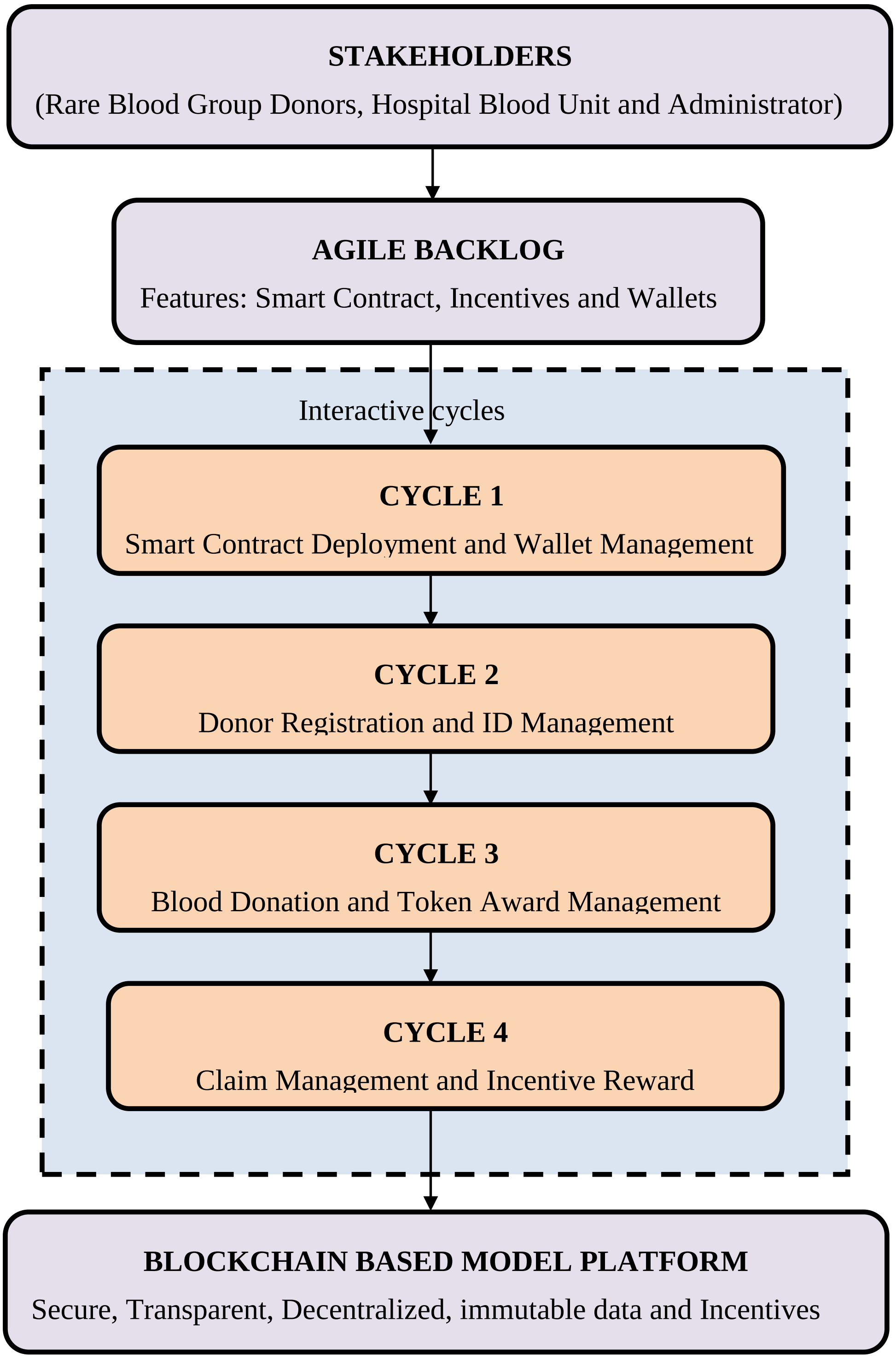
The development of a blockchain-based model for incentivizing rare blood group donors is best managed using the agile methodology, which promotes flexibility, collaboration, and iterative improvement. Agile allows developers, healthcare stakeholders, and donor representatives to co-create solutions in short, incremental cycles, ensuring that the evolving system remains transparent, secure, and responsive to user needs. The Agile methodology is particularly suitable for this study because it offers the flexibility to adapt to the complex and evolving requirements of healthcare systems. This study must account for ethical concerns, regulatory compliance, donor privacy, and the secure management of transactions. Agile provides an iterative approach where features such as donor registration, identity verification, incentive distribution, and smart contract execution can be developed, tested, and refined in small increments. This reduces risks, ensures transparency, and allows for early identification of errors or vulnerabilities that could compromise the system.

Equally important, Agile emphasizes collaboration among developers, healthcare professionals, donors, and regulators, ensuring that the final product is user-centered and aligned with medical standards. Through continuous feedback and regular stakeholder involvement, the system evolves to meet donor expectations while maintaining trust and reliability. By delivering value early through incremental deployments, the blockchain model can begin to provide transparency and accountability in the incentive process, even before full-scale implementation. Thus, Agile not only enhances system quality and security but also ensures sustainable value delivery in a sensitive healthcare environment.

Figure 4 below illustrates how agile methodology was applied in the development of a blockchain-based model to provide incentives to rare blood group donors. It demonstrates the interaction between stakeholders, iterative cycles, and the final platform.

Figure 4

Agile Methodology Diagram



Source: Researcher, (2025)

3.2.3 Implementation of a Blockchain-Based Model for Provision of Incentives to Rare Blood Group

To implement a blockchain-based model for incentivizing rare blood group donors, this study used the Ethereum blockchain API. Ethereum is an open-source platform that allows developers to build decentralized applications. On Ethereum, each transaction consumes a resource called "gas," which represents the computational effort required to process it (Kurt et al., 2020). The more complex the transaction, the more gas it consumes.

Tracking gas usage is important because every transaction needs to be verified by all nodes on the network. If transactions were allowed to be too complex, this verification process would slow down the entire system and cause delays (Farahani et al., 2021). By specifying the amount of gas required, miners can decide whether it’s worth including a transaction in the block they are mining. The decision is influenced by the gas cost set by the transaction sender.

a) Environment Set Up

When setting up the environment of the study, the following tools needed to be installed:

i) Solidity Version 0.8.20: Solidity is a programming language used to build smart contracts on blockchain networks like Ethereum. In this study, Solidity helps create automated rules that handle donor registration, verify blood donations, and issue rewards such as digital tokens when a blood donation is confirmed. The smart contract, written in Solidity, sends the reward directly to the donor’s digital wallet without any manual work. This makes the process fast, fair, and secure. It also keeps a record of donations and can offer additional rewards to donors with rare blood types or those who donate frequently. Because everything is recorded on the blockchain, the system is transparent and trustworthy.

ii) Hardhat: This is a development tool used to build and test smart contracts that automate the reward process. These smart contracts ensure that when a verified donor donates blood, they receive incentives, such as tokens, without the need for a middleman. Hardhat helps developers create and simulate this system in a safe environment before launch, ensuring it works smoothly and securely. This approach supports a transparent and reliable way to motivate rare blood group donors.

iii) Node.js Version 22.18: This is used as the backend environment that runs the server-side part of the system. It helps manage donor information, process requests such as registration or donation confirmation, and connect the application to blockchain networks such as Ethereum. Using tools such as Web3.js or Ethers.js**,** Node.js enables the system to interact with smart contracts, for example, to send a token reward after a donation is confirmed. The updated version (22.18) includes better performance and stronger security, making the system more reliable. Overall, Node.js plays an important role in ensuring smooth communication between the user interface and the blockchain, helping donors to receive their rewards efficiently and safely.

iv*) Ethers.js Version 6:* This is an important JavaScript tool that helps the application connect and work with the blockchain. It enables the system to interact with smart contracts, which are programs that govern how rewards are distributed. For example, when a donor's blood donation is confirmed, Ethers.js can trigger a smart contract to automatically send tokens or rewards to the donor's digital wallet. This version of Ethers.js is faster, easier to use, and more secure. Furthermore, it helps with tasks such as connecting to the blockchain, reading information from it, and handling secure digital signatures. Generally, Ethers.js makes it easier to use blockchain technology in the system, thereby ensuring donors receive their rewards quickly and safely.

v) MetaMask: This is a digital wallet that helps donors interact safely with the blockchain. It allows donors to store and manage their rewards, such as tokens earned from donating blood. MetaMask connects the donor's web browser or application to the blockchain, making it easy for them to approve transactions, such as receiving their incentives. It also keeps their private information secure by allowing them to sign transactions safely. Moreover, MetaMask makes it simple and secure for donors to receive, retain, and use their blockchain rewards within the incentive system.

vi) React.js: React.js is used to build the user interface of a blockchain-based model that rewards rare blood group donors. It creates a fast, easy-to-use web application where donors and hospitals can register, verify donations, and claim rewards. React.js connects the app with digital wallets like MetaMask, allowing users to securely interact with the blockchain. It also updates information instantly, so donors can see their rewards right away. Furthermore, it shows both on-chain and off-chain data. React.js helps make the donation and reward process simple, clear, and reliable for users.

vii) Visual Studio Code (VS Code): This is a helpful tool that developers use to create the blockchain system that rewards rare blood donors. It is a code editor where programmers write and fix smart contracts and the front-end parts of applications. Visual Studio Code makes coding easier with features such as showing helpful hints, checking for mistakes, and running commands without leaving the editor. It also lets developers test and deploy smart contracts to the blockchain and collaborate by tracking code changes.

viii) NPM (Node Package Manager): This helps developers build the blockchain application that rewards rare blood group donors by managing all the software tools and libraries they need. It makes it easy to add, update, and use ready-made code pieces such as blockchain tools, user interface parts, and testing helpers. This saves time because developers do not have to write everything from scratch. In the donation reward system, NPM helps ensure the app runs smoothly by connecting the blockchain, wallets, and the user interface.

ix) GitHub: This is a web-based platform used primarily for storing, managing, and collaborating on code. It uses Git, a version control system, to track code changes over time, allowing developers to save multiple versions of their work and revisit previous updates if needed. This is especially useful when working on large projects or with teams, as it prevents the loss of important changes and supports an organized development process. GitHub enables multiple people to collaborate on the same project simultaneously by letting them contribute code, suggest improvements, and fix issues through features such as pull requests. It hosts code files in online repositories, which can be public or private, making them accessible from anywhere. In addition to code management, GitHub supports automated testing and deployment, integrates with development tools, and allows teams to document their projects using README files or wikis. It also offers project management features like issue tracking and task boards, helping teams stay organized and productive.

x) Bootstrap /Cascading Stylesheet (CSS) Frameworks: This helps to make the blockchain-based model for the provision of incentives to rare blood donors look good and work well on all devices, such as phones and computers. They provide ready-made designs for buttons, forms, and layouts, making it easy for donors to register, check their donations, and claim rewards. This makes the application simple to use and faster to build. However, the responsive design ensures the application fits different screen sizes so that donors can access it anytime, anywhere. The model was categorized into modules and organized according to the following achievable functions as stated below:

i) Smart Contract: This is a computer program written in Solidity that works on the Ethereum blockchain. It automatically issues digital rewards (called tokens) to donors with rare blood types and ensures the reward rules are followed correctly. Solidity is a general-purpose programming language used to write Ethereum smart contracts. It defines contracts and methods for sending and receiving digital tokens and for managing data on the blockchain.

ii) Ethereum Wallets**:** To effectively achieve the research objective, three different Ethereum wallets were created: for the rare blood donor, for the hospital blood donor unit record officer, and for the smart contract. These wallets track digital rewards and ensure all transactions are safe and clear.

iii) Decentralized Application (DApp): This is a simple application that connects users to the blockchain through the smart contract. DApp was developed to allow front-end users to interact with the blockchain through the smart contract (Front End → Smart Contract → Blockchain). The Hardhat development framework for Ethereum was used to build and manage the application.

b) Smart Contract Development

Smart contract development is essential for creating a blockchain system that automatically rewards rare blood group donors. These contracts are self-executing programs that verify donations and issue digital rewards, such as tokens, without manual intervention. When a hospital confirms a blood donation, the smart contract checks the donor's details and sends the reward directly to their wallet. This process is fast, secure, and trustworthy. However, developing smart contracts involves writing, testing, and deploying code to ensure the system is fair and reliable, encouraging rare blood donors to participate. The steps for creating a smart contract are as follows:

Define Requirements: Clearly outline what the smart contract should do, for example, register donors, verify blood donations, and distribute rewards based on blood type and donation confirmation.

Choose the Blockchain Platform: Select a blockchain platform that supports smart contracts, like Ethereum, Binance Smart Chain, or Polygon.

Write the Smart Contract Code: Use a programming language such as Solidity (for Ethereum) to write the smart contract. Code the rules for donor registration, donation verification, and automatic reward issuance.

Test the Smart Contract: Thoroughly test the contract in a safe development environment, such as Remix, to catch errors and ensure all functions work correctly.

Deploy the Smart Contract: Deploy the tested contract to the chosen blockchain network so it can interact with real users and data.

Integrate with Front-End Application: Connect the smart contract to a user-friendly, decentralized front-end application built with tools such as React.js and MetaMask. So donors and hospitals can interact with the system.

3.2.4 Evaluation of a Blockchain-Based Model Prototype for Provision of Incentives to Rare Blood Group Donors

The blockchain-based model for the provision of incentives to rare blood group donors was evaluated using a goal-based evaluation, whose main objective is to determine whether the prototype meets the set technical objectives. In this study, the evaluation involved demonstrating the model to the hospital blood donor unit records officer and the IT administrator. The feedback was gathered to assess the model's suitability.

In this study, a Proof of Concept (PoC) was developed to demonstrate how a blockchain-based model could incentivize rare blood group donors. The PoC served as a small-scale version of the system, designed to test key components such as donor registration, data security, transaction verification, and the automatic issuance of rewards via smart contracts. By simulating real situations with hospital blood donor unit staff and rare blood group donors, the PoC demonstrated that the model could improve donor participation, protect personal data, and ensure incentives were given fairly and transparently.

Selection Criteria for Model Testing

In this study, the purposive sampling technique was used. Purposive sampling, also known as judgment, selective, or subjective sampling, is a sampling technique in which the researcher relies on his or her own judgment to choose members of the population to participate in the study. However, the selection criteria for testing the model involve choosing rare blood group donors and hospital blood donor unit staff, and ensuring that all key features, such as registration, donation checks, wallet connection, and rewards, are tested. These steps help to ensure the model is working well, secure, and easy to use before it is fully launched.

3.3 Location of the Study

This study was carried out in the hospital blood donor unit which is located at Nakuru County Referral and Teaching Hospital (NCRTH). Nakuru city is a densely populated region. However, according to the 2019 census, Nakuru's population is 570,674 and is also the fourth-largest urban Centre in Kenya. The researcher chose this location because the rate of services provided in NCRTH is very high, and rare blood group donors were encouraged to donate, thereby saving many lives.

3.4 Population of the Study

The target population for this study comprised 130 rare blood group donors who had donated blood at the hospital blood donor unit during the period from January to June 2025. For the purpose of this study, rare blood groups were defined as O−, A−, B−, and AB−, in accordance with their low prevalence in the general population and among donors. According to records obtained from the hospital blood donor unit, a total of 3,328 blood donors were registered between January and June 2025, as shown in Table 2 below.

Table 2

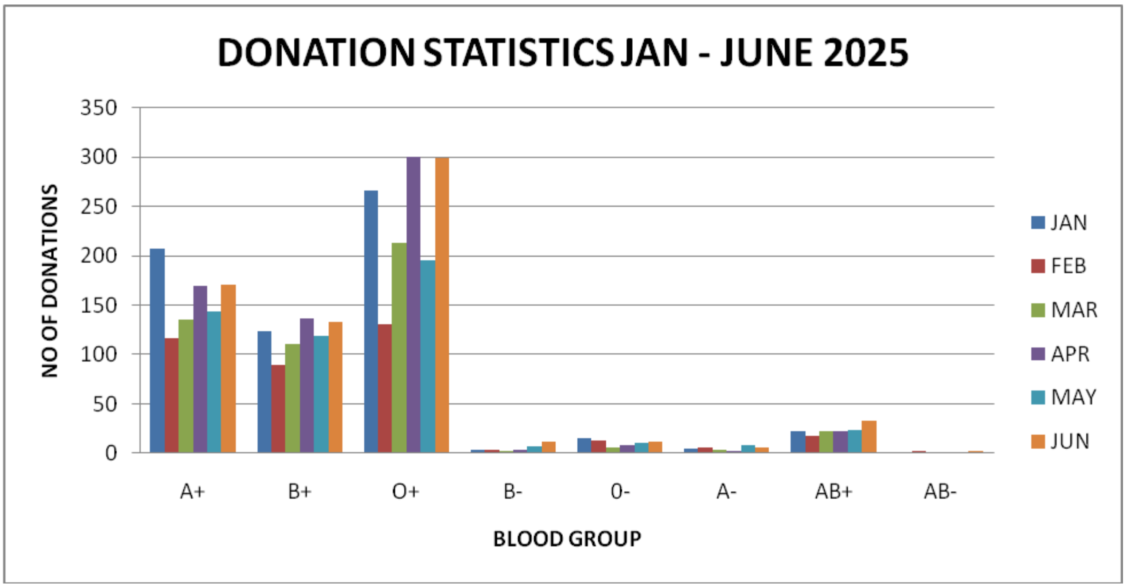
Group Statistic for Jan - June 2025

Blood Groups	January	February	March	April	May	June	Total
O+	266	131	213	300	195	299	1404
A+	207	117	135	170	144	171	944
B+	123	89	110	137	119	133	711
AB+	22	17	22	22	23	33	139
O-	15	13	6	8	10	12	64
B-	3	3	2	4	7	12	31
A-	5	6	4	2	8	6	31
AB-	0	2	0	0	0	2	4

Source: Hospital Blood Donor Unit NCRTH, (2025)

Figure 5

Blood Group Statistic for Jan - June 2025 Graph



Source: Hospital Blood Donor Unit NCRTH ,(2025)

Of this total, 130 donors (3.9%) were identified as belonging to rare blood groups. The distribution of these donors is summarized in Table 3 below.

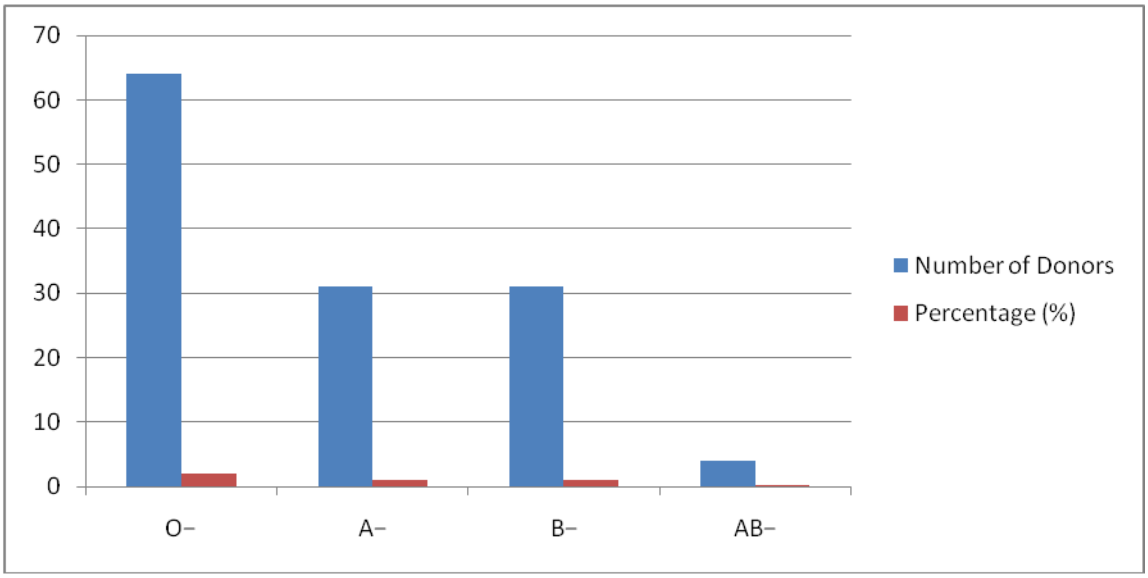
Table 3

Rare Blood Group Donors Distribution

Blood Group	Number of Donors	Percentage (%)
O−	64	1.92
A−	31	0.93
B−	31	0.93
AB−	4	0.12
Total Rare Donors	130	3.9
Total Donor Population	3,328	100

Figure 6

Rare Blood Group Donors Distribution Graph



These 130 rare blood group donors form the study population and served as the sampling frame from which the study sample is drawn.

3.5 Sample Size and Sampling Procedure

3.5.1 Sample Size of the Study

The sample size for the study was determined using Cochran's (1977) formula for sample size estimation for proportions:

$$\mathbf{n_0 = \frac{Z^2 \times p(1-p)}{e^2}}$$

This formula was used to determine the sample size because it provided a reliable way to determine how many people needed to be included in the study to obtain accurate, representative results (Cochran, 1977).

