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Enhancing Donation Traceability and Promoting Sustainability through Blockchain Technology

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Master in Digital Technologies for Business

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TECNOLOGIAS
E ARQUITETURA

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I dedicate this thesis to Madalena and Xavier. May you always remember that when we give, we open our hearts to the world, and what we receive in return is often much more than we could ever anticipate.

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To my wife and children for your patience and love during the times I was absorbed in this work and I was not able to spend the time you deserved. I couldn't have done it without your understanding and support.

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Resumo

Os donativos filantrópicos desempenham um papel de relevo nos desafios sociais e no apoio a causas. Contudo, preocupações quanto à transparência, responsabilidade e utilização eficiente dos fundos ou dos objetos doados persistem no setor filantrópico. Esta dissertação de mestrado investiga o potencial da tecnologia do Blockchain para enfrentar estes desafios e melhorar o rastreio das doações, promover a sustentabilidade e fomentar a confiança entre doadores, organizações e beneficiários.

A tese explora o conceito de *tokenizar itens* doados em NFTs (Non-Fungible Tokens) para registar a sua proveniência, histórico de utilização e impacto ambiental. Esta abordagem pode aumentar o ciclo de vida dos objetos doados, promover os princípios da economia circular e fornecer aos doadores uma prova real e confiável das suas contribuições. Adicionalmente, a tecnologia dos dados distribuídos segura e transparente da Blockchain pode rastrear o movimento dos donativos para as organizações e beneficiários, garantindo transparência e responsabilidade.

A pesquisa investiga os benefícios, desafios e soluções potenciais para a integração da Blockchain e dos NFTs no processo de doação. Com o aproveitamento das funcionalidades dos *Smart-Contracts* e dos registos imutáveis, esta tese visa contribuir para o desenvolvimento de um quadro seguro e transparente para a rastreabilidade de donativos. Para isso apresenta-se um caso de uso específico para demonstrar a aplicação prática desta abordagem.

Palavras-chave: Blockchain, Donativos, Rastreabilidade, NFTs, Sustentabilidade, Filantropia

Abstract

Philanthropic donations play a vital role in addressing societal challenges and supporting charitable causes. However, concerns about transparency, accountability, and the efficient utilization of donated funds or objects continue to persist in the philanthropic sector. This master's thesis investigates the potential of Blockchain technology and NFTs (Non-Fungible Tokens) to address these challenges and enhance donation traceability, promote sustainability, and foster trust among donors, charitable organizations, and beneficiaries.

The thesis explores the concept of tokenizing donated items into NFTs to record their provenance, usage history, and environmental impact. This approach can extend the lifecycle of donated items, promote circular economy principles, and provide donors with verifiable proof of their contributions. Additionally, Blockchain's secure and transparent distributed ledger technology can track the movement of donations from donors to organizations and beneficiaries, ensuring transparency and accountability.

The research examines the benefits, challenges, and potential solutions for integrating Blockchain and NFTs into the donation process. By leveraging smart contracts and immutable records, this thesis aims to contribute to the development of a secure and transparent framework for donation traceability. A specific use case is presented to demonstrate the practical application of this approach.

Keywords: Blockchain, Donation, Traceability, NFTs, Sustainability, Philanthropy

Abbreviations

API	Application Programming Interface
ABI	Application Binary Interface
dApps	Decentralized Applications
DID	Decentralized Identification
DSRM	Design Science Research Methodology
EVM	Ethereum Virtual Machine
NFC	Near Field Communication
NFT	Non-Fungible Token
NGO	Non-Governmental Organization
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PoA	Proof of Authority
PoS	Proof of Stake
PoW	Proof of Work
QR	Quick-Response
RFID	Radio Frequency Identification
RWA	Real World Assets
SSI	Self-Sovereign Identity
UI	User Interface
URI	Uniform Resource Identifier
UX	User Experience

Table of Contents

List of Figures

List of tables

Chapter 1
Introduction

The necessity for frequent replacement of eyeglass lenses, raises significant concerns regarding the sustainability and cost-effectiveness of current practices. This issue was highlighted during routine medical consultation for a young patient who required lens replacement at very regular intervals. The revelation that perfectly functional, yet expensive, lenses were disposed due to the absence of a reuse or recycling protocol, highlights a critical gap in the lifecycle management of eyewear.

Motivated by the desire to make a positive change, I embarked on a mission to explore possibilities that would prevent the unnecessary disposal of these lenses. I wanted to create a system that would enable the donation and tracking of these perfectly good eyeglass lenses.

This issue sparked my desire to find a sustainable solution, not only to reduce waste but also to extend the life cycle of objects using for this a particular use case of eyeglass lenses donation.