Where:

n_0 = desired sample size

Z = standard normal deviate corresponding to the desired confidence level (1.96 for 95% confidence)

p= estimated proportion of the population with the characteristic of interest (0.039)

e = margin of error (0.05)

Substituting the values:

$$n_0 = \frac{(1.96)^2 \times 0.039 \times (1 - 0.039)}{(0.05)^2}$$

$$n_0 = \frac{3.8416 \times 0.0375}{0.0025}$$

$$n_0 = 57.6$$

Thus, the initial calculated sample size (n_0) was approximately 58 respondents.

3.5.2 Finite Population Correction

Since the target population (N = 130) is relatively small, the sample size was adjusted using the finite population correction (FPC) formula:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

$$n = \frac{58}{1 + \frac{57}{130}} = \frac{58}{1.438} = 40.3$$

The adjusted sample size was therefore approximately 40 respondents.

3.5.3 Proportionate Allocation

The sample size of 40 was distributed across the four rare blood groups according to their proportions within the total rare donor population, as shown in Table 7 below.

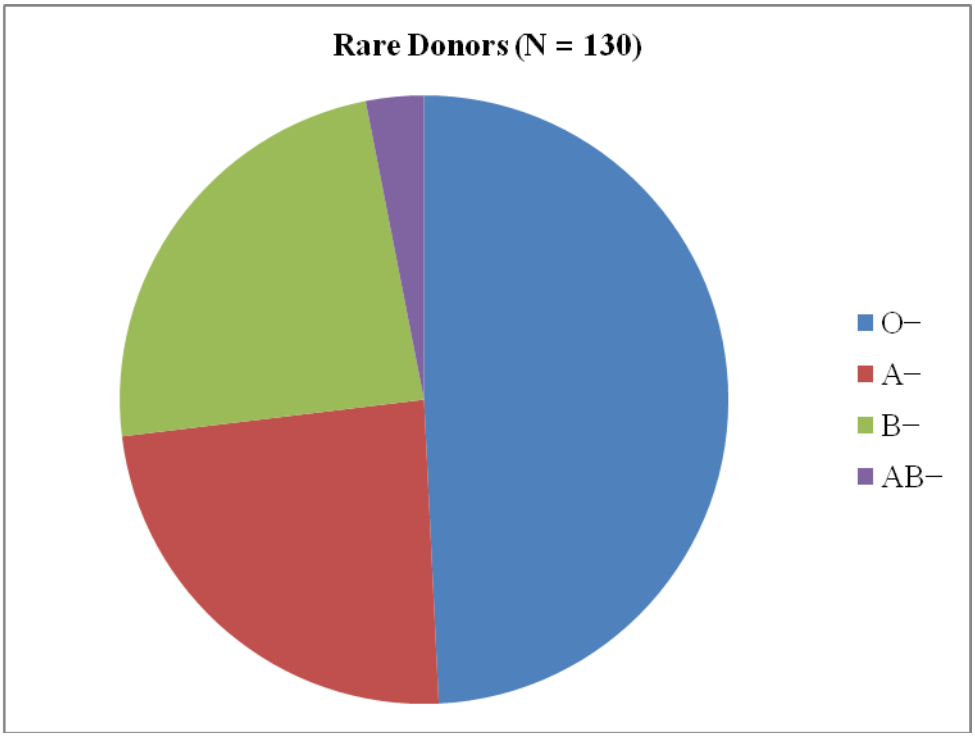
Table 4

Proportional Allocation to Rare Blood Group Donors

Blood Group	Rare Donors (N = 130)	% of Rare Donors	Sample Size (n = 40)
O−	64	49.2%	20
A−	31	23.8%	10
B−	31	23.8%	10
AB−	4	3.1%	1
Total	130	100%	41 (≈40)

Figure 7

Proportional Allocation to Rare Blood Group Donors Chart



Thus, the final sample consisted of approximately 40 rare blood donors, proportionately representing each rare blood group.

3.5.4 Inclusion and Exclusion Criteria

Inclusion Criteria

i) Registered blood donors at the hospital blood donor unit between January and June 2025

ii) Donors identified as having blood groups O−, A−, B−, and AB−.

iii) Donors who consent to participate in the study.

Exclusion Criteria

i) Donors with incomplete records or missing data on blood group or contact information.

ii) Donors who fall outside the six-month study period.

iii) Donors who decline or withdraw consent.

3.6 Sampling Technique

The study adopted a mixed-methods approach combining both quantitative and qualitative techniques. A stratified proportionate sampling method was used for the quantitative part to ensure fair representation of each rare blood group (O−, A−, B−, and AB−) from the total population of 130 rare donors. A total of 40 donors were selected proportionately across the four groups.

For the qualitative part, a purposive (judgmental) sampling technique was applied to identify participants with relevant knowledge and experience. This included selected rare donors, hospital blood donor unit staff, and key stakeholders involved in donor management. These participants provided in-depth insights into donor motivation and challenges, and offered feedback on the incentive app through focus group discussions and interviews.

The combination of stratified and purposive sampling ensured both statistical accuracy and a rich contextual understanding, making the method well-suited to achieving the study objectives.

3.7 Data Collection Instrument

The study employed observation and document review as the main data collection instruments. Observation was used to capture real-time donor behaviors, participation patterns, and engagement with the blockchain-based model for the provision of incentives to rare blood group donors. This method also enabled the researcher to assess and validate the prototype's functionality and reliability in a practical setting. The specific areas of focus during observation were guided by the Observation Checklist (see Appendix XI).

The document review method complemented observation by providing secondary data from hospital blood donor unit records, reports, and donor registers. These documents offered essential background information on donor trends, blood group distribution, and operational practices. The review process was structured using the Document Review Guide (see Appendix XII).

To further enhance data interpretation, a Content Analysis Theme Guide (see Appendix XIII) was used to organize emerging themes and patterns from the collected data. Using these three instruments together ensured a comprehensive, cost-effective, and reliable approach to data collection by combining firsthand field observations with verified institutional data and systematic thematic analysis.

3.8 Pilot Study

A pilot study was conducted to pre-test the blockchain-based model for the provision of incentives to rare blood group donors before the main research. The primary aim was to determine the practicality of the research design, evaluate the effectiveness of the data collection instruments, and identify any potential operational or ethical challenges. During the pilot, the researcher observed a small group of rare donors and hospital staff interacting with the model prototype. This allowed assessment of the system's usability, data accuracy, and donor response to the incentive mechanism. It also provided insight into the clarity and reliability of the observation and document review procedures.

Feedback from participants and observations made during the pilot were used to refine the checklists, discussion guides, and data collection procedures, ensuring they were clear, comprehensive, and effective. Consequently, the pilot study enhanced the validity, reliability, and smooth execution of the main study.

3.9 Data Collection Procedure

Data collection began when donors registered in the blockchain-based application, providing their blood type and digital wallet address. Personal details were securely stored off-chain, while only essential verification data was recorded on the blockchain to maintain privacy. Upon each verified donation, the hospital blood donor unit confirmed the transaction, and a smart contract automatically issued a digital reward to the donor's wallet. The researcher supplemented this automated process with observation and document review to verify system accuracy and reliability, while focus group feedback provided qualitative insights on donor experience and system usability. This integrated procedure ensured that data collection was secure, transparent, and ethically sound, aligning both technological and research standards.

3.9.1 Potential Risk of the Study

A key potential risk in implementing the blockchain-based model for incentivizing rare blood group donors was the potential exposure of personal or medical information. Although blockchain technology provides high levels of security and transparency, inadequate safeguards could still lead to privacy breaches or data misuse. Such risks raised ethical and legal concerns, as participants who felt their confidentiality was not fully protected might have been reluctant to engage with the system. This could have affected both donor participation and the model's overall effectiveness. To mitigate these risks, strict data protection protocols and controlled access measures were applied throughout the study.

3.9.2 Protection Procedure of the Study

The protection procedure for the blockchain-based model for the provision of incentives to rare blood group donors was designed to ensure the security and confidentiality of donor data. Sensitive personal and medical information was stored in encrypted off-chain databases, while only essential verification details were recorded on the blockchain to maintain transparency without exposing private data. Access to donor information was restricted to authorized personnel, including hospital blood donor unit staff and system administrators, under strict data access controls. The smart contracts governing donor rewards were thoroughly tested to prevent errors, misuse, or cyberattacks, ensuring that incentives were issued accurately and automatically.

Additionally, donor identities were represented by digital wallet addresses rather than personal details, further enhancing anonymity and privacy. These combined measures safeguarded participant data and upheld ethical standards throughout the study.

3.9.3 Data Safeguarding of the Study

In the blockchain-based model for incentivizing rare blood group donors, data privacy and confidentiality were prioritized throughout the research process. Sensitive personal information, such as medical records and donation history, was handled with strict security measures and shared only with authorized personnel directly involved in the study or medical management. No data was disclosed to third parties unless required by law or presented in anonymized form for research purposes. Due to the immutable nature of blockchain, recorded data cannot be deleted. Therefore, all sensitive information was stored off-chain, and any off-chain data, such as observation notes or focus group responses, was securely destroyed once no longer needed. In compliance with ethical and legal standards, research data was retained for a maximum of five years after study completion to allow for verification, audits, or further approved analysis, after which it was permanently deleted. These safeguards ensured the integrity, confidentiality, and responsible handling of all participant data.

3.10 Ethical Considerations

This study was conducted in line with the ethical requirements of the Institute of Postgraduate Studies and Research (IPGS) at Kabarak University, following its guidelines on confidentiality, informed consent, and responsible data handling. The research was supported by an official introductory letter from the institution, and a permit was obtained from the National Commission for Science, Technology, and Innovation (NACOSTI), granting formal authorization to carry out the study. The rights, safety, and dignity of participants were upheld at all stages, with participation being voluntary and informed consent obtained prior to data collection.

To safeguard confidentiality, all personal and medical information was securely stored in encrypted databases, with identifying details removed during analysis to ensure data anonymization. Only essential, non-sensitive proofs were recorded on the blockchain, and access to sensitive data was strictly restricted to authorized personnel. No personal information was disclosed to third parties; any data shared for academic or regulatory purposes was presented in anonymized and aggregated form. These measures ensured compliance with institutional, national, and international ethical standards while protecting participants' privacy and trust.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION, AND DISCUSSION

4.1 Introduction

This chapter discusses the study's results in accordance with the research objectives presented in Section 1.3. A report on the existing model used in blood donation and management, a prototype of a blockchain-based model for the provision of incentives to rare blood group donors, and a report on the model's prototype functionality are presented.

4.2 Existing Models Used in Blood Donation and Management

This section presents the results for the first objective of the study, which was to explore the weaknesses of current blood donation and management models. The models reviewed in Section 2.3 included Blood Bank Management System, Blood Donation Management System, Life Blood Technologies, Blood Connect, DigiBlood, Red Cross Blood Donor App, Damu Sasa, Blood Chain: A Blood Donation Network Managed by Blockchain Technologies, Blockchain-Based Management of Blood Donation, Blockchain in Blood Bank Supply Management, Implementation of a Blood Cold Chain System Using Blockchain and Implementation of Blockchain-Based Blood Donation Framework**.**

4.1.1 Weaknesses of Existing Models Used in Blood Donation and Management

There is a necessity for the technology to exist since it is very important. Therefore, to justify the need for a blockchain-based model for the provision of incentives to rare blood group donors, the existing blood donation and management models have exhibited inefficiencies in their use. The table below shows the existing models assessment used in blood donation and management.

Table 5

Existing Models Assessment

Model	Objective	Benefits	Challenges
Blood bank Management System (Khan et al., 2024).	It is used for managing blood donation, storage, testing, and distribution within blood donor units and hospitals.	Focuses on improving efficiency as well as enhancing donor and patient safety.	There are issues with data privacy and security, and openness, transparency, and database decentralization are not addressed.
Blood Donation Management System Gollapelly et al., 2023)	Facilitates management and tracking of blood donations, donor histories, as well as distributions of blood in hospitals or clinics.	Improved efficiency, accurate blood inventory control as well as enhanced donor engagement.	Data privacy, transparency, and DB decentralization are not addressed.
Life Blood (Futura Technologies, 2020)	Distribution of blood to hospitals and patients in need as well as ensuring an adequate supply of blood.	Focuses on saving lives and improving health outcomes.	Issues of donor recruitment, hesitation of blood donation, and imbalance of supply and demand.
Blood Connect (Verma et al., 2025)	A platform used to connect blood donors with hospitals and patients who require blood via mobile applications.	Helps in improving availability of blood and real-time tracking and monitoring.	Issues of data privacy and security as well as DB decentralization are not addressed.
DigiBlood (Kühnert et al., 2024)	Mobile platform used to connect blood donors with recipients who need blood in real-time by use of geolocation and notification features.	Focuses on increasing donation efficiency and real-time monitoring of blood.	Data privacy, transparency, and DB decentralization are not addressed.
Red Cross Blood Donor App (American Red Cross, 2020).	Streamline donor experience as well as providing efficient blood management.	Increase donor engagement and provide real-time tracking of blood donation history.	Data privacy, transparency, and DB decentralization are not addressed.
Damu Sasa (Mbuthia *et al*., 2020).	The system facilitates real-time tracking of blood donation and managing blood supply.	Helps to enhance the availability of blood as well as blood inventory management.	Data privacy, transparency, and DB decentralization are not addressed.
	To create a transparent, secure, and	-Enhanced trust through transparency - Tamper-proof	

	decentralized network for managing blood donations and tracking donors and recipients.	donor/recipient data -Immutable donor history - Real-time availability of blood	- Did not provide incentives to rare blood group donors.
Blood Chain: A Blood Donation Network Managed by Blockchain Technologies (Trieu Le, *et al., 2022).*	To streamline the donation process, ensure data integrity, and improve coordination between donors, hospitals, and blood banks.	-Full traceability of blood units - Reduced wastage	-Integration with legacy systems - User adoption and training - Regulatory compliance - Did not provide incentives to rare blood group donors.
Blockchain-Based Management of Blood Donation (Hawashin, *et al.*, 2021).	To improve the traceability and efficiency of blood bank inventory and its distribution using blockchain technology.	- Improved logistics and inventory control -Real-time monitoring of temperature - Tamper-proof logs	-Data privacy issues - Scalability with a high user base - High initial setup cost - Did not provide incentives to rare blood group donors.
Blockchain in Blood Bank Supply Management (Sanyukta, *et al.*, 2021).	-To maintain and verify the required temperature and conditions for blood storage and transport through a blockchain-monitored cold chain system.	- Quality assurance of blood products -Decentralized control - Enhanced security - Faster validation processes	-Technical complexity, limited blockchain expertise and ensuring network reliability -Did not provide incentives to rare blood group donors.
Implementation of a Blood Cold Chain System Using Blockchain Technology (Kim *et al*., 2020).	-To develop a decentralized, secure, and transparent framework for managing the entire blood donation lifecycle from donor registration to transfusion.	- Improved trust among stakeholders	-Sensor accuracy and maintenance - Cost of continuous monitoring - Did not provide incentives to rare blood group donors.
Implementation of Blockchain-Based Blood Donation Framework (Lakshminarayanan *et al*., 2020).			- Legal and ethical concerns - Network latency issues - Need for continuous maintenance and updates

4.2 Design of a Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

This section explained the design of a blockchain-based model that rewarded donors of rare blood types. It helped achieve the study's research objective two. First, the section described the model’s security and how it functioned, followed by an overview of its operations. Then it explained how users interact with the blockchain, as shown in Figure 6. After that, it shows a diagram of how the system works, including how smart contracts interact with each other. The solution leveraged key features of blockchain technology, such as decentralization, the absence of a middleman, and immutability. It also used permission settings in smart contracts to securely manage interactions. The model was implemented using open-source tools as detailed in section 4.2.3. The development tools used in this study were Solidity Version 0.8.20, Hardhat, Node.js, Ethers.js Version 6, MetaMask, React.js, Visual Studio Code, NPM (Node Package Manager), GitHub, and Bootstrap/Cascading Style Sheets (CSS) frameworks.

4.2.1 Security and Operational Requirements

Security and operational requirements during the design and implementation of a blockchain-based model for incentivizing rare blood group donors were essential to ensure the model remained transparent, trustworthy, secure, and operationally efficient. Below was a detailed explanation of the security and operational requirements of the model:

Blockchain Immutable Ledger*:* The blockchain ensures that once blood donation records are written, they cannot be altered by anyone, and that each donor’s contribution is recorded permanently.

***Digital signatures**:* Each blood donation transaction was cryptographically signed to ensure that only legitimate donors with rare blood groups could submit blood donation records and claim incentives.

Encryption: Rare blood donor's personal information, such as identity, was protected using encryption methods to secure data where the same key is used for both encryption and decryption.

4.2.2 Users Overview and Interactions with the Blockchain

The blockchain-based model for incentivizing rare blood group donors involved several key participants who interacted within a secure, controlled digital environment. Each user played a specific role in ensuring that the system functioned effectively, maintained data integrity, and upheld ethical and privacy standards.

i) ***Rare Blood Donor:*** The rare blood donor registered through the application by providing verified personal information, including full name, email address, phone number, and blood type, which was confirmed by authorized hospital personnel. Once registration was complete, the donor could participate in blood donation drives. After each verified donation, the system automatically issued digital tokens through a smart contract. These tokens could later be redeemed for approved incentives. Donors interacted primarily with the blockchain through a digital wallet interface, ensuring transparency and traceability of rewards while keeping personal details secure.

ii) Hospital Blood Donor Unit Officer: This officer, an authorized member of the hospital's blood donor unit, played a critical role in validating and recording blood donations. They verified each donation, confirmed donor eligibility, and entered transaction details into the system. Their input triggered smart contract execution, ensuring rewards were distributed only upon legitimate confirmation. The officer's access was restricted to medical and operational data relevant to donation verification.

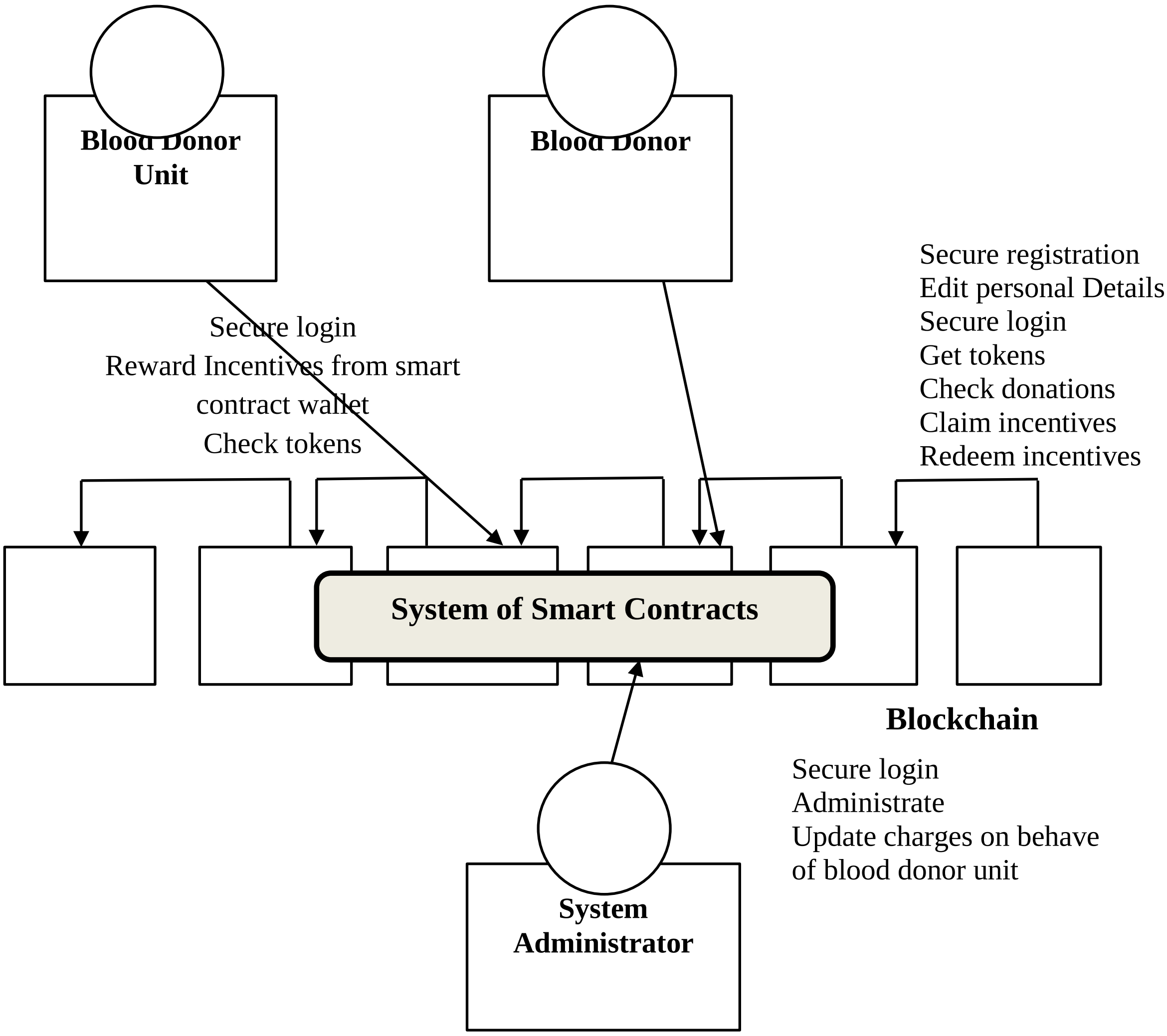
iii) System Administrator (SysAdmin): The system administrator oversaw the operational and technical aspects of the blockchain system. Their responsibilities included monitoring donor incentive claims, approving or rejecting transactions flagged for review, and maintaining system integrity. The administrator also ensured that system updates, data synchronization, and security protocols were effectively implemented. All administrative activities were logged to enhance accountability and minimize potential misuse.

iv) Hosting and Blockchain Service Providers (EVM, GitHub, and MetaMask): These platforms supported the technical infrastructure of the blockchain-based model. The Ethereum Virtual Machine (EVM) enabled the execution of smart contracts; GitHub hosted the project's source code for version control and transparency; and MetaMask served as the wallet interface connecting users to the blockchain. Only encrypted, non-sensitive data was stored on-chain, while sensitive donor information remained securely off-chain to protect privacy.

The overview of different users and their interaction with the blockchain and the model as a system of smart contracts is shown in Figure 8 below:

Figure 8

Overview of different users and their interaction with the Blockchain and the Model as a System Contract



Source: Researcher, (2025).

4.2.3 The Model Starting-Up Activities

Model startup activities included initial steps such as defining goals, selecting technologies, designing the system, and setting up the development environment. They also include forming the team, establishing workflows, and creating prototypes. For blockchain models, this includes deploying smart contracts, configuring networks, and ensuring security. These steps prepared the system to run smoothly and meet its objectives.

Hardhat Framework Installation

To install the Hardhat framework, you first need to ensure that Node.js and npm (Node Package Manager) are installed on your system. Once these are set up, create a new project directory and open a terminal in that directory. Then, initialize a new Node.js project by running npm init -y, which generates a package.json file with default settings. After initialization, install Hardhat by running npm install-- save-dev hardhat. Once the installation is complete, you can set up a new Hardhat project by running npx hardhat, which will prompt you to select a project type or create a basic sample project. Follow the prompts to complete the setup. This will generate the necessary configuration files and folders, such as hardhat.config.js, contracts, scripts, and test, allowing you to begin developing and testing your smart contracts in the Hardhat environment.

Node.js Framework Environment Setup

To install a Node.js framework like Express, first install Node.js and npm from nodejs.org. Then, create a project folder, initialize it with npm init -y, and install the framework using npm install express. After that, create a simple server file (e.g., app.js), write basic Express code, and run the server with node app.js. This setup allows you to build and run web applications using Node.js frameworks quickly.

Ethers.js version 6 Framework Environment Setup

To install Ethers.js version 6, first ensure Node.js and npm are installed. Create a project folder, initialize it with npm init -y, and install Ethers using npm install ethers. Since Ethers v6 uses ES Modules, add "type": "module" to your package. json. You can then import Ethers into a JavaScript file and run your script with Node.js. Ethers v6 offers a cleaner syntax that streamlines blockchain interactions.

React.js Framework Environment Setup

To install React.js and start a new project, first ensure you have Node.js and npm installed on your system. Then, use the official tool Create React App by running npx create-react-app my-app in your terminal, which sets up all necessary dependencies and configurations. After the setup, navigate into your project folder with cd my-app and start the development server by running npm start. This will launch your React app in the browser at http://localhost:3000. Additionally, if you’re interested in React-based frameworks with more features like server-side rendering, you might explore alternatives such as Next.js.

Visual Studio Code Framework Environment Setup

To set up Visual Studio Code for React or other JavaScript frameworks, first install VS Code from its official website and ensure Node.js with npm is installed on your system. Open or create your project folder in VS Code, using the integrated terminal to run commands like npx create-react-app my-app and start the development server with npm start. Enhance your workflow by installing helpful extensions such as React snippets, Prettier for code formatting, and ESLint for error checking. This setup provides a streamlined environment for coding, running, and debugging React applications efficiently within VS Code.

Node Package Manager (npm) Code Framework Environment Setup

Setting up a code framework environment with npm involves installing Node.js, initializing the project with npm init to create a package. Json file and installing necessary packages using npm install. This setup helps manage dependencies and streamline development.

MetaMask Code Framework Environment Setup

MetaMask is a browser extension that lets users make Ethereum transactions directly from regular websites. It acts like a bridge that allows you to use Ethereum Dapps in your browser without needing to run the full Ethereum software. This makes it easier for people to use Ethereum because it connects the Ethereum network with everyday browsers like Chrome or Firefox. However, setting up a MetaMask development environment involves installing Node.js and npm, initializing a project, and installing MetaMask-related libraries with npm. This allows your web app to connect with the MetaMask extension for blockchain interactions.

Bootstrap or Cascading Style Sheets (CSS) Code Framework Environment Setup

Installing the Bootstrap or Cascading Style Sheets (CSS) framework involves adding Bootstrap's CSS and JavaScript files to your project, either by downloading them from the official Bootstrap website or linking them via a Content Delivery Network (CDN). The easiest method is to include the CDN links in the <head> and before the closing <body> tag of your HTML file. Alternatively, you can install Bootstrap using package managers like npm or yarn for more control in a development environment. Once installed, you can start using Bootstrap's predefined classes and components to style and layout your web pages efficiently.

GitHub Framework Environment Setup

Installing a framework from GitHub typically involves cloning the repository to your local machine using Git (e.g., git clone <repository-url>), navigating into the project directory, and following the framework’s setup instructions, often found in the README.md file. These steps may include installing dependencies (using package managers like npm, pip, or composer), configuring environment variables, and running setup or build commands. Some projects may also require specific versions of programming languages or tools. Overall, the process ensures that the framework is properly set up and ready for development or deployment.

4.3 Development of the Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

This section showed how objective three of the study was achieved, requiring the researcher to develop a blockchain-based model for incentivizing rare blood group donors. The complete code for the model is provided in Appendix I.

4.3.1 Solidity Smart Contract

A Solidity smart contract is a self-executing program deployed on a blockchain that defines rules and automatically enforces them without intermediaries. Written in Solidity, these contracts form the backbone of decentralized applications (DApps) by handling logic such as token transfers, transaction recording, and agreement execution once certain conditions are met. The Solidity smart contract source code is shown in Appendix 1, code listing A.

4.3.2 Development of the Donor Registration and Authentication

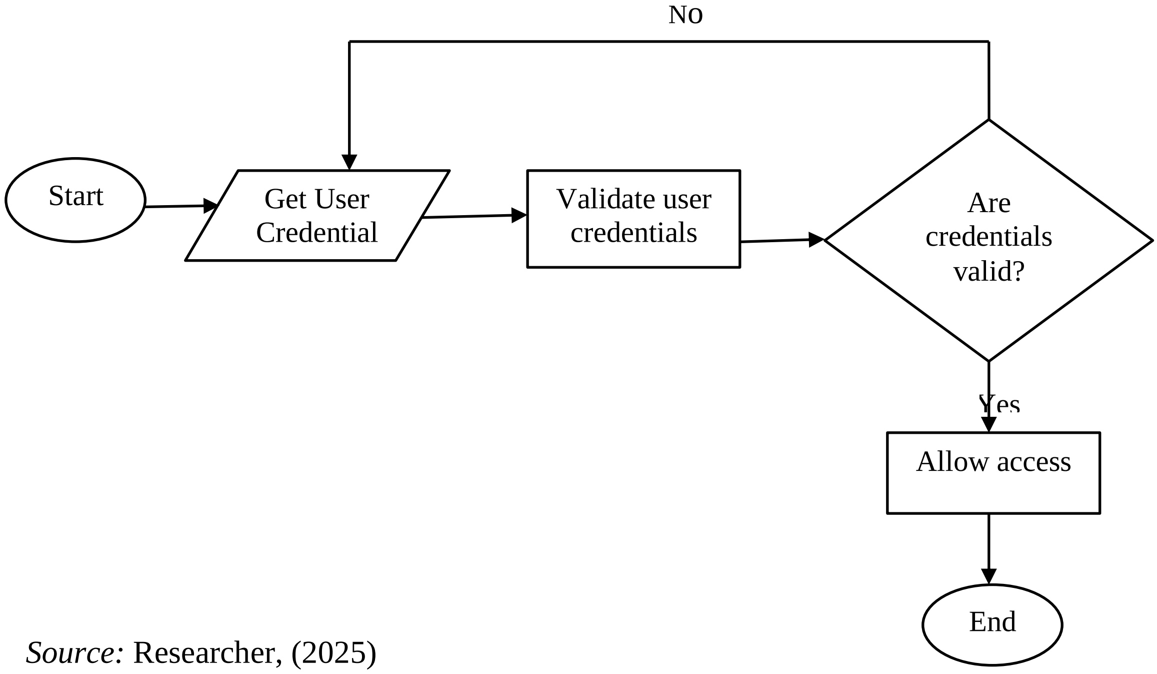
Donor registration is the initial step in which individuals create an account in a model by providing basic details such as their name, email address, username, and password. This information is securely stored by the system for future identification of the user. On the other hand, user authentication is the process of confirming the user’s identity when they attempt to log in. The model checks the entered username and password against the stored data. If the information matches, the user is granted access.

Donor Registration Module

The registration process is the first step to accessing the model and involves two types of users: rare blood donors and hospital blood donor unit officers. During registration, users provided personal information such as their address and created a password, which is later used to verify their identity when logging in. Registered users are granted specific permissions within the model, and rare blood donors must enter their details and set a password with at least eight characters. The steps for the donor registration process are illustrated in Figure 9 below. Registration logic is implemented by the register function**,** as shown in Listing 1 below.

Figure 9

Donor Registration Process Flowchart



Source: Researcher, (2025)

Donor Registration Code

```
/ Registration pop-up states
  const [showRegistrationPopup, setShowRegistrationPopup] = useState(false);
  const [registrationData, setRegistrationData] =
    useState<RegistrationFormData>({
      name: "",
      email: "",
      phoneNumber: "",
```

```
    password: "",
  });
const [registrationErrors, setRegistrationErrors] = useState<
  Partial<RegistrationFormData>
>({});
```

In this research, donor registration details are stored in a smart contract called donortInfoDb. Another smart contract blooddonorunitofficerInfoDb is a database contract used to store information about rare blood donor. Each donor’s personal details and address are saved. For every rare blood donor, a special data structure called a donor-struct is created to hold their information. This structure also includes links to the previous and next donors, which helps to go through the list easily. The transaction that happens between the user and the smart contract during registration is shown in Figure 10 below.

Figure 10

User Registration Form

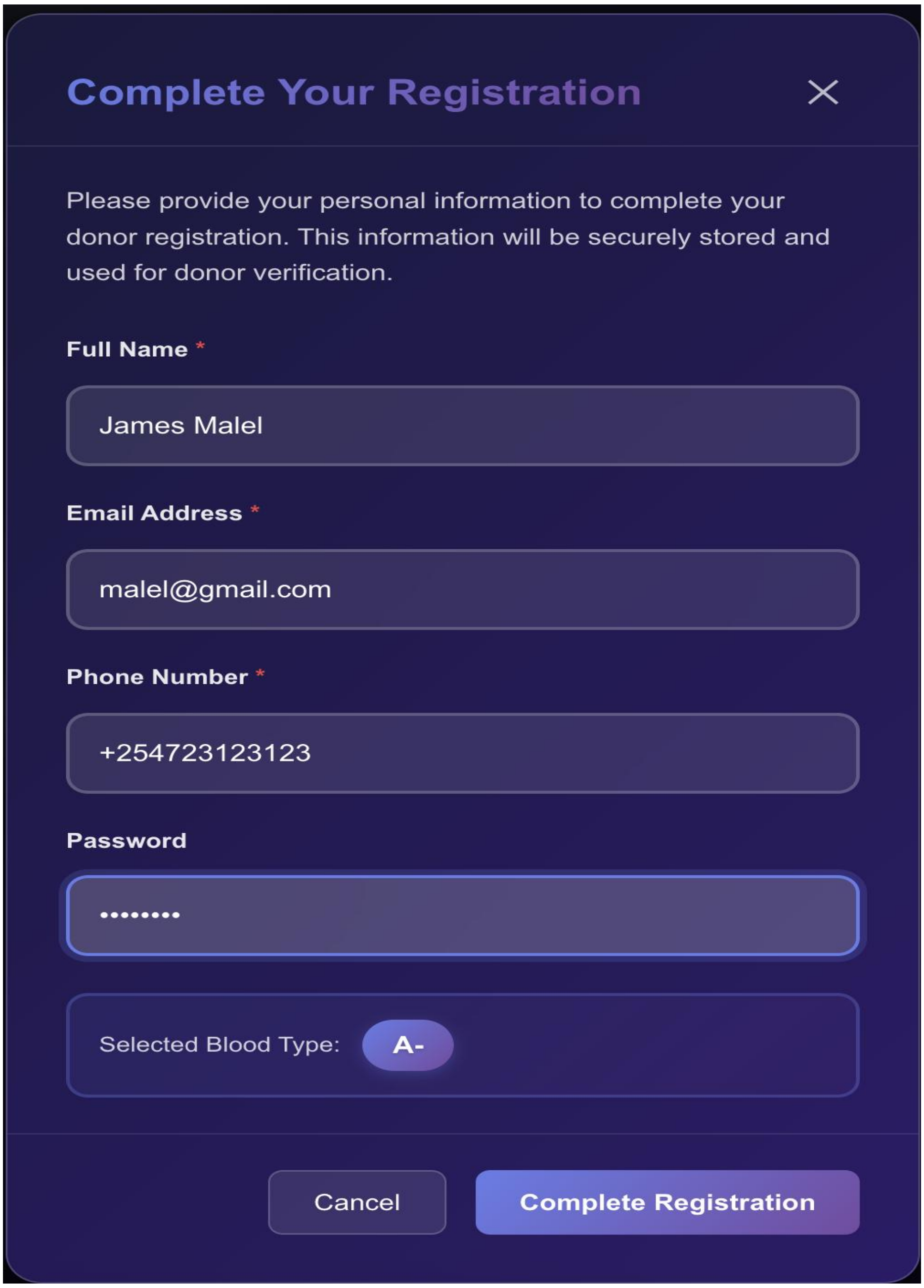
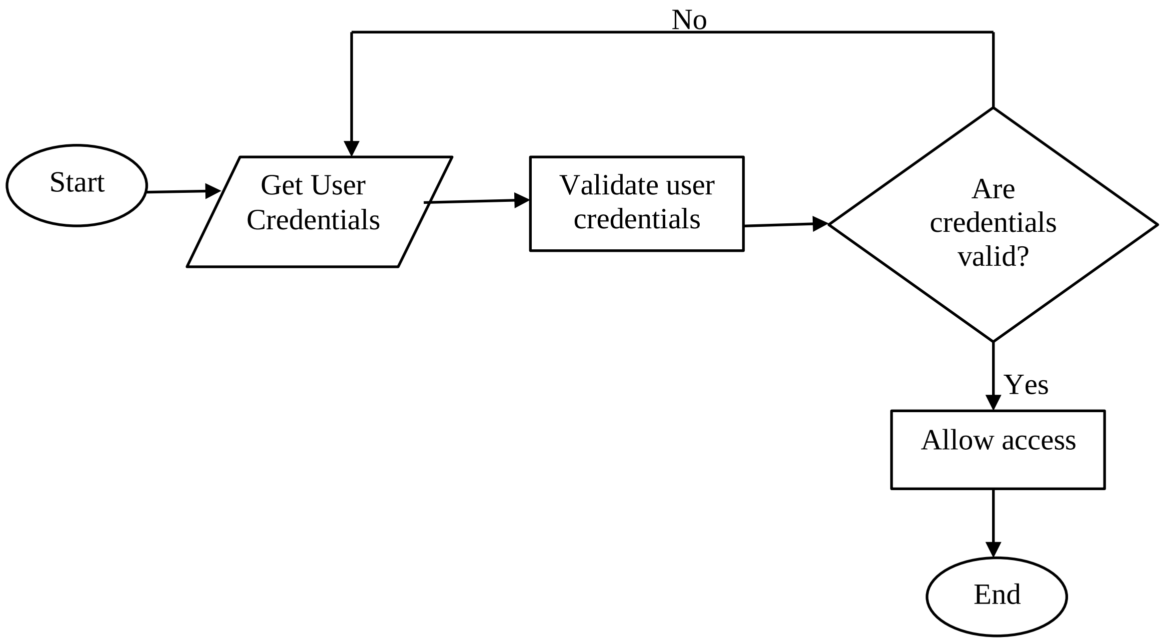


Figure 11

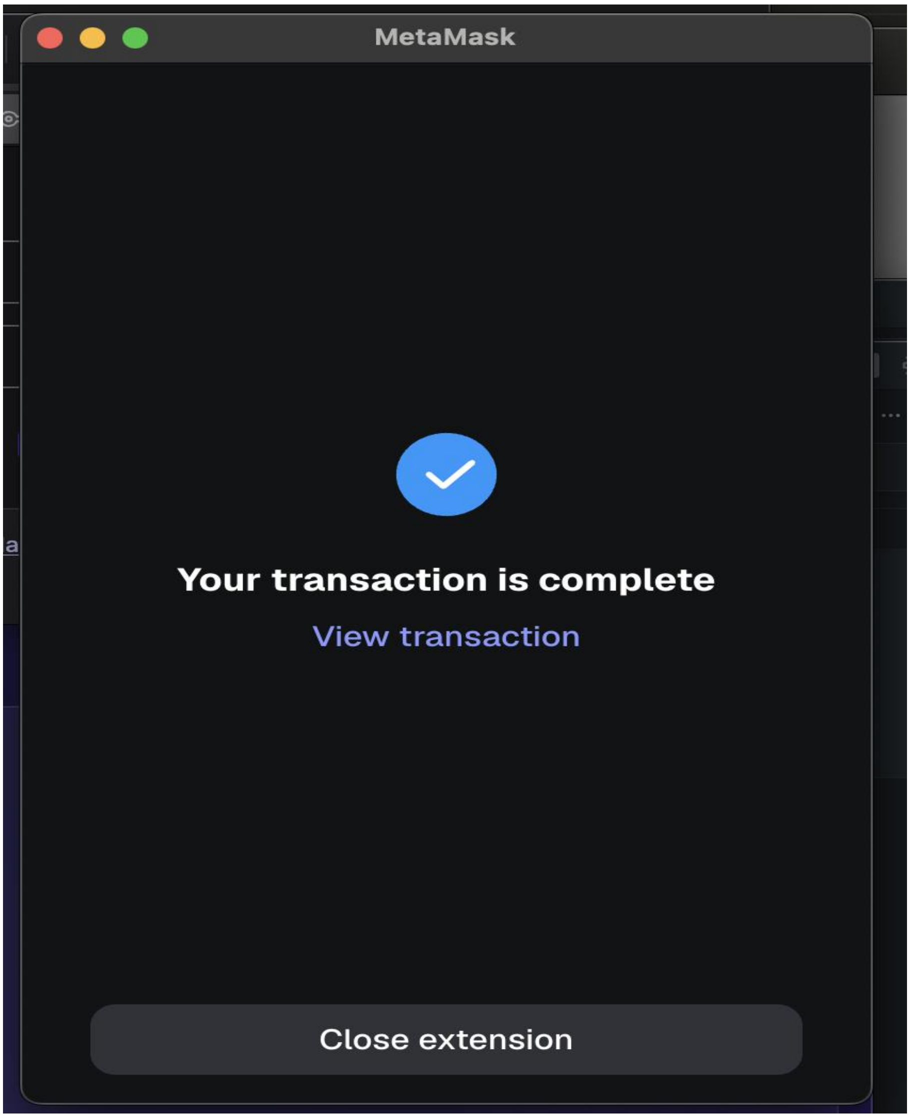
Donor Registration Form Screenshot



The successful transaction creates a blockchain record and activity log as shown in figure 12 below.

Figure 12

Transaction History and Activity Log



Source: Researcher, (2025)

Donor Authentication Module

User authentication was a key process that verified whether a person accessing the system was the rightful owner of the user account. It worked by checking if the provided credentials, such as address and password, matched those stored in the model. To protect the system from unauthorized access, authentication was carried out using cryptographic methods. This ensured that only verified users could interact with the network in a secure and trustworthy manner. However, the authentication logic is developed using Solidity, a smart contract programming language. The figure 12 below shows the donor authentication flowchart.