Incorporating the principles of circular economy into the eyewear industry presents a viable solution to the challenges identified in the reuse and recycling of eyeglass lenses. The circular economy model, characterized by its emphasis on resource efficiency and waste minimization, aligns perfectly with the goal of extending the lifespan of eyewear components.

This model not only reduces environmental impact through decreased waste generation but also promotes economic sustainability. By creating a system where any perfectly functional and valuable item can be refurbished and redistributed, the industry can also significantly lower the costs associated with manufacturing new items.

Furthermore, this approach can democratize access to valuable goods, especially for underprivileged communities, by providing high-quality or perfectly working items at a fraction of the cost or even for free.

By Implementing a thoughtful framework to track and distribute donated valuable objects, we can make a significant impact on people's lives, providing them with the opportunity to access quality products without the burden of excessive costs.

1.1 Overview

In this work I would like to provide a comprehensive exploration of how Blockchain technology can revolutionize the philanthropic sector. The core premise is that this technology can significantly

enhance transparency, accountability, and the efficient use of donations, addressing long-standing challenges in philanthropy.

1.2 Motivation

I am deeply motivated to encourage people to donate valuable objects because it has the potential to create positive social impact and promote sustainability. By donating items that are still in good condition but no longer needed, we can help reduce waste and extend the lifespan of these objects.

One important aspect of my motivation is to ensure that donors feel confident their donations are being used as intended. Transparency and accountability are crucial in building trust between donors and the organizations they support.

I am dedicated to implementing reliable systems and processes that guarantee the proper utilization of each donated item, aligning with the donor's intentions.

Because I truly believe that it can make a big difference in society and help taking care of our planet by redefining the idea of reusing things and making sure we have clear rules and honesty in place. This way we can create a cycle of giving that has a positive impact.

Confident that this work can bring a real change. Together, we can build a future where donations play a key role in making the world a better place—a world that is fair, caring, and environmentally responsible.

1.3 Goals

1.3.1 Create a Blockchain Donation Framework

Design a framework structure that enables transparency, accountability, reliability, and traceability of donated items by leveraging the power of Blockchain technology and its resources. This framework aims to create a system that enhances the visibility and trustworthiness of the entire donation process.

By utilizing Blockchain technology, we can establish a decentralized and immutable ledger that records every step of the donation journey. To each donated item it is assigned a unique digital identity or token on the Blockchain. This token stores relevant information about the item, such as its description, condition, and donor details.

Transparency is a crucial aspect of this framework. Anyone involved in the donation process, including donors, recipients, and other stakeholders, can access a public record of all transactions and interactions related to the donated items. This transparency enforces confidence in the system, ensuring that all parties can verify the integrity and legitimacy of the donations.

Accountability is another key element facilitated by the Blockchain-based framework. The decentralized nature of the Blockchain eliminates the need for central authority, reducing the

possibility of fraudulent activities or mismanagement. Each transaction and transfer of ownership is securely recorded on the Blockchain, creating a transparent trail that can be audited at any time. This enables increased accountabilities for all participants in the donation ecosystem.

Reliability is essential in the donation process, as it ensures that the items reach the intended recipients and are utilized for their intended purpose. By leveraging the immutability and security features of the Blockchain, we can establish a robust system where every transaction and transfer is verifiable and cannot be altered or tampered with. This reliability minimizes the risk of items getting out of track and being misused.

Lastly, traceability plays a significant role in the framework. Each donated item's journey, from the initial donation to its final recipient, can be traced through the Blockchain. This allows donors and recipients to track the progress of the donation and ensures that items are distributed fairly and efficiently. Additionally, the traceability feature helps organizations and donors understand the impact of their contributions by providing insights into how their donations are being utilized.

In summary, the proposed framework leverages Blockchain technology to establish a transparent, accountable, reliable, and traceable system for managing donated items. By implementing this structure, we can leverage trust, enhance efficiency, and make a positive impact in the world of donations.

1.3.2 Implement a Use Case of this Framework

Develop a practical example to show the effectiveness and usability of the specified framework. In this case, It considered a solution to track the donation of eyeglasses, focusing specifically on their lenses. The goal is to establish a system that enables donors to monitor the progress and impact of their donations by providing detailed tracking information. I aim to promote the idea of a positive cycle of giving, where donors are motivated and encouraged by the positive outcomes of their contributions.

Moreover, this concept can take a step further by leveraging Blockchain technology and its decentralization to ensure that both local and international social organizations/non-governmental organizations (NGOs) have access to detailed information about the availability of specific lenses based on their parameters. This way, these organizations can efficiently match individuals in need with the most suitable lenses based on the availability stated on the Blockchain records. Through the Blockchain, they can access real-time data, identify the lenses that meet the required specifications, and provide timely assistance to those who require them.