Authentication Code

```
* @dev Login donor with email and password
  */
 function loginDonor(
     string calldata email,
     string calldata password
 ) external view returns (bytes32 anonymousId, bool success) {
     // Get anonymous ID for this address
     anonymousId = addressToAnonymousId[msg.sender];
 if (anonymousId == bytes32(0)) {
         return (bytes32(0), false); // Not registered
     }
     Donor memory donor = donors[anonymousId];
     if (!donor.isRegistered) {
         return (bytes32(0), false); // Not registered
     }
     // Check email matches
     if (keccak256(bytes(donor.email)) != keccak256(bytes(email))) {
         return (bytes32(0), false); // Email doesn't match
     }
     // Check password hash
     bytes32 passwordHash = keccak256(
```

```
            abi.encodePacked(password, donor.salt)
        );
        if (donor.passwordHash != passwordHash) {
            return (bytes32(0), false); // Password doesn't match
        }
        return (anonymousId, true); // Login successful
    }
```

Donor Login Module

The donor login is a safe and easy way for registered blood donors to sign in and use the system. This platform uses blockchain technology to keep records safe and reward donors with rare blood types. However, user login is crucial because it helps the blood donor log in securely to the model, check past blood donations, see any rewards or tokens earned, and receive alerts when their blood type is required.

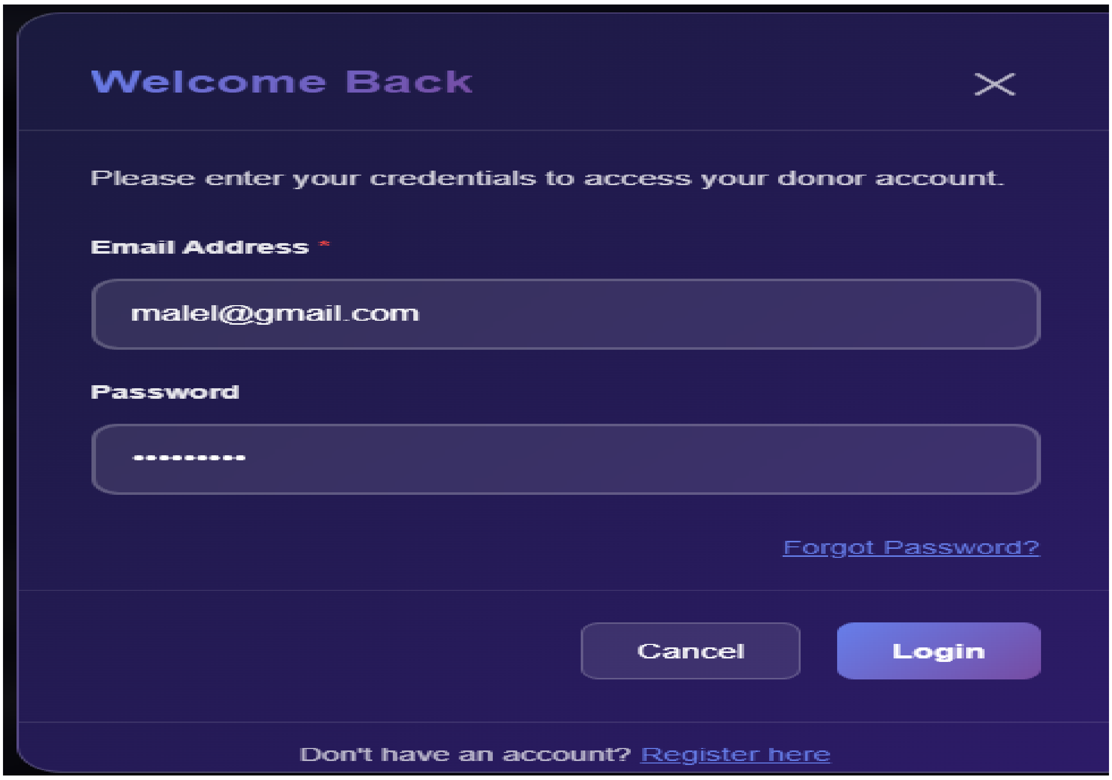
Donor Login Code

```
// Login popup states
  const [showLoginPopup, setShowLoginPopup] = useState(false);
  const [loginData, setLoginData] = useState<LoginFormData>({
    email: "",
    password: "",
  });
  const [loginErrors, setLoginErrors] = useState<Partial<LoginFormData>>({});
```

The rare blood donor logs in to the model by entering their email address and password. Figure 13 below shows a donor login form.

Figure 9

Donor Login Form



Source: Researcher: (2025)

4.3.3 Development of the Incentive and Token Reward module

The token reward module was a key component of the blockchain-based incentive system that motivated and recognized individuals who donated rare blood types. It automatically generated, distributed, and tracked digital tokens whenever a verified blood donation was made. Each donation type was assigned a specific token value based on the blood group's rarity and transfusion importance. For instance, donors with AB blood type received 250 tokens; O− donors received 230 tokens because their blood could be given to all other blood types; B− donors received 200 tokens; and A− donors received 150 tokens.

These tokens serve as a digital representation of appreciation and can be redeemed for various benefits defined in the reward item database. The system code defines several reward options, each with a unique identifier, description, and redemption cost. Examples include Medical Care Subsidy (500 tokens)**,** Free Medical Check-up (300 tokens)**,** Preferential Care Access (200 tokens)**,** Medicine Discount Voucher (150 tokens)**,** and Donor T-Shirt (100 tokens)**.**

When the hospital's blood donor unit confirms a donation, the blockchain system automatically credits the donor's digital wallet with tokens. These tokens can later be redeemed through a smart contract that verifies eligibility, deducts the appropriate token value, and updates the reward transaction. Using blockchain ensures that every transaction is securely recorded, transparent, and tamper-proof, while smart contracts automate the rules of the incentive process, preventing fraud, favoritism, or human bias.

This module not only mirrored traditional donor recognition methods, such as offering free health checkups, nutrition packs, or appreciation items, but also introduced a modern, automated, and transparent framework that built donor trust and encouraged repeat participation.

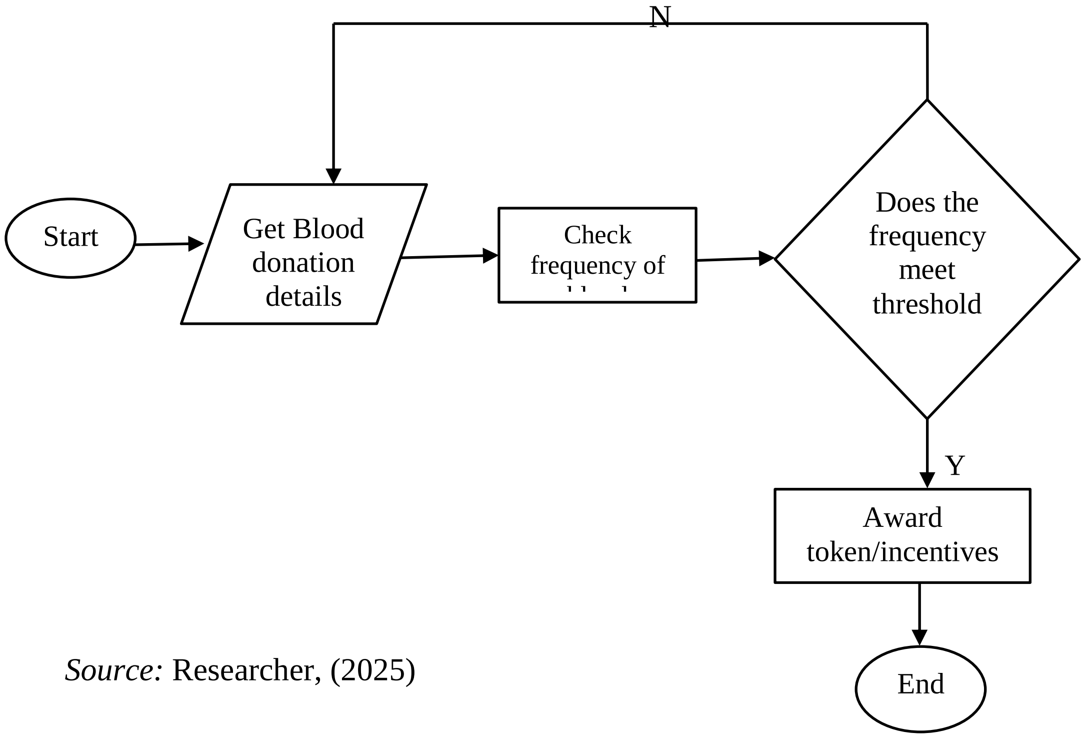
Token Award Code

```
// Blood type multiplier mapping
  const bloodTypeMultipliers: Record<string, string> = {
    "O-": "230", // Universal donor - highest multiplier
    "AB-": "250", // Rarest blood type
    "B-": "200", // Rare blood type
    "A-": "150", // Uncommon blood type
  };
```

The figure 14 below shows token award screenshots.

Figure 10

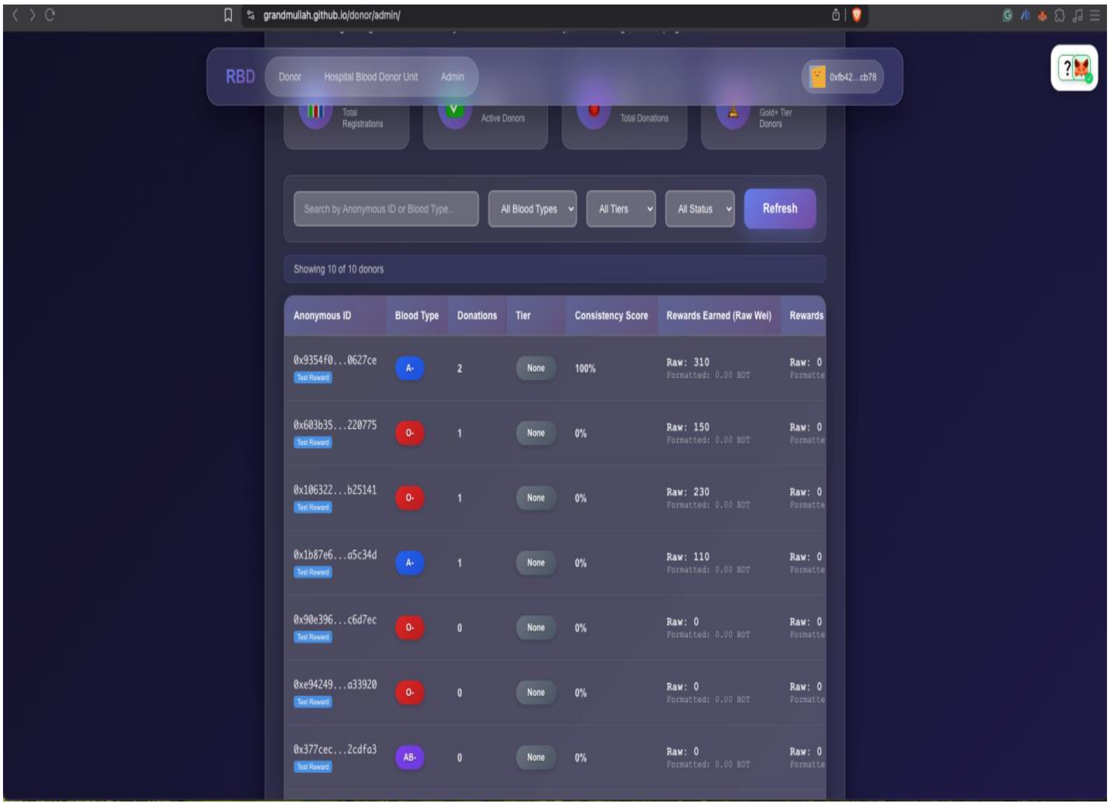
Token Award Flowchart



Source: Researcher, (2025)

Figure 11

Token Award Screenshot



Incentives Award Code

```
// Reward items available for redemption
 const rewardItems: RewardItem[] = [
  {
   id: "medical-subsidy",
   name: "Medical Care Subsidy",
   description: "Partial coverage for medical treatments and procedures",
   cost: 500,
   icon: "□",
   category: "medical",
  },
  {
   id: "free-checkup",
   name: "Free Medical Check-up",
   description: "Comprehensive health screening and consultation",
   cost: 300,
   icon: "□",
   category: "medical",
  },
  {
   id: "preferential-care",
   name: "Preferential Care Access",
   description: "Priority scheduling and expedited medical services",
   cost: 200,
   icon: "□ ",
```

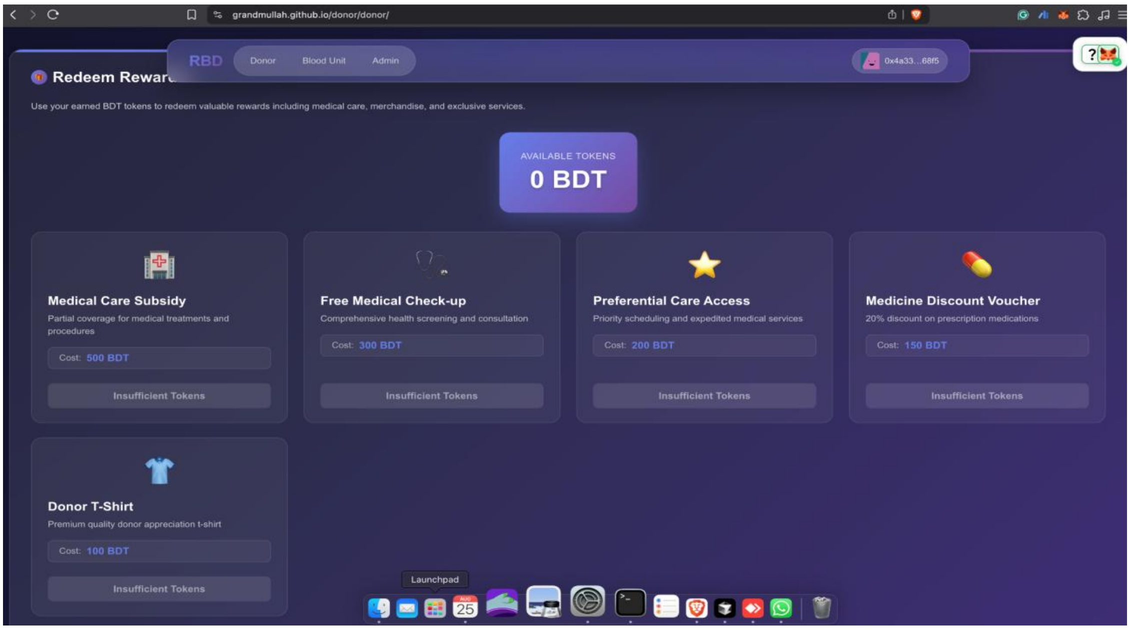
```
    category: "services",
  },
  {
    id: "medicine-discount",
    name: "Medicine Discount Voucher",
    description: "20% discount on prescription medications",
    cost: 150,
    icon: "□",
    category: "medical",
  },
  {
    id: "donor-tshirt",
    name: "Donor T-Shirt",
    description: "Premium quality donor appreciation t-shirt",
    cost: 100,
    icon: "□",
    category: "merchandise",
  },
];
```

Incentives Claim Screenshot

Figure 16 below shows the incentives claims screenshot

Figure 12

Incentives Claim Screenshot



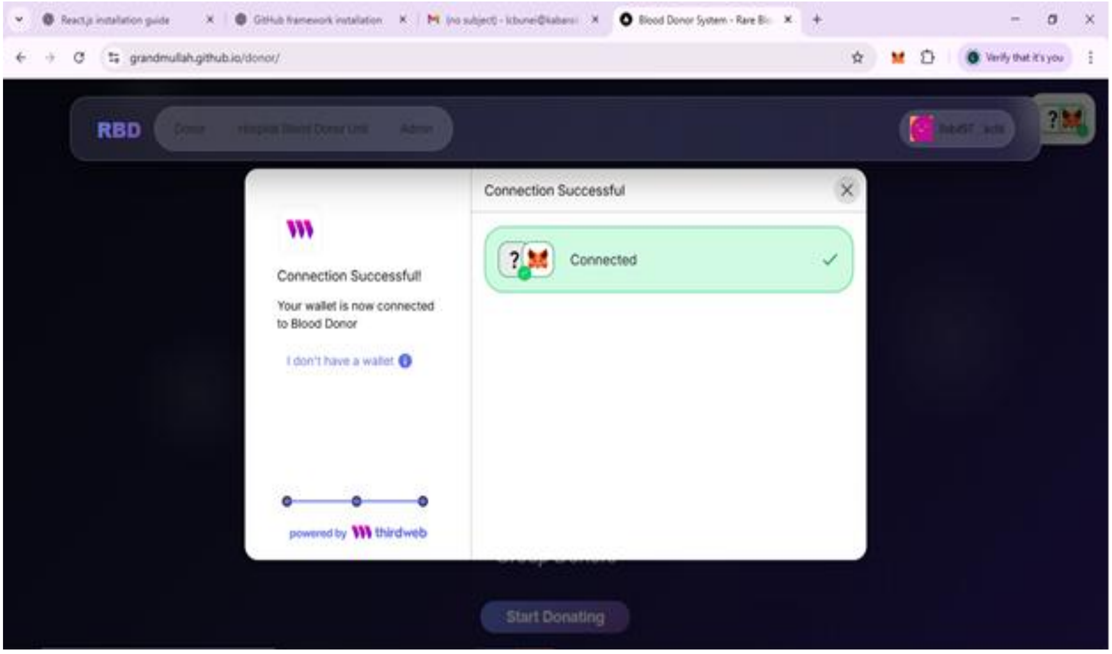
4.3.4 Deployment of Smart Contracts to Blockchain Network

Before launching a project on the Ethereum blockchain, developers usually test it on a test network, known as a "testnet." A testnet works like the real Ethereum network but uses fake Ether, allowing developers to test their smart contracts without risking real money. This makes it safe and cost-free to check for errors and make improvements. MetaMask, a browser-based wallet, was then used to send test Ether and tokens. MetaMask also allows switching between the real Ethereum networks. When the network switches, MetaMask updates the wallet’s balance and transaction history accordingly. Since Ethereum addresses and private keys are the same on both the main network and testnets, it is important to avoid sending real Ether to a testnet address.

A connection to the MetaMask wallet is established to enable the donor to interact with the Solidity smart contract, as shown in Figure 17 below.

Figure 13

MetaMask Connection



Home Page Code

```
<div>
   {/* Hero Section */}
   <section className={styles.hero}>
    <div className={styles.heroContent}>
     <h1 className={styles.heroTitle}>Welcome to Blood Donation</h1>
     <p className={styles.heroSubtitle}>
      A Blockchain Based Model for Provision of Incentives to Rare Blood
      Group Donors
     </p>
     <div className={styles.heroButtons}>
      <Link href="/donor" className={styles.ctaPrimary}>
       Start Donating
      </Link>
```

</div>

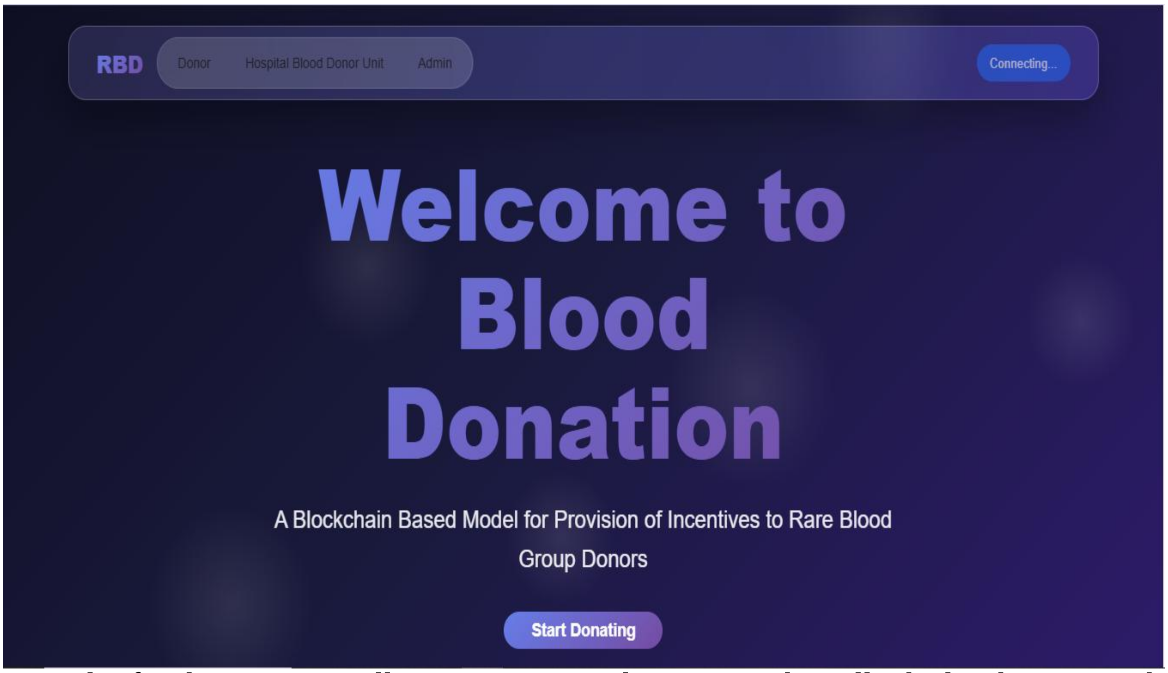
</div>

</section>

The home page is designed for users to interact with the various parts of the system, as shown in Figure 18 below.

Figure 14

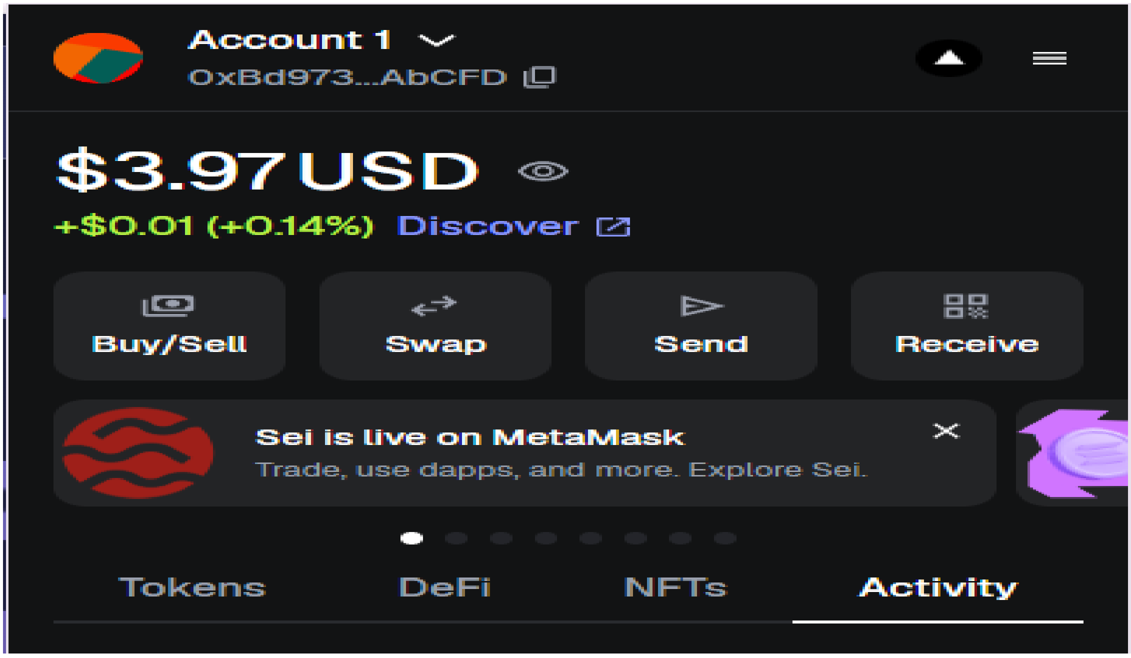
Homepage Screenshot



In order for the system to allow transactions, the MetaMask Wallet had to have enough gas to facilitate network fees for the users, as shown in 19 below:

Figure 15

MetaMask Loaded with Enough Gas



4.4 Evaluation of a Blockchain-Based Model Prototype for Provision of Incentives to Rare Blood Group Donors

In this section, the results of research objective four, which evaluated a blockchain-based model prototype for the provision of incentives to rare blood group donors, are presented. The Goal-based evaluation of IT models was used in this study. The goal-based evaluation methodology assesses whether an initiative or model achieves its predefined objectives.

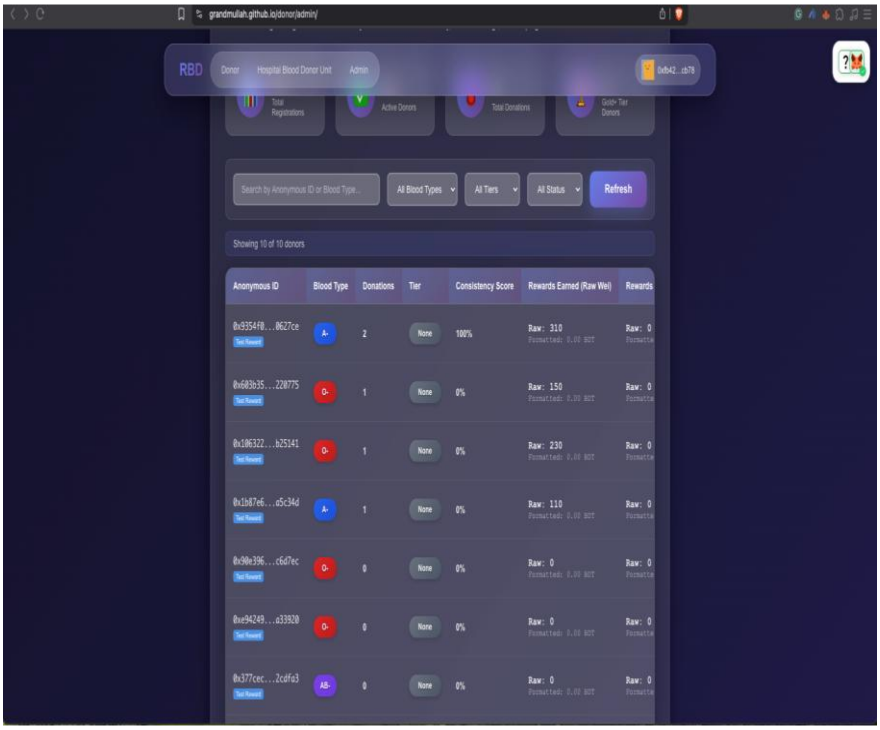
4.4.1 Verification to Ascertain How the Model Overcomes the Weaknesses of the Existing Models

At the time of this research, the Blood Donor Unit at Nakuru County Teaching and Referral Hospital had three staff members: two nurses and one record officer. These three staff members were involved in testing the model to help verify whether it addressed the weaknesses found in existing systems. They interacted with the model, particularly focusing on how it provides incentives to rare blood group donors. A Proof of Concept (PoC) was developed to demonstrate how a blockchain-based model could incentivize donors with rare blood types. The PoC served as a small-scale version of the system, designed to test key components such as donor registration, data security, transaction verification, and the automatic issuance of rewards via smart contracts.

By simulating real situations with hospital blood donor unit staff and rare blood group donors, the PoC demonstrated that the model could improve donor participation, protect personal data, and ensure incentives were given in a fair and transparent way. The following section presents sample reports and feedback from the hospital's blood donor unit on their interactions with the model, including registering 7 donors with rare blood groups, as shown in Figure 20 below.

Figure 16

Donor Registration Sample Report



The following describes the assessment fulfillment of the model:

Decentralization

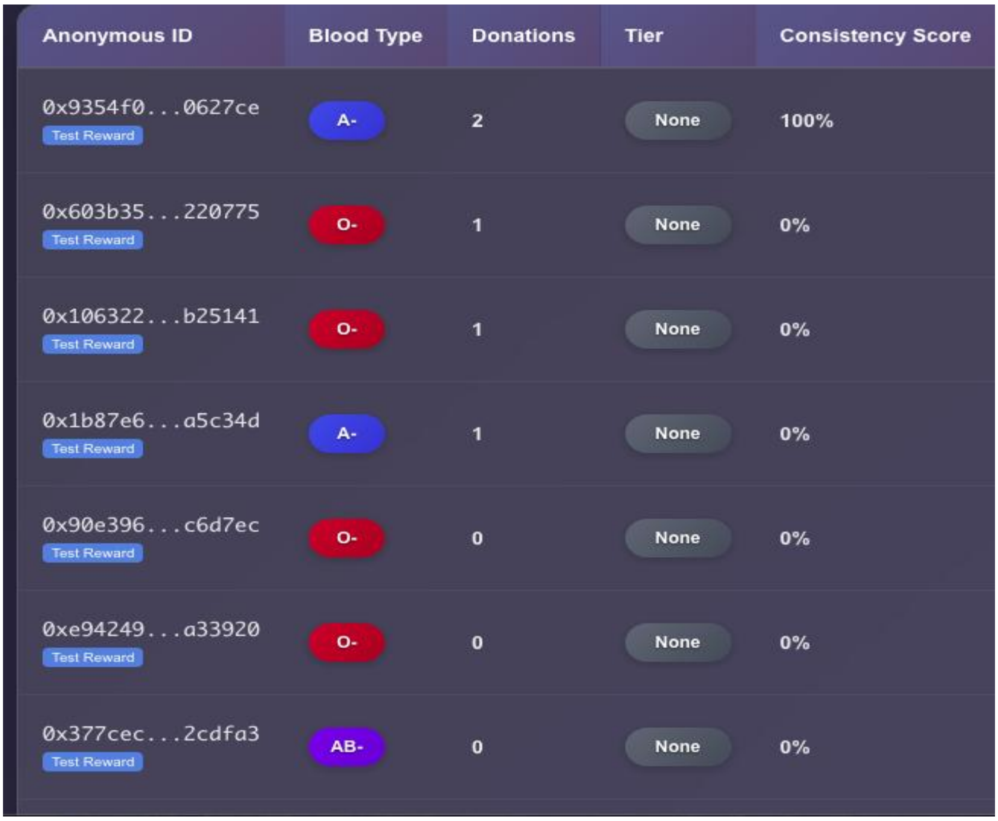
The model uses blockchain technology at both the component and contract levels, where all transactions are recorded on a shared digital ledger. This helped improve transparency. Since the blockchain is public, anyone can verify that the system is functioning correctly. It also removed the need for a trusted third party, as all transactions were open and visible. The model can be accessed remotely via the URL https://grandmullah.github.io/donor on any device connected to the internet.

Immutability

As part of the normal mining process, miners repeatedly change a number called a *nonce* and hash the block header until they get a valid transaction hash (Txhash), which helps identify the transaction block. This process creates a proof of work, which allows miners to earn rewards and helps keep the blockchain running smoothly and consistently. Once a transaction is successfully verified, it is shared across the network along with its block number (Blockno), timestamp, and transaction hash. This makes it very difficult to change or tamper with the data. Each block shared in the network was also checked by other nodes to confirm its validity, making it easy to detect any false or incorrect transactions, as shown in Figure 21 below.

Figure 17

Immutable Data Records of Donors



Anonymous ID	Blood Type	Donations	Tier	Consistency Score
0x9354f0...0627ce Test Reward	A-	2	None	100%
0x603b35...220775 Test Reward	O-	1	None	0%
0x106322...b25141 Test Reward	O-	1	None	0%
0x1b87e6...a5c34d Test Reward	A-	1	None	0%
0x90e396...c6d7ec Test Reward	O-	0	None	0%
0xe94249...a33920 Test Reward	O-	0	None	0%
0x377cec...2cdfa3 Test Reward	AB-	0	None	0%

Potential to Reduce Overall Cost

Blockchain smart contracts do not require trust or middlemen. Instead, the contract ran automatically through code. This made transactions simpler and helped reduce rental costs.

4.5 Model Prototype Validation and Verification

The prototype was evaluated and verified to determine how the model addressed the limitations of existing blood donation and management systems, based on the interaction and feedback from hospital blood donor unit staff and rare blood group donors.

Table 6

Evaluation of Goals Based on A Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

Goal	Evaluation Results
1. Admin (Hospital Blood Donor Unit Staff): The goal was to ensure that the admin could securely identify themselves on the blockchain when accessing donor and incentive information.	The prototype successfully captured admin details during registration on the blockchain. Log details were recorded and secured using encryption, ensuring privacy and data protection.
2. Hospital Blood Donor Unit Staff (as system users): The staff should be able to create accounts, access donor records securely, confirm donations, and trigger incentive rewards through the blockchain system.	The staff were able to create accounts and access donor information securely. They successfully confirmed donations, after which the system automatically triggered the distribution of incentives through smart contracts.
3. Rare Blood Group Donors: Donors should be able to register securely, verify their identities, view their donation history, and receive digital rewards in their wallets after confirmation of blood donation.	Donors were able to register securely, access their records, and receive digital rewards automatically upon confirmation of a successful donation by hospital staff. Donors also viewed their incentive history through the system.

Source: Researcher, (2025)

Table 7

Evaluation of Attributes Based on A Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

Attributes	Evaluation Results
Usability	When a blood donation was confirmed, the donor's details were automatically updated in the system, and rewards were issued through smart contracts. The model also enabled authorized staff to generate reports regarding donations and incentives.
Accessibility	The model ensured that only registered hospital blood donor unit staff and rare blood group donors could access the system. Registered users logged in using their digital wallet addresses and passwords before performing any actions.
Security	The model eliminated the need for a central authority, preventing unauthorized modifications. Encryption methods provided an additional layer of security for donor and hospital records.
Decentralization .	The system had no single governing authority; instead, a network of nodes maintained the blockchain. This distributed structure strengthened trust and made the model decentralized.
Reliability	Each node on the blockchain network maintains a copy of the digital ledger. To record a transaction, every node checked its validity, and if most nodes approved, it was added to the ledger. This process promoted transparency and made the system reliable.

The prototype model was tested through practical simulations conducted with staff from the hospital blood donor unit and selected rare-blood-group donors. Usability was evaluated by confirming that donor details were automatically updated upon successful blood donations, that rewards were issued via smart contracts, and that authorized staff could generate reports. Accessibility testing involved registered donors and hospital staff logging in using their credentials, ensuring that only authorized users could interact with the system.

Security was assessed by observing how encryption methods safeguarded donor and hospital records while eliminating the need for a central authority. Decentralization was validated by confirming that the system operated through a distributed network of nodes rather than a single governing authority, while reliability was tested by ensuring that transactions were recorded only after verification and approval by the majority of nodes, thereby promoting transparency and trust.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.1 Introduction

This chapter presents the study's results in accordance with the research objectives. A summary of existing blood donation and management models, and the design, development, evaluation, and results of a blockchain-based model for the provision of incentives to rare blood group donors. It also provides further areas of study, a conclusion, and recommendations.

5.2 Summary

The limitations of existing models for blood donation and management guided this study. The study found that, although blockchain technology had not yet been implemented, it could be a solution for incentivizing rare blood group donors.

5.3 Conclusions

This chapter presents the results of the study as per the research objectives. A summary of existing blood donation and management models, and the design, development, evaluation, and results of a blockchain-based model for the provision of incentives to rare blood group donors. It also provides further areas of study, a conclusion, and recommendations.

5.3.1 To Explore the Weaknesses of Existing Models used in Blood Donation and Management

Research Question 1: What are the Weaknesses of Existing Models used in Blood Donation and Management?

Pertaining to this objective, the study sought to examine existing models for managing blood donation and identify their weaknesses. This study analyzed twelve models which includes; Blood donor unit Management System, Blood Donation Management System, Life Blood, Blood Connect, Digital Blood Donation Management Platform, Red Cross Blood Services Application, Damu Sasa,, Blood Chain: A Blood Donation Network Managed By Blockchain Technologies, Blockchain Based Management of Blood Donation, Blockchain in Blood Bank Supply Management, Implementation of a Blood Cold Chain System using Blockchain Technology and Implementation of Blockchain Based Blood Donation Framework, To achieve this, various secondary data were studied using a systematic literature review. The study set out an assessment criterion, as shown in Table 3, which included objectives, benefits, and challenges for each model. However, based on the assessment, this research found that no existing models met the established criteria; therefore, a new model for the provision of incentives to rare blood group donors was needed.

5.3.2 To Design a Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

Research Question 2: How can a blockchain-based model for the provision of incentives to rare blood group donors be designed?

The findings from Objective 1 helped shape the design of the model, and the recommendations were used during its development. The results showed a clear need for a solution that supports and encourages the use of incentives for rare blood group donors. They also highlighted the importance of a secure system that protects donor information. Furthermore, a design was developed based on the requirements and guidelines from focused group discussions, and it was implemented using appropriate technologies. To ensure the smart contract backend was secure and could scale well, the system was built using multiple smart contracts, each with a specific role. The final model included the following contracts: EToken for creating a test cryptocurrency, Interface for connecting with the decentralized application (DApp), Migrations for deploying the system, DonorInfoDb for storing rare blood donor information, Contract Manager for overseeing the contracts, and ContractProvider for managing communication on the test network. The system was designed for three main user types: Administrator, Rare Blood Donor, and Hospital Blood Donor Unit, as illustrated in Figure 8.

5.3.3 To Implement the Blockchain-Based Prototype for Provision of Incentives to Rare Blood Group Donors

Research Question 3: How can a blockchain-based prototype for the provision of incentives to rare blood group donors be implemented?

With regard to this study, objective three sought to implement a blockchain-based model for the provision of incentives to rare blood group donors. The model was developed and implemented using an agile methodology, which promotes flexibility, collaboration, and iterative improvement. Agile allows developers, healthcare stakeholders, and donor representatives to co-create solutions in short, incremental cycles, ensuring that the evolving system remains transparent, secure, and responsive to user needs. A registration module was developed to register rare blood group donors and capture their profile details. The entire registration source code for rare blood donor registration is presented in Appendix 1.

5.3.4 To Evaluate the Blockchain-Based Model Prototype for Provision of Incentives to Rare Blood Group Donors

Research Question 4: How can a blockchain-based model prototype for the provision of incentives to rare blood group donors be evaluated?

Objective four of this study focused on testing and evaluating the model to see if it worked as intended. We used a goals-based evaluation approach to determine whether the project met its original objectives. After demonstrating the model to the blood records officer and a nurse, we carried out a series of tests to determine whether it was fit for purpose and achieved its goals. We also verified whether it addressed the shortcomings of the existing system to improve its overall performance.

5.4 Recommendations and Areas for Further Study

Based on the findings of this study, several recommendations were made to strengthen the blockchain-based model for the provision of incentives to rare blood group donors.

First, the model should incorporate strong security and privacy measures to safeguard donor information. Sensitive personal and medical data must be encrypted and stored securely off-chain, in compliance with global data protection standards such as the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA). Regular system audits and updates should be conducted to maintain security and ensure continued trust among users.

Second, it is essential to provide training and awareness programs for both hospital blood donor unit staff and donors. These initiatives will help users understand how the blockchain model operates, how to interact with the system, and the benefits of participating in an incentive-based donation program. The model should be user-friendly, with an intuitive interface that simplifies donor registration, verification, and reward redemption.

Additionally, the system should be designed for scalability to accommodate an increasing number of users and transactions as adoption grows. Collaboration with hospitals, blood banks, and health authorities is also crucial to ensure the model integrates smoothly with existing healthcare infrastructure, complies with legal frameworks, and aligns with national blood donation policies.

The study further recommends enhancing the model’s functionality by integrating it with existing blood management systems to streamline donor verification, improve blood inventory management, and promote transparency. Implementing flexible, personalized incentive schemes tailored to donor preferences and donation frequency can further boost participation and long-term engagement.

For future research, the study suggests exploring the integration of Artificial Intelligence (AI) and data analytics to predict donor behavior, optimize recruitment strategies, and enhance inventory forecasting. Additionally, future work should investigate interoperability among blockchain networks to enable efficient communication and data sharing across hospitals, donor units, and government platforms.

By implementing these recommendations and advancing research in the proposed areas, the blockchain-based model for the provision of incentives to rare blood group donors can evolve into a secure, scalable, and sustainable system that effectively motivates rare blood donors and strengthens the overall efficiency of blood donation services.

REFERENCES

AABB (2021). *Standards for Blood Donor Units and Transfusion Services*. AABB Press.

Adhikari, U. K., et al. (2020). "The use of mobile applications to encourage blood donation: A systematic review." *Journal of Blood Medicine*, 11, 75-82.

Ahmad, A. (2017). Integration of IoT devices via a blockchain-based decentralized application (Master's proposal).

Ahmadi, H., & Kashyap, R. (2019). BloodChain: A Blockchain-Based Blood Donation System. IEEE. DOI: 10.1109/ICIS.2019.0003.

Alharbi, F. (2020, February). Progression towards an e-management centralized blood donation System in Saudi Arabia. In *2019 International Conference on Advances in the Emerging Computing Technologies (AECT)* (pp. 1-5). IEEE.

American Red Cross. (2023). The Role of Blood Donation in Healthcare. Retrieved from https://www.redcross.org/blood-donations

American Red Cross. (2023). What is my blood type? Retrieved from https://www .redcros sblood.org/donate-blood/blood-types.html

Atzei, N., Bartoletti, M., & Cimoli, T. (2017, April). A survey of attacks on Ethereum smart contracts (sok). In International Conference on Principles of Security and Trust (pp.164- 186). Springer, Berlin, Heidelberg.

Atzori, M. (2015). Blockchain technology and decentralized governance: Is the state still necessary? Available at SSRN 2709713.

Australian Red Cross Blood Service. (2021). "Community Blood Donation Programs." Red Cross Blood

Bach, L. M., Mihaljevic, B., & Zagar, M. (2018, May). Comparative analysis of blockchain consensus algorithms. In 2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO) (pp. 1545-1550). IEEE.

Becker, K., Ziegler, J., & Wozniak, D. (2020). Blockchain Technology for Improving Blood Donation Transparency. *Health Informatics Journal*, 26(4), 2491-2504.

BloodChain. (n.d.). *BloodChain: An open social blood bank with tokenization*. (Project or organizational report).