This integration of Blockchain technology with the donation tracking system adds an extra layer of transparency, efficiency, and effectiveness, ultimately facilitating a more impactful and targeted approach in assisting those in need.

1.4 Methodology

The methodology applied in this research is the Design Science Research Methodology (DSRM) [1]as this allows to validate the process of creating and evaluating an artifact which is the main target of this thesis. Its process establishes the steps to effectively validate the idea and through the iterations process conduct the research of designing new tools to solve specific problems. On Figure 1 it is showed the process model of the DSRM.

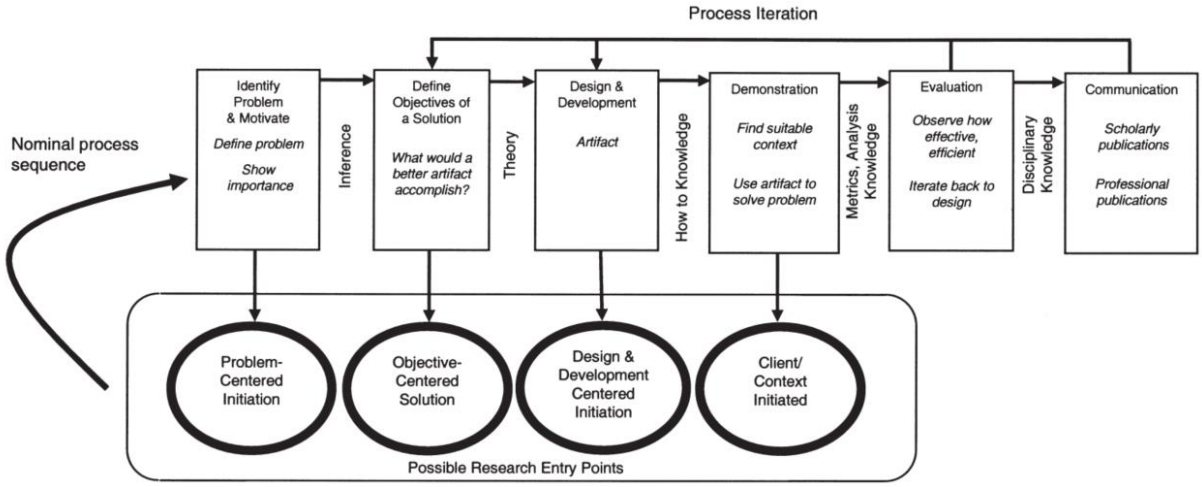

Figure 1 – DSRM Process Model from [1]

The Methodology has four different entry points. The Problem Centered Initiation which starts with identifying a specific problem in a real-world context. The focus is to understand and define the problem clearly. Researchers then develop an artifact to address this problem. It's a direct response to practical challenges faced in a specific domain.

The Objective-Centered Solution entry point starts point is an innovative solution or idea. The researcher has an idea for a new artifact, like a tool, method, or model, and the research revolves around developing this artifact. The focus then moves to finding a problem or setting where this solution could be effectively applied.

The third entry point is the Design and Development Centered where the research focuses primarily on the creation and development of an artifact. The emphasis is on the design process itself, exploring new methods, materials, or technologies to create something new. The artifact's application to a specific problems is secondary to its development.

The fourth entry point is the Client/Context-Initiated. Here it begins in a specific context or with a client's needs. It's often used in consultancy where the artifact is developed in response to a client's specific requirements or within a particular operational context.

1.5 Dissertation Outline

With the goals defined and the methodology selected, below it is outlined the structure of the work emphasizing the process defined by the methodology. Knowing that the introduction was made on Chapter 1, the remaining work is conducted and explained throughout the following chapters:

Chapter 2 offers a comprehensive review of current advances in Blockchain and donation traceability by performing a systematic review of the available work.

Chapter 3 details the artifact of our system: “Blockchain Donation Framework”. It explores the architecture and the development process during the first iteration of the Design Science Research Methodology (DSRM), providing an in-depth analysis of each component, its implementation, and their overall contribution to the system.

Chapter 4 describes the scenario in which the artifact was tested, including details about the environment and members. This chapter also presents the evaluation of the artifact, focusing on the results based on the predefined criteria for each of the DSRM iterations.

Chapter 5 summarizes the work done, highlighting the contributions and limitations of the research. It emphasizes areas for future improvement, leading to suggestions for consequent research in this field.

Chapter 2

Related Work

2.1 Introduction

This literature review was preformed to understand a new approach on donation traceability supported by the Blockchain technology, starting from key academic sources including Scopus, the ACM Digital Library, and IEEE Xplore. These databases were chosen for their comprehensive coverage and in the fields of Blockchain, Computer Science and Technology.