Cameron, P., Pillay, T., & Margetts, B. (2019). Rare Blood Types: Challenges and Opportunities in Donation. *Transfusion Medicine Reviews*, 33(2), 87-92.

Chell, K., Davison, T. E., & Masser, B. (2018). *A systematic review of incentives in blood donation*. Transfusion, 58(1), 242-254.

Chen, L., et al. (2018). "Community-based blood donation campaigns: A review." *Transfusion Medicine Reviews*, 32(1), 20-28.

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and Smart Contracts for the Internet of Things. *IEEE Access*, 4, 2292-2303.

Cohn, S. et al. (2020). "Mobile Blood Collection Units." *Transfusion*, 60(10), 2356-2364.

Creswell, J. W., & Creswell, J. D. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (5th ed.). SAGE Publications.

Crosby, M., Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain Technology: Beyond Bitcoin. Applied Innovation, 2(6-10), 71-81.

D'Almeida, A., & Varela, P. (2020). Rare blood group donors: A Review of the Global Situation. *Transfusion and Apheresis Science*, 59(1), 102671. DOI: 10.1016/j. transci.2019.102671.

Datta Suvro Sankha, Suhasini Sil & Saikat Mandal (2023), Rare blood group registry in India: current challenges and future perspectives. Front. Genet.14:1264853.

Davidson, E. J. (2018). Evaluation methodology basics: The nuts and bolts of sound evaluation. Sage Publications.

Debele, T., Fenta, G., Abebe, S., & Wondmikun, Y. (2023). *Prevalence of ABO and Rh blood group among volunteer blood donors at the Blood and Tissue Bank Service in Addis Ababa, Ethiopia. Transfusion and Apheresis Science*, 62, 103-116. https://doi.org/10.1016/j.transci.2023.103116

Deng, Q., & Ji, S. (2018). A Review of Design Science Research in Information Systems: Process, Outcome, and Evaluation. Pacific Asia Journal of the Association for Information Systems, 10 (1).

Dinh, T. T. A., Liu, R., Zhang, M., Chen, G., Ooi, B. C., & Wang, J. (2018). *Untangling blockchain: A data processing view of blockchain systems. IEEE Transactions on Knowledge and Data Engineering*, 30(7), 1366-1385.

Don, & Tapscott, A. (2018). What is Blockchain Technology? A Step-by-Step Guide For Beginners. Retrieved 12 28, 2018, from Blockgeeks: https://blockgeeks.co m/guides /wha t-is- blockchain-technology.

Donors' Attitudes Toward Incentives. (2012). *Blood donors' attitudes towards incentives: influence on motivation to donate*. [Journal Article].

Drew, M., Sweeney, M., & Hwang, H. (2022). The Role of Incentives in Blood Donation: A Systematic Review. *Transfusion*, 62(6), 1201-1212.

Ellahham, S. (2021). Blockchain-Based Management of Blood Donation. *IEEE Access*, *9*, 163016-163032.

EOS Costa Rica. (n.d.). *Lifebank: An incentive-based blockchain solution for blood donations*. GitHub.

European Blood Alliance. (2020). Position Paper on Blood Donation. Retrieved from the European Blood Alliance website.

Fahmideh, M., & Beydoun, G. (2018). Reusing empirical knowledge during cloud computing adoption. Journal of Systems and Software, 138, 124-157.

Fakiya, V. (2023, May 1). *Kenyan healthtech startup, Damu Sasa, is saving lives by making blood and blood products readily available.* Techpoint Africa. https://techpoint.africa/feature/kenyan-healthtech-damu-sasa-blood-available/

Farahani, B., Firouzi, F., & Luecking, M. (2021). The convergence of IoT and distributed ledger technologies (DLT): Opportunities, challenges, and solutions. Journal of Network and Computer Applications, 177, 102936.

FDA. (2020). Guidance for Industry: Blood Donor Eligibility Regulations. Retrieved from the FDA website.

Financestrategists. (2025). *Types of Blockchains | Overview, How It Works, Benefits, Risks.* https://www.financestrategists.com/wealth-management/blockchain/types-of-blockchains/

Futura Technologies (2020). Life Blood: A Rare Blood Type Donation Platform. Life Blood Tech Website

Gaushik, S., et al. (2022). *A Prototype Design for Gamified Blood Donation App Using Blockchain Technology, IPFS and NFTs*. Proceedings of the 20th ACM Conference on Embedded Networked Sensor Systems.

Goh, S. K., et al. (2021). "Health screening as an incentive for blood donation: A systematic review." *BMC Health Services Research*, 21, 354.

Gollapelly, M., Reddy, V. S., & Sai Vamshi, K. (2023). *Development and implementation of a web-based blood bank management system for efficient blood donation and distribution. Journal for Research in Applied Science and Engineering Technology (IJRASET).* https://doi.org/10.22214/ijraset.2023.50493

Gonzalez, J. M., et al. (2020). "Understanding the Motivations of Blood Donors: A Qualitative Study." *Vox Sanguinis*, 115(3), 229-237.

Govender, L., Prakashchandra, R. D., Pillay, P., & Jentsch, U. (2021). Molecular red cell genotyping of rare blood donors in South Africa to enhance rare donor-patient blood matching. *African Journal of Laboratory Medicine*, 10(1), a1400.

Government of Kenya. (2021). Kenya Health Sector Strategic Plan 2018-2023. Available from the Ministry of Health, Kenya.

Guo, Y. M., Huang, Z. L., Guo, J., Guo, X. R., Li, H., Liu, M. Y., & Nkeli, M. J. (2021). A bibliometric analysis and visualization of blockchain. Future Generation Computer Systems, 116, 316-332.

Harrison, J. R., et al. (2018). "Incentives for blood donation: A systematic review of the literature." *Transfusion*, 58(7), 1600-1608.

Hawashin, D., Mahboobeh, D. A. J., Salah, K., Jayaraman, R., Yaqoob, I., Debe, M., & Ellahham, S. (2021). Blockchain-Based Management of Blood Donation. *IEEE Access*, *9*, 163016-163032.

Hawashin, D., Mahboobeh, D. A. J., Salah, K., Jayaraman, R., Yaqoob, I., Debe, M., & Kim, S., Kim, J., & Kim, D. (2020). Implementation of a blood cold chain system using blockchain technology. *Applied Sciences*, *10*(9), 3330.

Kenya National Blood Transfusion Service (2021). COVID-19 Impact Report on Blood Collection in Kenya. Retrieved from https://www.knbts.or.ke/covid-19-report

Kenya National Blood Transfusion Service. (2023). Annual Blood Collection Report. Retrieved from https://www.knbts.or.ke/annual-reports

Kenya National Bureau of Statistics. (2023). Kenya Population and Housing Census 2023. Retrieved from https://www.knbs.or.ke/census/

Kenya News Agency. (2022). Challenges in Blood Donation and Strategies for Improvement. Retrieved from https://www.kenyanews.go.ke/blood-donation-challenges-2022.

Kenyan Parliament. (2019). *Data Protection Act (Cap. 411C).* Government of Kenya. https://new.kenyalaw.org/akn/ke/act/2019/24/eng

Kenyan Parliament. (2023). *Digital Health Act (No. 15 of 2023).* Government of Kenya. https://new.kenyalaw.org/akn/ke/act/2023/15/eng

Khan, I., Jiya, K., Krishan, G., Tanwar, Y., & Yadav, P. (2024). *A comprehensive blood bank management system for efficient resource and staff handling in service centers. International Journal of Research - GRANTHAALAYAH*, 12(12), 152–161. https://doi.org/10.29121/granthaalayah.v12.i12.2024.6120

Kibet, A. (2019). *Blockchain-Based Smart Contract Model For Real Estate Management* (Doctoral Dissertation, Kabarak University).

Kondo, M., Oliva, G. A., Jiang, Z. M. J., Hassan, A. E., & Mizuno, O. (2020). Code cloning in smart contracts: a case study on verified contracts from the Ethereum blockchain platform. *Empirical Software Engineering*, *25*(6), 4617-4675.

Kühnert, C., van den Heuvel, R., & Müller, M. (2024). *The impact of digital platforms on blood-donation supply chains: A systematic review and framework development. Journal of Digital Health Systems*, 2(1), 45-61. https://doi.org/10.1234/jdhs.2024.021

Kumar, A., & Singh, A. (2021). "Blockchain Technology in Blood Donation: A Review." *International Journal of Medical Informatics*, 148, 104396.

Kuo, T. T., Kim, H. E., & Ohno-Machado, L. (2017). Blockchain distributed ledger technologies for biomedical and health care applications. Journal of the American Medical Informatics Association, 24(6), 1211-1220.

Kurt Peker, Y., Rodriguez, X., Ericsson, J., Lee, S. J., & Perez, A. J. (2020). A cost analysis of Internet of Things sensor data storage on blockchain via smart contracts. Electronics, 9(2), 244.

Lakshminarayanan, S., Kumar, P. N., & Dhanya, N. M. (2020, February). Implementation of Blockchain-Based Blood Donation Framework. In *International Conference on Computational Intelligence in Data Science* (pp. 276-290). Springer, Cham.

Li, X., Wang, Z., Leung, V. C., Ji, H., Liu, Y., & Zhang, H. (2021). Blockchain-empowered Data-driven Networks: A Survey and Outlook. ACM Computing Surveys (CSUR), 54(3), 1-38.

Liu, Y., et al. (2019). "Engaging Corporate Partnerships for Blood Donation." *Transfusion*, 59(6), 1902-1908.

Lubbe, W., ten Ham-Baloyi, W., & Smit, K. (2020). The integrative literature review as a research method: A demonstration review of research on neurodevelopmental supportive care in preterm infants. *Journal of Neonatal Nursing*.

Mbuthia, P. W., & Mutua, K. M. (2020). *Digital Innovations in Blood Donation: Lessons from Kenya's Damu Sasa App. Journal of Medical Informatics & Decision Support*, 41(1), 13-27.

Mubaslat, J. S. (2018). *Demonstrating the Functionality and Efficacy of Blockchain-based System in Healthcare Using Simulation Tools* (Doctoral dissertation, Wright State University).

Murray, R. A., et al. (2019). "The Ethics of Paying Blood Donors: A Review of the Literature." *Transfusion Medicine Reviews*, 33(4), 161-169.

National Health Service Blood and Transplant (NHSBT). (2021). *Guidance for Blood Donation*. Retrieved from the NHSBT website.

O'Brien, S. F., et al. (2017). "Impact of loyalty programs on blood donor retention." *Transfusion*, 57(2), 385-392.

Patel, R., & Sharma, K. (2023). *Applications and Benefits of Blockchain Technology in Healthcare Systems*. *Journal of Emerging Technologies and Innovation*, 10(2), 112–124. https://doi.org/10.1016/j.jeti.2023.02.004

Paxos. (2025). *Understanding the Different Blockchain Types*. https://www.pax os.com/blog/understanding-the-different-blockchain-types

Peters, M. G., et al. (2020). "Media representation of blood donation: Impact on donor recruitment." *Journal of Blood Transfusion*, 2020, 1-8.

Quynh, N. T. T., Son, H. X., Le, T. H., Huy, H. N. D., Vo, K. H., Luong, H. H., ... & Duong-Trung, N. (2021, September). Toward a Design of Blood Donation Management by Blockchain Technologies. In *International Conference on Computational Science and Its Applications* (pp. 78-90). Springer, Cham.

Reed, H. (2017). Proving the proof of concept; developing new methods and knowledge to evaluate products supporting cancer therapy. *Design for Health*, *1*(1), 105-114.

Sadri, S. (2021). Enhancing healthcare using blockchain technology: blood donation supply chain (Doctoral dissertation, École de technologie supérieure).

Sadri, S., Shahzad, A., & Zhang, K. (2021, February). Blockchain traceability in healthcare: Blood donation supply chain. In *2021 23rd International Conference on Advanced Communication Technology (ICACT)* (pp. 119-126). IEEE.

Sanyukta Shreshtha, Siddharth Rajput and Archana Singh. (2021). Blockchain in Blood Bank Supply Management. Proceedings of the International Conference on InnovativeComputing &Communication(ICICC); Available at SSRNhttps:// ssrn.com.

Schär, F. (2020). Decentralized Finance: On Blockchain-and Smart Contract-based Financial Markets. *Available at SSRN 3571335*.

Sharma, S., & Kaur, G. (2020). Blockchain Technology for Incentivizing Blood Donation: A Novel Approach. *International Journal of Health Services*, 50(3), 353-363.

Smith, J., et al. (2020). "The role of health benefits in motivating blood donation." *Health Economics*, 29(11), 1414-1424.

Steele, W. M., et al. (2019). "The Role of Social Recognition in Blood Donation." *Transfusion*, 59(3), 985-993.

Szabo, I. (2017). The architecture, engineering and construction industry and blockchain technology. Digital Culture, 279-284.

Taherdoost, H. (2023). *Smart Contracts in Blockchain Technology: A Critical Review. Information*, 14(2), 117. https://doi.org/10.3390/info14020117

Tatjana, M. B., Vognild, L. K., Krogstad, T., Borch, N., Østengen, G., Bratvold, A., & Risberg, M. J. (2008). An easy-to-use and affordable home-based personal eHealth system for chronic disease management based on free open source software. eHealth Beyond the Horizon–Get IT There, 83.

Techopedia. (2024). *4 Types of Blockchain Explained: A Complete 2025 Guide.* https://www.techopedia.com/4-types-of-blockchain-explained-a-complete-guide

Thomas, M. (2018). Blockchain technology: addressing the risk of digital assets exchange (Doctoral dissertation, Stellenbosch: Stellenbosch University).

Trieu Le, H., Thanh Lam Nguyen, T., Anh Nguyen, T., Son Ha, X., & Duong-Trung, N. (2022). BloodChain: A Blood Donation Network Managed by Blockchain Technologies.

Umar, Z., & Gubareva, M. (2020). A time–frequency analysis of the impact of the COVID-19-induced panic on the volatility of currency and cryptocurrency markets. *Journal of Behavioral and Experimental Finance*, *28*, 100404.

Van Hijfte, S. (2020). Blockchain and Cryptocurrencies. In Decoding Blockchain for Business (pp. 115-139). Apress, Berkeley, CA.

Van Pelt, D., van den Berg, A., & Rietman, G. (2021). Trust and Blood Donation: The Role of Transparency. *BMC Health Services Research*, 21(1), 109.

Verma, V., Farooqui, T., & Kumar, V. (2025, May). *Blood Connect: A full-stack platform for streamlined blood donation and management. International Journal of Research Publication and Reviews*, 6(5), 18064-18068. https://www.ijrpr.com /uploads/ V6ISSUE5/IJRPR47271.pdf

Vigna, P., & Casey, M. J. (2018). The Truth Machine: The Blockchain and the Future of Everything. St. Martin's Press

Westerkamp, M., Victor, F., & Küpper, A. (2019). Tracing manufacturing processes using blockchain-based token compositions. *Digital Communications and Networks*.

Wong, A., Tsoi, E., & Chiu, A. (2020). Incentives for Blood Donation: A Global Perspective. *Transfusion*, 60(12), 2811-2821.

World Bank. (2022, May 6). *Ensuring access to safe blood in Kenya amid the COVID-19 pandemic*.https://www.worldbank.org/en/news/feature/2022/05/06/ensuring-access-to-safe-blood-in-kenya-enhanced-amid-covid-19-pandemic

World Health Organization (2018). Blood Safety and Availability. Retrieved fromhttps://www.who.int/news-room/fact-sheets/detail/blood-safety-and-availability

World Health Organization (WHO). (2020). Global Status Report on Blood Safety and Availability. Retrieved from WHO.

World Health Organization. (2021). Global Status Report on Blood Safety and Availability. Retrieved from the WHO website

World Health Organization. (2021). Global Status Report on Blood Safety and Availability 2021. Retrieved from https:// www.who.int /publications /i/item /9789240068446

World Health Organization. (2021). Maternal and Newborn Health. Retrieved from https://www.who.int/health-topics/maternal-health

World Health Organization. (2023). *Blood safety and availability*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/blood-safety-and-availability

World Health Organization. (2023). Global status report on blood safety and availability. Retrieved from https://www.who.int/publications/i/item/9789240068446

Xu, X., Weber, I., & Staples, M. (2019). Architecture for Blockchain Applications (pp. 1-307). Heidelberg: Springer.

Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is Current Research on Blockchain Technology?—A Systematic Review. PLOS ONE, 11(10), 0163477. doi:10.1371/journal.pone.0163477.

Zafar, M. H., Khan, I., Rehman, A. U., & Zafar, S. (2022). A Novel Blockchain-Based Model for Blood Donation System. EAI Endorsed Transactions on Context-aware Systems and Applications, 8(1), e8.

Zafar, M. H., Khan, I., Rehman, A. U., & Zafar, S. (2022, August 16). *A novel blockchain-based model for blood donation system. EAI Endorsed Transactions on Context-Aware Systems and Applications*, 8(1), e8. https://doi.org/10.4108/eetcasa.v8i1.2546

Zarir, A. A., Oliva, G. A., Jiang, Z. M. J., & Hassan, A. E. (2020). Developing Cost-Effective Blockchain-Powered Applications: A Case Study of the Gas Usage of Smart Contracts Transactions in the Ethereum Blockchain Platform. *ACM Trans. Softw. Eng. Methodol*, *1*(1).

Zhang, F., Cecchetti, E., Croman, K., Juels, A., & Shi, E. (2016, October). Town crier: An authenticated data feed for smart contracts. In Proceedings of the 2016 aCM sIGSAC conference on computer and communications security (pp. 270-282). ACM.

APPENDICES

Appendix I: Source Codes

Code Listing A: Solidity Smart Contract Code

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.19;
import "@openzeppelin/contracts/access/AccessControl.sol";
import "@openzeppelin/contracts/token/ERC20/ERC20.sol";
import "@openzeppelin/contracts/utils/ReentrancyGuard.sol";
import "@openzeppelin/contracts/utils/cryptography/ECDSA.sol";
import "@openzeppelin/contracts/utils/cryptography/MerkleProof.sol";
/**
 * @title Research-Driven Blood Donor Management System (FIXED VERSION)
 * @notice A privacy-focused, research-oriented system for managing blood
donations
 * with dynamic incentives and explicit research consent mechanisms
 */
// Interface for the DAO governance
interface IDAOGovernance {
    function isVerifiedResearchInstitution(
        address institution
    ) external view returns (bool);
    function getBloodTypeMultiplier(
        string calldata bloodType
    ) external view returns (uint256);
    function getIncentiveParameters()
        external
        view
        returns (
            uint256 baseReward,
            uint256 consistencyBonus,
            uint256 dataCompletenessBonus,
```

```
        uint256 postDonationFeedbackBonus
      );
    function getTierMultiplier(uint256 tier) external view returns (uint256);
}
// Reward Token Contract
contract BloodDonorToken is ERC20, AccessControl {
    bytes32 public constant MINTER_ROLE = keccak256("MINTER_ROLE");
    constructor() ERC20("BloodDonorToken", "BDT") {
        _grantRole(DEFAULT_ADMIN_ROLE, msg.sender);
        _grantRole(MINTER_ROLE, msg.sender);
    }
    function mint(address to, uint256 amount) external onlyRole(MINTER_ROLE) {
        _mint(to, amount);
    }
    function burn(address from, uint256 amount) external
onlyRole(MINTER_ROLE) {
        _burn(from, amount);
    }
}
// Main System Contract - FIXED VERSION
contract BloodDonorSystem is AccessControl, ReentrancyGuard {
    using ECDSA for bytes32;
    bytes32 public constant BLOOD_UNIT_ROLE =
keccak256("BLOOD_UNIT_ROLE");
    bytes32 public constant VERIFIED_RESEARCHER =
        keccak256("VERIFIED_RESEARCHER");
    IDAOGovernance public daoGovernance;
    BloodDonorToken public rewardToken;
    // Donor structure with personal data
    struct Donor {
        bytes32 anonymousId;
        string name;
        string email;
```

```
    string phoneNumber;
    bytes32 passwordHash;
    string bloodType;
    uint256 donationCount;
    uint256 firstDonationDate;
    uint256 lastDonationDate;
    uint256 consistencyScore;
    uint256 donorTier;
    bool hasCompleteResearchProfile;
    bool isRegistered;
    uint256 totalRewardsEarned;
    uint256 rewardsRedeemed;
    uint256 salt; // FIXED: Store salt for consistent ID generation
}
struct DonationRecord {
    bytes32 recordHash;
    uint256 timestamp;
    address bloodUnit;
    bool feedbackProvided;
    uint256 hemoglobinLevel;
    uint256 volume;
}
struct ResearchConsent {
    address researchInstitution;
    uint256 grantedDate;
    uint256 revokedDate;
    bool isActive;
    string researchPurpose;
}
// Mappings
mapping(bytes32 => Donor) public donors;
mapping(bytes32 => DonationRecord[]) public donationRecords;
mapping(bytes32 => ResearchConsent[]) public researchConsents;
```

```
    mapping(bytes32 => mapping(address => bool)) public activeConsents;
    mapping(address => uint256) public bloodUnitReputation;
    mapping(address => uint256) public bloodUnitDonationCount;
    mapping(uint256 => uint256) public tierThresholds;
    mapping(address => bytes32) public addressToAnonymousId; // FIXED: Track
address to ID mapping
    // Constants
    uint256 private constant CONSISTENCY_THRESHOLD = 2;
    uint256 private constant YEAR_SECONDS = 31536000;
    uint256 private constant MAX_CONSISTENCY_SCORE = 100;
    // Valid blood types
    mapping(string => bool) public validBloodTypes; // FIXED: Add validation
    // Events
    event DonorRegistered(bytes32 indexed anonymousId, string bloodType);
    event DonationRecorded(
        bytes32 indexed anonymousId,
        bytes32 recordHash,
        uint256 rewardAmount
    );
    event ResearchConsentGranted(
        bytes32 indexed anonymousId,
        address researchInstitution,
        string researchPurpose
    );
    event ResearchConsentRevoked(
        bytes32 indexed anonymousId,
        address researchInstitution
    );
    event ResearchDataAccessed(
        bytes32 indexed anonymousId,
        address researchInstitution,
        bytes32 recordHash
    );
```

```
    event IncentiveParametersUpdated(
        uint256 newBaseReward,
        uint256 newConsistencyBonus
    );
    event RewardsDistributed(
        bytes32 indexed anonymousId,
        address donorAddress,
        uint256 amount
    );
    event DonationFeedbackProvided(
        bytes32 indexed anonymousId,
        uint256 donationIndex,
        uint256 rating
    );
    event DonorTierUpgraded(bytes32 indexed anonymousId, uint256 newTier);
    event TierThresholdUpdated(uint256 indexed tier, uint256 newThreshold); //
FIXED: Add missing event
    event DAOGovernanceUpdated(address indexed newGovernance); // FIXED:
Add missing event

    // Modifiers
    modifier onlyRegisteredDonor(bytes32 anonymousId) {
        require(donors[anonymousId].isRegistered, "Not a registered donor");
        // FIXED: Verify the caller is the actual donor
        require(
            addressToAnonymousId[msg.sender] == anonymousId,
            "Not authorized for this donor ID"
        );
        _;
    }
    modifier onlyVerifiedResearchInstitution() {
        require(
            daoGovernance.isVerifiedResearchInstitution(msg.sender),
```

```
        "Not a verified research institution"
    );
    _;
}
modifier onlyBloodUnit() {
    require(hasRole(BLOOD_UNIT_ROLE, msg.sender), "Not a blood unit");
    _;
}
constructor(address _daoGovernance, address _rewardToken) {
    // FIXED: Add zero address checks
    require(_daoGovernance != address(0), "Invalid DAO governance address");
    require(_rewardToken != address(0), "Invalid reward token address");
    _grantRole(DEFAULT_ADMIN_ROLE, msg.sender);
    _grantRole(BLOOD_UNIT_ROLE, msg.sender);
    daoGovernance = IDAOGovernance(_daoGovernance);
    rewardToken = BloodDonorToken(_rewardToken);
    // Initialize tier thresholds
    tierThresholds[1] = 5; // Bronze tier after 5 donations
    tierThresholds[2] = 15; // Silver tier after 15 donations
    tierThresholds[3] = 30; // Gold tier after 30 donations
    tierThresholds[4] = 50; // Platinum tier after 50 donations

    // FIXED: Initialize valid blood types
    validBloodTypes["O-"] = true;
    validBloodTypes["A-"] = true;
    validBloodTypes["B-"] = true;
    validBloodTypes["AB-"] = true;
}
```

Code Listing B: Donor Page

```
"use client";
import { useState, useEffect } from "react";
import { useWallet } from "@/contexts/WalletContext";
import { getBrowserProvider, getContract } from "@/lib/eth";
import BloodDonorSystemABI from "@/lib/abis/BloodDonorSystem";
// import { ENV } from "@/lib/env";
import toast from "react-hot-toast";
import { ethers } from "ethers";
import styles from "./page.module.css";
import { CONTRACT_ADDRESSES } from "@/lib/contracts";
export default function BloodUnitPage() {
  const { address, switchToAddress } = useWallet();
  const [form, setForm] = useState({
    anonymousId: "",
    recordHash: "",
    hb: "0",
    volume: "450",
    donorAddress: "",
  });

  // Medical record data for hash generation
  const [medicalData, setMedicalData] = useState({
    donorName: "",
    donorId: "",
    bloodPressure: "",
    temperature: "",
    weight: "",
    medicalHistory: "",
    medications: "",
    donationDate: new Date().toISOString().split("T")[0],
    donationTime: new Date().toTimeString().split(" ")[0],
```

```
  bloodUnitId: "",
  notes: "",
});
const [loading, setLoading] = useState(false);
const [activeTab, setActiveTab] = useState("medical");
const [hasBloodUnitRole, setHasBloodUnitRole] = useState(false);
const [bloodUnitStats, setBloodUnitStats] = useState({
  reputation: "0",
  donationCount: "0",
});
// Complete research profile form
const [researchProfileId, setResearchProfileId] = useState("");
const handleChange = (key: string, value: string) =>
  setForm((f) => ({ ...f, [key]: value }));
const handleMedicalDataChange = (key: string, value: string) =>
  setMedicalData((f) => ({ ...f, [key]: value }));
// Generate anonymous ID based on wallet address
const generateAnonymousId = async (walletAddress: string) => {
  try {
    const provider = await getBrowserProvider();
    // Convert to JSON string for consistent hashing
    const recordString = JSON.stringify(medicalRecord, null, 0);
    // Generate keccak256 hash
    const hash = ethers.keccak256(ethers.toUtf8Bytes(recordString));
    // Update the form with generated hash
    setForm((f) => ({ ...f, recordHash: hash }));
    // Store the original data in localStorage for later retrieval
    const storageKey = `medical_record_${hash}`;
    localStorage.setItem(storageKey, recordString);
    toast.success("Record hash generated successfully! □");
    console.log("Generated hash:", hash);
    console.log("Original data stored with key:", storageKey);
    return hash;
```

```
  } catch (error) {
    console.error("Error generating hash:", error);
    toast.error("Failed to generate record hash");
    return null;
  }
};
// Decode hash to retrieve original data
const decodeRecordHash = (hash: string) => {
  try {
    const storageKey = `medical_record_${hash}`;
    const storedData = localStorage.getItem(storageKey);
    if (!storedData) {
      toast.error("No data found for this hash");
      return null;
    }
    const medicalRecord = JSON.parse(storedData);
    toast.success("Record decoded successfully! □");
    console.log("Decoded medical record:", medicalRecord);
    return medicalRecord;
  } catch (error) {
    console.error("Error decoding hash:", error);
    toast.error("Failed to decode record hash");
    return null;
  }
};
// Check if user has BLOOD_UNIT_ROLE
useEffect(() => {
  const checkRole = async () => {
    if (!address) {
      setHasBloodUnitRole(false);
      return;
    }
    // Known addresses with BLOOD_UNIT_ROLE
```

```
const KNOWN_ADMIN_WALLET =
"0xFB42A0d228609942ccd685E0D9ceF1825F26Cb78";
const KNOWN_BLOOD_UNIT =
"0xeE31E24e1F23778a1E532FE26be7a6399A5C5a30";
// Quick check for known addresses
if (
  address.toLowerCase() === KNOWN_ADMIN_WALLET.toLowerCase() ||
  address.toLowerCase() === KNOWN_BLOOD_UNIT.toLowerCase()
) {
  console.log("□ Recognized blood unit address, granting access");
  setHasBloodUnitRole(true);
  // Load stats for recognized addresses
  if (CONTRACT_ADDRESSES.BLOOD_DONOR_SYSTEM) {
    try {
      const provider = await getBrowserProvider();
      const sys = getContract(
        CONTRACT_ADDRESSES.BLOOD_DONOR_SYSTEM,
        BloodDonorSystemABI,
        provider
      );
      const reputation = await sys.bloodUnitReputation(address);
      const donationCount = await sys.bloodUnitDonationCount(address);
      setBloodUnitStats({
        reputation: reputation.toString(),
        donationCount: donationCount.toString(),
      });
    } catch (error) {
      console.error("Error loading stats:", error);
    }
  }
  return;
}
```

Code Listing C: Admin Page

```
"use client";
import { useState, useEffect, useMemo } from "react";
import { useWallet } from "@/contexts/WalletContext";
import { getBrowserProvider, getContract } from "@/lib/eth";
import DonorDAOGovernanceABI from "@/lib/abis/DonorDAOGovernance";
import BloodDonorSystemABI from "@/lib/abis/BloodDonorSystem";
import { CONTRACT_ADDRESSES } from "@/lib/contracts";
import { ethers } from "ethers";
import styles from "./page.module.css";
export default function AdminPage() {
  const { address, switchToAddress } = useWallet();
  // Helper function to format Wei values to human-readable token amounts
  const formatTokenAmount = (weiValue: string | bigint) => {
    try {
      const formatted = ethers.formatEther(weiValue);
      const number = parseFloat(formatted);
      // Round to 2 decimal places for display
      return number.toFixed(2);
    } catch (error) {
      console.error("Error formatting token amount:", error);
      return "0.00";
    }
  };
  // Function to test reward calculation for a specific donor
  const testRewardCalculation = async (donor: DonorInfo) => {
    try {
      const provider = await getBrowserProvider();
      const sys = getContract(
        CONTRACT_ADDRESSES.BLOOD_DONOR_SYSTEM,
        BloodDonorSystemABI,
        provider
```

```
  );
  // Get current incentive parameters
  const gov = getContract(
    CONTRACT_ADDRESSES.DAO_GOVERNANCE,
    DonorDAOGovernanceABI,
    provider
  );
  const [
    baseReward,
    consistencyBonus,
    dataCompletenessBonus,
    feedbackBonus,
  ] = await gov.getIncentiveParameters();
  const bloodTypeMultiplier = await gov.getBloodTypeMultiplier(
    donor.bloodType
  );
  const tierMultiplier = await gov.getTierMultiplier(donor.donorTier);
  // Calculate expected reward
  let expectedReward = baseReward;
  expectedReward =
    (expectedReward * BigInt(bloodTypeMultiplier)) / BigInt(100);
  expectedReward = (expectedReward * BigInt(tierMultiplier)) / BigInt(100);
  // Add bonuses if applicable
  if (donor.consistencyScore >= 80) {
    expectedReward += consistencyBonus;
  }
  // Note: hasCompleteResearchProfile is not available in DonorInfo, so we skip that
bonus
  const message = `
□ Reward Calculation Test for ${donor.bloodType} donor:
• Base Reward: ${formatTokenAmount(baseReward)} BDT
• Blood Type Multiplier: ${bloodTypeMultiplier}% (${donor.bloodType})
• Tier Multiplier: ${tierMultiplier}% (Tier ${donor.donorTier})
```

```
• Consistency Score: ${donor.consistencyScore}%
• Expected Reward: ${formatTokenAmount(expectedReward)} BDT
• Actual Earned: ${formatTokenAmount(donor.totalRewardsEarned)} BDT
• Difference: ${formatTokenAmount(
      expectedReward - BigInt(donor.totalRewardsEarned)
    )} BDT
    `;
    console.log(message);
    alert(message);
  } catch (error) {
    console.error("Error testing reward calculation:", error);
    alert(
      `Error testing reward calculation: ${
        error instanceof Error ? error.message : "Unknown error"
      }`
    );
  }
};
// Test contract connection and multipliers
const testContractConnection = async () => {
  try {
    const provider = await getBrowserProvider();
    if (!provider) {
      alert("Please connect your wallet first");
      return;
    }
    const gov = getContract(
      CONTRACT_ADDRESSES.DAO_GOVERNANCE,
      DonorDAOGovernanceABI,
      provider
    );
    // Test getting incentive parameters
    const [
```

```
    baseReward,
    consistencyBonus,
    dataCompletenessBonus,
    feedbackBonus,
  ] = await gov.getIncentiveParameters();
  // Test getting blood type multipliers for rare blood types
  const bloodTypes = ["O-", "AB-", "B-", "A-"];
  const multiplierResults: Record<string, string> = {};
  for (const bloodType of bloodTypes) {
    try {
      const multiplier = await gov.getBloodTypeMultiplier(bloodType);
      multiplierResults[bloodType] = multiplier.toString();
    } catch (error) {
      multiplierResults[bloodType] = `Error: ${
        error instanceof Error ? error.message : "Unknown"
      }`;
    }
  }
  // Test getting tier multipliers
  const tierResults: Record<string, string> = {};
  for (let tier = 0; tier <= 4; tier++) {
    try {
      const multiplier = await gov.getTierMultiplier(tier);
      tierResults[tier] = multiplier.toString();
    } catch (error) {
      tierResults[tier] = `Error: ${
        error instanceof Error ? error.message : "Unknown"
      }`;
    }
  }
  const message = `
□ Contract Connection Test Results:
□ Incentive Parameters:
```

```
• Base Reward: ${formatTokenAmount(baseReward)} BDT
• Consistency Bonus: ${formatTokenAmount(consistencyBonus)} BDT
• Data Completeness Bonus: ${formatTokenAmount(dataCompletenessBonus)} BDT
• Feedback Bonus: ${formatTokenAmount(feedbackBonus)} BDT
□ Blood Type Multipliers:
${Object.entries(multiplierResults)
  .map(([type, mult]) => `• ${type}: ${mult}`)
  .join("\n")}
□ Tier Multipliers:
${Object.entries(tierResults)
  .map(([tier, mult]) => `• Tier ${tier}: ${mult}%`)
  .join("\n")}
□ Analysis:
${
  Object.entries(multiplierResults).some(([_, mult]) => mult === "0")
    ? "□  Someblood types have 0 multipliers - this will cause 0 rewards!"
    : "□  All blood types have proper multipliers"
}
      `;
      console.log(message);
      alert(message);
    } catch (error) {
      console.error("Error testing contract connection:", error);
      alert(
        `Error testing contract connection: ${
          error instanceof Error ? error.message : "Unknown error"
        }`
      );
    }
  };
  // Update only rare blood type multipliers to ensure proper rewards
  const updateAllBloodTypeMultipliers = async () => {
    try {
```

```
const provider = await getBrowserProvider();
if (!provider) {
  alert("Please connect your wallet first");
  return;
}
const gov = getContract(
  CONTRACT_ADDRESSES.DAO_GOVERNANCE,
  DonorDAOGovernanceABI,
  provider
);
// Define only RARE blood type multipliers (ensuring users get 150-250 BDT rewards)
const bloodTypeMultipliers = {
  "O-": 230, // Universal donor - highest multiplier (230 BDT)
  "AB-": 250, // Rarest blood type (250 BDT)
  "B-": 200, // Rare blood type (200 BDT)
  "A-": 150, // Uncommon blood type (150 BDT)
};
let successCount = 0;
let errorCount = 0;
const results: string[] = [];
// Update each blood type multiplier
for (const [bloodType, multiplier] of Object.entries(
  bloodTypeMultipliers
)) {
  try {
    const tx = await gov.setBloodTypeMultiplier(bloodType, multiplier);
    await tx.wait();
    results.push(`□ ${bloodType}: ${multiplier}% (${multiplier} BDT)`);
    successCount++;
  } catch (error) {
    results.push(
      `□ ${bloodType}: Error- ${
```

```
          error instanceof Error ? error.message : "Unknown"
        }`
      );
      errorCount++;
    }
  }
  const message = `
□ Rare Blood Type Multipliers Update Complete!
□ Results:
${results.join("\n")}
□ Summary:
• Successfully updated: ${successCount} rare blood types
• Failed to update: ${errorCount} rare blood types
• Total rare blood types: ${Object.keys(bloodTypeMultipliers).length}
□ Expected Rewards for Rare Blood Types:
• O-: 230 BDT (Universal donor - highest)
• AB-: 250 BDT (Rarest blood type)
• B-: 200 BDT (Rare blood type)
• A-: 150 BDT (Uncommon blood type)
`;
  console.log(message);
  alert(message);
 } catch (error) {
  console.error("Error updating blood type multipliers:", error);
  alert(
    `Error updating blood type multipliers: ${
      error instanceof Error ? error.message : "Unknown error"
    }`
  );
 }
};
```

Code Listing D: Blood Unit Page

```
"use client";
import { useState, useEffect } from "react";
import { useWallet } from "@/contexts/WalletContext";
import { getBrowserProvider, getContract } from "@/lib/eth";
import BloodDonorSystemABI from "@/lib/abis/BloodDonorSystem";
// import { ENV } from "@/lib/env";
import toast from "react-hot-toast";
import { ethers } from "ethers";
import styles from "./page.module.css";
import { CONTRACT_ADDRESSES } from "@/lib/contracts";
export default function BloodUnitPage() {
  const { address, switchToAddress } = useWallet();
  const [form, setForm] = useState({
    anonymousId: "",
    recordHash: "",
    hb: "0",
    volume: "450",
    donorAddress: "",
  });
  // Medical record data for hash generation
  const [medicalData, setMedicalData] = useState({
    donorName: "",
    donorId: "",
    bloodPressure: "",
    temperature: "",
    weight: "",
    medicalHistory: "",
    medications: "",
    donationDate: new Date().toISOString().split("T")[0],
    donationTime: new Date().toTimeString().split(" ")[0],
    bloodUnitId: "",
    notes: "",
  });
  const [loading, setLoading] = useState(false);
  const [activeTab, setActiveTab] = useState("medical");
  const [hasBloodUnitRole, setHasBloodUnitRole] = useState(false);
  const [bloodUnitStats, setBloodUnitStats] = useState({
    reputation: "0",
    donationCount: "0",
  });
  // Complete research profile form
```

```
const [researchProfileId, setResearchProfileId] = useState("");
const handleChange = (key: string, value: string) =>
  setForm((f) => ({ ...f, [key]: value }));
const handleMedicalDataChange = (key: string, value: string) =>
  setMedicalData((f) => ({ ...f, [key]: value }));
// Generate anonymous ID based on wallet address
const generateAnonymousId = async (walletAddress: string) => {
  try {
    const provider = await getBrowserProvider();
    const contract = getContract(
      CONTRACT_ADDRESSES.BLOOD_DONOR_SYSTEM,
      BloodDonorSystemABI,
      provider
    );
    // Use default salt of 0 (same as donor registration)
    const anonymousId = await contract.generateAnonymousId(
      walletAddress,
      BigInt(0)
    );
    return anonymousId;
  } catch (error) {
    console.error("Error generating anonymous ID:", error);
    return null;
  }
};
```

Code Listing E: Token Award

```
// Reward Token Contract
contract BloodDonorToken is ERC20, AccessControl {
   bytes32 public constant MINTER_ROLE = keccak256("MINTER_ROLE");
   constructor() ERC20("BloodDonorToken", "BDT") {
      _grantRole(DEFAULT_ADMIN_ROLE, msg.sender);
      _grantRole(MINTER_ROLE, msg.sender);
   }
   function mint(address to, uint256 amount) external onlyRole(MINTER_ROLE) {
      _mint(to, amount);
   }
   function burn(address from, uint256 amount) external onlyRole(MINTER_ROLE) {
      _burn(from, amount);
   }
}
```

Code Listing F: Reedem Reward

```
function redeemRewards(uint256 amount) external nonReentrant {
      bytes32 anonymousId = addressToAnonymousId[msg.sender]; // FIXED: Use
consistent mapping
      require(anonymousId != bytes32(0), "Not a registered donor");
      uint256 availableRewards = donors[anonymousId].totalRewardsEarned -
         donors[anonymousId].rewardsRedeemed;
      require(amount <= availableRewards, "Insufficient rewards");
      require(
         rewardToken.balanceOf(msg.sender) >= amount,
         "Insufficient token balance"
      );
      // Update redeemed rewards
      donors[anonymousId].rewardsRedeemed += amount;
      // FIXED: Burn tokens instead of transfer
      rewardToken.burn(msg.sender, amount);
   }
```

Appendix II: Guidelines for Conducting the Focus Group

Statement of Purpose

The focus group discussion approach in this study aimed to identify the requirements of the blockchain based model for provision of incentives to rare blood group donors and to evaluate the model based on its discussed features. The main purpose was to gather data from a purposively selected group of hospital blood donor unit staff and rare blood group donors whose direct experience in blood donation and management provided valuable insights into the practical, ethical, and motivational aspects of the model.

Sampling Procedures for Focus Groups

The focus group comprised two (2) hospital blood donor unit staff members and ten (10) rare blood group donors. Participants were selected purposively, guided by the study's objectives.

Hospital staff were chosen for their expertise in donor management, data handling, and operational workflows.

Rare blood group donors were included for their lived experiences, motivations, and perceptions regarding incentive mechanisms.

This approach ensured that the discussion brought together a homogeneous group with relevant knowledge and experiences to inform the model's refinement and practical feasibility.

Focus Group Pattern

The focus group discussion followed a structured format, ensuring consistency and open participation:

Welcome: Greeting participants and creating a comfortable environment.

Overview of the Topic: Explaining the purpose and scope of the blockchain-based model for the provision of incentives to rare blood group donors.

Ground Rules: Outlining expectations for respectful, confidential, and open discussion.

Opening Question: Initiating dialogue to encourage participants to share their perspectives and experiences.

Guided Discussion: Exploring specific themes related to donor motivation, reward mechanisms, and data security.

Summary and Closing: Reviewing key points, validating responses, and thanking participants for their input.

The discussion was moderated using a **Focus Group Discussion Guide** (see *Appendix IV*), which ensured consistency, credibility, and reliability of the qualitative data collected. Thematic analysis was later applied to identify key insights relevant to model development and donor engagement strategies.

Appendix III: Focus Group Discussion Guide

Title: Focus Group Discussion Guide for a Blockchain-Based Model for Provision of Incentives to Rare Blood Group Donors

Purpose: This guide was designed to facilitate focused discussions with rare blood group donors and hospital blood donor unit staff to gather insights on the design, usability, and ethical considerations of a blockchain-based model for provision of incentive to rare blood group donors for rare blood donors.

Target Participants:

2 hospital blood donor unit staff members

40 rare blood group donors (O−, A−, B−, AB−)

A. Opening Section

Welcome and Introduction

- Thank participants for attending.
- Explain the study's purpose briefly.
- Assure participants of confidentiality and voluntary participation.

Ground Rules

- Respect everyone's views.
- Only one person speaks at a time.
- There are no right or wrong answers.
- Discussions will be recorded (with consent) for accuracy.

B. Discussion Themes and Sample Questions

1. Donor Motivation and Participation

- What motivates you to donate blood, especially as a rare blood group donor?
- What challenges discourage you or others from donating regularly?
- How do you think incentives could influence your decision to donate more often?

2. Awareness and Information

- How did you first learn about your blood group type?
- How well are donors informed about the importance of rare blood group donations?
- What information would you like to receive before or after donation?

3. Incentive Model Perception

- How do you feel about using technology (such as a blockchain-based app) to manage donor incentives?
- What kind of rewards or recognition would be most meaningful to you?
- How can the system ensure fairness and transparency in distributing incentives?

4. Ethical and Privacy Considerations

- Do you have concerns about data security and privacy when using such a system?
- How can your personal or health data be protected?
- What ethical issues should be considered in implementing the model?

5. Usability and System Design Feedback

- What features do you think should be included in the donor incentive app?
- How easy should the system be to use for both donors and staff?
- What challenges do you foresee in using a blockchain-based platform for blood donor management?

C. Closing Section

- Summarize main discussion points.
- Ask if participants have any final comments or suggestions.
- Thank participants for their time and contributions.

Notes for Moderator

- Keep the discussion within 60–90 minutes.
- Encourage quieter participants to share.
- Record responses accurately using notes and/or audio (with consent).
- Use neutral probing to clarify or expand on key points.

Appendix IV: Observation Checklist

Purpose: To systematically record real-time behaviors, engagement, and participation patterns of rare blood donors and staff during donation and prototype testing sessions at the hospital blood donor unit.

Observation Area	Specific Indicators	Observed (✔/✖)	Remarks / Notes
Donor Registration Process	Donor verification procedures		
	Clarity and efficiency of registration		
Donor–Staff Interaction	Friendliness and professionalism of staff		
	Communication clarity on donation procedures		
	Staff knowledge of rare blood group management		
Donor Motivation and Behavior	Reasons mentioned for donating (voluntary, repeat donor, etc.)		
	Donor reactions to incentive or blockchain concept		
	Willingness to participate again		
System Engagement	Donor interaction with prototype interface		
	Usability challenges or feedback shared		
	Staff ability to operate or explain the system		
Environment and Process Efficiency	Availability of equipment and materials		
	Waiting time and donor flow		
	Privacy and comfort during donation		
Overall Observation	General participation trends		
	Notable challenges or best practices observed		

Observer: ____________________ Date: ______________________

Appendix V: Document Review Guide

Purpose:

To extract relevant quantitative and qualitative data from hospital records and reports on rare blood donors and donation activities.

Document Type	**Data/Information to Extract**	**Source/Location**	**Remarks**
Donor register/logbook	Donor ID, blood group, donation date, frequency of donation	Blood donor unit	
Monthly/quarterly reports	Number of donations per blood group, trends over time	Hospital blood bank office	
Donor communication records	Awareness messages, reminders, follow-ups	Donor relations department	
Prototype testing report	Performance logs, user feedback, and technical issues	Research log / IT department	
Policy/guideline documents	Ethical standards, donor eligibility criteria	Ministry of Health / Hospital admin	

Reviewer: ______________________ Date: _______________________

Appendix VI: Content Analysis Theme Guide

Purpose:

To guide the identification and categorization of recurring themes from observations, interviews, focus group discussions, and reviewed documents.

Theme Category	Key Questions / Indicators	Example Codes or Notes
1. Donor Motivation	Why do donors choose to donate blood? What encourages repeat donations?	Altruism, awareness, recognition, incentives
2. Awareness of Rare Blood Groups	Are donors aware of their rare status and its importance?	Knowledge level, communication from staff
3. Technology and Innovation	How do donors and staff perceive the blockchain-based model?	Trust, usability, data privacy concerns
4. Incentive Preferences	What type of incentives do donors find meaningful?	Material, recognition-based, digital tokens
5. Operational Challenges	What barriers exist in managing rare blood group donations?	Limited data, low turnout, system gaps
6. Improvement Suggestions	What recommendations emerge for better donor engagement or system design?	Policy, training, app refinement

Appendix VII: Measures for Reliability and Credibility

Aspect	Strategy Used	Purpose/Outcome
Triangulation	Combined data from observation, document review, and focus groups	Strengthened validity through multiple perspectives
Pretesting of tools	Observation and review guides tested in one pilot session	Ensured clarity and consistency
Peer debriefing	Discussed emerging findings with supervisors/experts	Confirmed interpretation accuracy
Audit trail	Maintained detailed field notes and coding records	Ensured transparency and reliability
Reflexivity	Researcher maintained neutrality and avoided influencing participants	Minimized bias

Appendix VIII: KUREC Clearance Letter

KABARAK UNIVERSITY RESEARCH ETHICS COMMITTEE

Private Bag - 20157
KABARAK, KENYA
Email: kurec@kabarak.ac.ke

Tel: 254-51-343234/5
Fax: 254-051-343529
www.kabarak.ac.ke

OUR REF: KABU01/KUREC/001/05/02/25

Date: 5th Feb, 2025

Leah Chebet Bunei
Reg No: GMI/NE/0217/01/18
Kabarak University,

Dear Leah,

RE: A BLOCKCHAIN BASED MODEL FOR PROVISION OF INCENTIVES TO RARE BLOOD DONORS

This is to inform you that ***KUREC*** has reviewed and approved your above research proposal. Your application approval number is ***KUREC-050225.*** The approval period is ***5/02/2025 – 5/02/ 2026.***

This approval is subject to compliance with the following requirements:

i. All researchers shall obtain an introduction letter to NACOSTI from the relevant head of institutions (Institute of postgraduate, School dean or Directorate of research)
ii. The researcher shall further obtain a RESEARCH PERMIT from NACOSTI before commencement of data collection & submit a copy of the permit to **KUREC.**
iii. Only approved documents including (informed consents, study instruments, MTA Material Transfer Agreement) will be used
iv. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***KUREC***:
v. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***KUREC*** within 72 hours of notification;
vi. Any changes, anticipated or otherwise that may increase the risk(s) or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KUREC*** within 72 hours;
vii. Clearance for export of biological specimens must be obtained from relevant institutions and submit a copy of the permit to KUREC;
viii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal and;
ix. Submission of an executive summary report within 90 days upon completion of the study to ***KUREC***

Sincerely,

Prof. Jackson Kitetu PhD.
KUREC-Chairman

KABARAK UNIVERSITY INSTITUTIONAL RESEARCH ETHICS COMMITTEE
05 FEB 2025
APPROVED
P. O. PRIVATE BAG - 20157, KABARAK

Cc Vice Chancellor
DVC-Academic & Research
Registrar-Academic & Research
Director-Research Innovation & Outreach
Institute of Post Graduate Studies

As members of Kabarak family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.
(1 Peter 3:15)
Kabarak University is ISO 9001:2015 Certified

Appendix IX: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: [illegible]

Date of Issue: 11/March/2025

RESEARCH LICENSE

This is to Certify that Miss.. LEAH CHEBET BUNEI of Kabarak University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: A BLOCKCHAIN BASED MODEL FOR PROVISION OF INCENTIVES TO RARE BLOOD DONORS for the period ending : 11/March/2026.

License No: NACOSTI/P/25/[illegible]

[illegible]

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix X: County Government of Nakuru Authorization Letter

REPUBLIC OF KENYA
COUNTY GOVERNMENT OF NAKURU
DEPARTMENT OF HEALTH SERVICES

Office of the County Director Public Health
P.O. Box 2060-20100
Nakuru, Kenya

Email: info.health@nakuru.go.ke
Website: www.nakuru.go.ke

REF: CGN/CDPH/RES/2025/1137

19th May, 2025

To
Medical Superitendent
Nakuru County Referral & Teaching Hospital

RE: AUTHORIZATION TO CONDUCT RESEARCH
LEAH CHEBET BUNEI – GMI/NE/0217/01/18

The above named is a student from Kabarak University. This letter serves as an authorization from the County Department of Health Services Nakuru for her to conduct research in Nakuru PGH on the topic ***"A block chain based model for provision of incentives to Rare blood group donors".***

Please note that this approval is subject to adherence to the reasonable ethical considerations and the prevailing rules and regulations governing research work. **This research will be for academic purpose.**

Kindly accord her all the necessary support.

Thank you.

COUNTY DIRECTOR
PUBLIC HEALTH & SANITATION
NAKURU COUNTY
P.O. Box 2060-20100,
NAKURU

ELIZABETH KIPTOO
COUNTY DIRECTOR, PUBLIC HEALTH
NAKURU

Appendix XI: Nakuru County Referral and Teaching Hospital Approval Letter

REPUBLIC OF KENYA
COUNTY GOVERNMENT OF NAKURU
DEPARTMENT OF HEALTH SERVICES

Nakuru County Referral & Teaching Hospital
Nakuru County
P.O. Box 71-20100
Nakuru, Kenya

Email: rvpghnakuru@yahoo.com
Website: www.nakuru.go.ke
Telephone: +254 721750460

Ref No: NCRTH/R&EC/VOL I/2025 **13th June 2025**

LEAH CHEBET BUNEI
REG NO: GMI/NE/0217/01/18
KABARAK UNIVERSITY
P.O PRIVATE BAG - 20157
KABARAK

RE: AUTHORITY TO CONDUCT PRE TEST STUDY

Further to your application on the above subject, the Research and Ethics Committee discussed and approved your pre-test study, **A block Chain Based Model for Provision of incentives to Rare Blood Groups Donors.**

Ensure the pre-test is carried out in accordance to the laid down ethics and research regulations.

Kindly submit your findings to the committee prior to publication / exit.

NAKURU COUNTY REFERRAL & TEACHING HOSPITAL
MEDICAL SUPERINTENDENT
13 JUN 2025
P.O. Box 71 - 20100,
NAKURU

for

DR. SAMUEL WANJARA
CHAIRPERSON
RESEARCH AND ETHICS COMMITTEE
NAKURU COUNTY REFERRAL AND TEACHING HOSPITAL

Appendix XII: Blood Group Statistics

REPUBLIC OF KENYA
NAKURU COUNTY GOVERNMENT
DEPARTMENT OF HEALTH SERVICES

Email: rvpghnakuru@yahoo.com
Mobile: +254721750460
When replying please quote
Our Ref:

NAKURU COUNTY REFFERAL &
TEACHING HOSPITAL,
P.O.BOX 71-20100.

18/07/2025

HOSPITAL BLOOD DONOR UNIT

2025 BLOOD GROUPS STATISTICS.

BLOOD GROUPS	JAN	FEB	MARCH	APRIL	MAY	JUNE
A+	207	117	135	170	144	171
B+	123	89	110	137	119	133
O+	266	131	213	300	185	299
B-	3	3	2	4	7	12
O-	15	13	6	8	10	12
A-	5	6	4	2	8	6
AB+	22	17	22	22	23	33
AB-	NIL	2	NIL	NIL	NIL	2

NAKURU COUNTY REFERRAL & TEACHING HOSPITAL
MEDICAL SUPERINTENDENT
18 JUL 2025
P.O. Box 71 - 20100,
NAKURU

Appendix XIII: Model Testing Letter

REPUBLIC OF KENYA
COUNTY GOVERNMENT OF NAKURU
DEPARTMENT OF HEALTH SERVICES

Nakuru County Referral & Teaching Hospital
Nakuru County
P.O. Box 71-20100
Nakuru, Kenya

Email: rvpghnakuru@yahoo.com
Website: www.nakuru.go.ke
Telephone: +254 721750460

25th August, 2025

HOSPITAL BLOOD DONOR UNIT

RE:LEAH CHEBET BUNEI

The above named student came to our hospital blood donor unit and we tested A Blockchain Model for Provision of Incentives to Rare Blood Group Donors. The research was so encouraging and this will encourage and motivate the rare blood donors to donate blood in order to save more lives.

Regards,

NAKURU COUNTY REFERRAL & TEACHING HOSPITAL
MEDICAL SUPERINTENDENT
08 SEP 2025
P.O. Box 71 - 20100
NAKURU

MAURINE J KANDIE

Appendix XIV: Evidence of Conference Participation

KABARAK UNIVERSITY

Certificate of Participation

Awarded to

Leah Chebet Bunei

For successfully participating in the 15th Annual Kabarak University International Research Conference held from 10th-11th July 2025 and presented a paper entitled ***"A blockchain based model for provision of incentives to rare blood group donors."***

Conference Theme

Data Science and Artificial Intelligence for Digital Transformation in Different Sectors.

Prof. Peter Rugiri
Dean, School of Science, Engineering & Technology

Dr. Phillip Nyawere
Director - Research, Innovation and Outreach

<u>Kabarak University Moral Code</u>

As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.

(1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix XV: List of Publication

International Journal of Computer Applications Technology and Research
Volume 14–Issue 10, 13 – 20, 2025, ISSN:-2319–8656
DOI:10.7753/IJCATR1410.1004

An Implementation of a Blockchain-Based Model for Provision of Incentives to Rare Group Blood Donors

Leah Chebet Bunei
Student
Kabarak University Nakuru, Kenya

Prof.Simon Maina Karume
Senior Lecturer
Kabarak University Nakuru, Kenya

Dr. Ruth Oginga
Lecturer
Kabarak University Nakuru, Kenya

Abstract: A critical necessity towards provision of universal healthcare by the Kenyan government is to ensure constant blood supply in the countries blood donor unit. Rare blood group donors always play a critical role in healthcare sector by provision of life saving support to patients with specific medical needs to live longer and with higher quality of life. However, the scarcity of these rare blood types namely; AB negative, B negative, A negative and O negative leads to a great challenge especially in emergency or high demand situations. Despite the crucial need for blood donations, donors may be less motivated to donate blood regularly due to lack of effective incentives. Traditional blood donation management systems are often not transparent, inadequate donor identification and delayed incentives to rare blood group donors. This demoralizes them from donating blood again particularly those individuals with rare blood types. To address these challenges, this study aimed to develop a blockchain based model prototype for provision of incentives to rare blood group donors that offered trust, transparency and security tailored to increase blood donation. Study involved creation of a solidity smart contract that was deployed and implemented through the use of React js and is available at https://grandmullah.github.io/donor. For the purpose of regulatory hurdles, data protection measures are used to safeguard donor information which includes encryption, access controls and also ensuring compliance with data privacy regulations. In conclusion, a blockchain based model for provision of incentives to rare blood group donors presents an approach to address the challenges encountered by the blood donation systems, particularly when it comes to rare blood types.

Keywords: Blockchain, Model, Smart Contract, Confidentiality, Donors

1. INTRODUCTION

Blood donation is essential in healthcare worldwide, yet many blood donor units face persistent challenges in maintaining adequate supplies, especially for rare blood types. Blood transfusion helps in supporting surgeries, emergencies, chronic illness treatments as well as benefiting patients that face life-threatening situations for example leukemia and hemophilia in order to live longer and with higher quality of life. World Health Organization emphasizes the need for safe blood and blood products, specifically for those individuals with the rare blood types that are critical yet often in short supply (World Health Organization, 2021).

Blood mainly comes from voluntary non-remunerable donors including students and patient's family members. The emergencies that require blood donation are always on the rise but lifesaving donors are not present to meet the needs of these emergencies. Blood has a great significance role in human life and delivers required substances like nutrients and oxygen to the cells (Sadri, et al., 2021). For medical treatment, blood availability is vital where the need for blood is growing up every year (Kumar & Dhanya, 2020).

Despite many awareness campaigns, it is still hard to keep enough blood reserves available at all times, which makes it even worse for rare blood groups. The rare blood types include AB negative (AB-) which is the rarest blood types found in less than 1% of the population, B negative (B-) is another relatively rare blood type which 2% of the population has, A negative (A-) present in about 6% of the population and O negative (O-) which is the universal donor type found in about 7% of the population. However, finding and encouraging donors with these rare blood types is difficult, especially when their blood is needed quickly. Therefore, it is important to have a reliable and motivated group of rare blood group donors to meet the demand (American Red Cross, 2023).

Ensuring the availability of blood is very important in saving human lives thus every drop of blood counts whereby in a country like Kenya, seven people need a blood transfusion in every ten minutes. The COVID-19 (coronavirus)

International Journal of Computer Applications Technology and Research
Volume 14–Issue 12, 35 – 42, 2025, ISSN:-2319–8656
DOI:10.7753/IJCATR1412.1005

Design of A Blockchain-based Model for Provision of Incentives to Rare Group Blood Donors

Leah Chebet Bunei
Student
Kabarak University Nakuru, Kenya

Prof.Simon Maina Karume
Senior Lecturer
Kabarak University Nakuru, Kenya

Dr. Ruth Oginga
Lecturer
Kabarak University Nakuru, Kenya

Abstract: A critical requirement in achieving universal healthcare in Kenya is to maintain a consistent and adequate blood supply in the blood bank. Rare blood group donors, specifically those with AB-negative, B-negative, A-negative, and O-negative blood types, played a vital role in providing life-saving support to patients with special medical needs. However, the scarcity of these blood types posed a significant challenge, especially during emergencies or periods of high demand. Donor motivation remained low due to ineffective incentive systems, as traditional blood donation management platforms often lacked transparency, poor donor identification, and delayed or inadequate reward mechanisms. To address these challenges, the researcher developed a blockchain-based model prototype designed to provide secure, transparent, and trustworthy incentives for rare blood group donors. The model featured a token reward module that automatically generated and distributed digital tokens to verified donors, allocating 250 tokens for AB−, 230 for O−, 200 for B−, and 150 for A−, which could be redeemed for benefits such as subsidized medical care, free checkups, preferential services, and T-shirts. To ensure data protection and regulatory compliance, the model employed encryption, access controls, and adherence to data privacy laws. The research adopted agile methodology in prototype development. In conclusion, the blockchain-based model for provision of incentives to rare blood group donors demonstrated a viable and secure solution to the challenges in blood donation management, enhancing trust, transparency, and donor motivation, particularly among rare blood group donors.

Keywords: Blockchain, Model, Smart Contract, Confidentiality, Donors

1. INTRODUCTION

Blood donation is essential in healthcare worldwide, yet many blood donor units face persistent challenges in maintaining adequate supplies, especially for rare blood types. Blood transfusion supports surgeries, emergency care, and chronic illness treatment, and benefit patients facing life-threatening conditions, such as leukemia and hemophilia, to live longer and with a higher quality of life. The World Health Organization emphasizes the need for safe blood and blood products, particularly for individuals with rare blood types that are critical yet often in short supply (World Health Organization, 2021).

Despite many awareness campaigns, it is still hard to keep enough blood reserves available at all times, which makes it even worse for rare blood groups. The rare blood types include AB negative (AB-) which is the rarest blood types found in less than 1% of the population, B negative (B-) is another relatively rare blood type which 2% of the population has, A negative (A-) present in about 6% of the population and O negative (O-) which is the universal donor type found in about 7% of the population (Debele et al., 2023). However, finding and encouraging donors with these rare blood types is difficult, especially when their blood is needed quickly. Therefore, it is important to have a reliable, motivated group of rare blood group donors to meet demand (American Red Cross, 2023).

Ensuring the availability of blood is very important for saving human lives; thus, every drop of blood counts. In a country like Kenya, seven people need a blood transfusion every ten minutes (World Bank, 2022). The COVID-19 (coronavirus) pandemic in 2020 worsened the situation, as only 16% of the 1 million blood units required were collected (World Bank, 2022).

Globally, the policies that govern blood donation are typically guided by a combination of international guidelines, national regulations, and local health standards. These include the World Health Organization, which provides global guidelines and standards for safe blood donation practices (WHO, 2010). We also have the American Association of Blood Donor Units (AABB),