Scopus provided an overview of current research trends, the ACM Digital Library offered in-depth insights into computing and information technology and also Web of Science contributed with valuable perspectives. Together, these sources allowed a systematic exploration of Blockchain applied to donation traceability, highlighting ongoing and upcoming developments and trends around this subject. This review aims to synthesize these findings, presenting a consolidated view of the current state and potential future directions in this dynamic upcoming technology field.

A research query was created to filter the articles that are analyzed below. Because the query syntax is not the same on each database, below there are the queries used on each of them. Also the queries were last performed in January 2024 and they include all the articles available until then.

- Scopus: (ABS (Blockchain) AND ABS (Donation) AND ABS (Traceability)
- ACM: [Abstract: Blockchain] AND [Abstract: Donation] AND [Abstract: Traceability]
- Web of Science: AB=(Blockchain) AND AB=(Donation) AND AB=(Traceability)

Because the number of reported studies was low, no more filters were added to the query to ensure that there was enough data to be analyzed in this research.

2.2 Study Selection

To select the articles and studies that were on the scope of this work the PRISMA[2] framework was applied, using the designed guidelines to improve the reporting and quality of this systematic review and meta-analyses. On Figure 2 is presented the flow used to identify studies on the scope of this thesis.

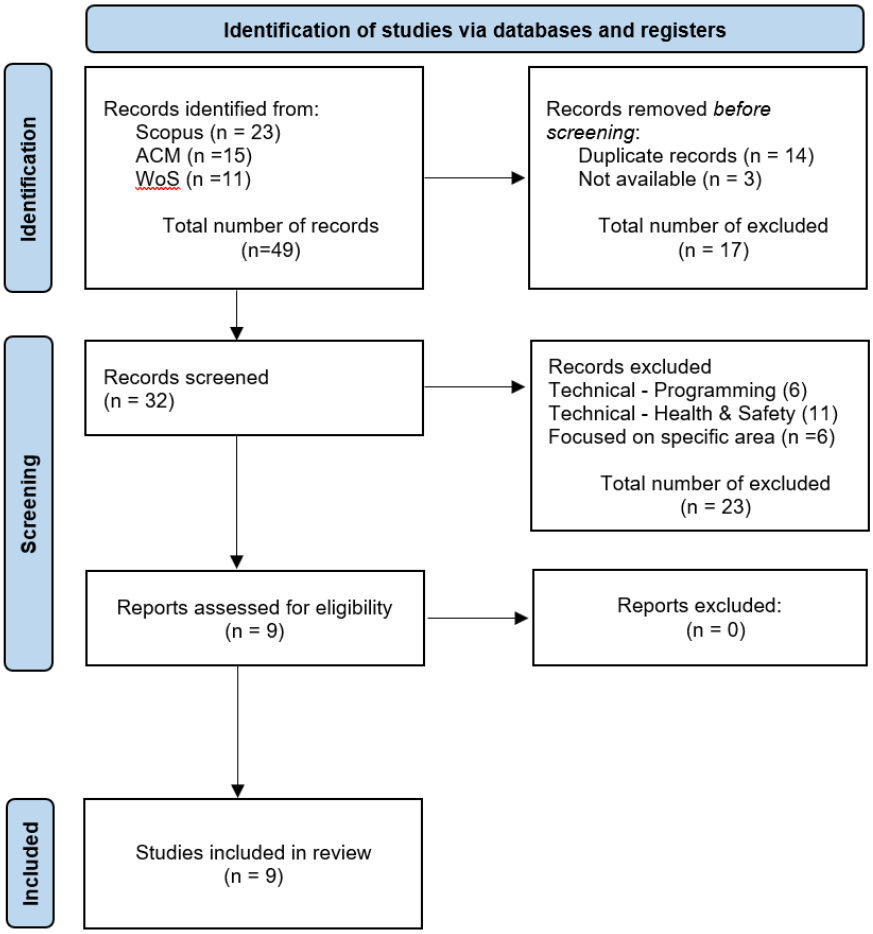

Figure 2 - PRISMA Methodology

On table 1 is showed the list of the 32 screened documents. All of these are divided by its scope:

- Traceability and Donation, for those who focus on general non-technical blockchain perspectives.
- Specific Area, for those that are looking at some very specific or niche areas.
- Technical Programming, for those that are focused on software development and software engineering.
- Technical Health and Safety, for those that are mainly focused on the health business or people safety.

Table 1 – List of the Screened documents

ID	TRACEABILITY & DONATION	SPECIFIC AREA	(TECHNICAL) PROGRAMMING	(TECHNICAL) HEALTH & SAFETY
[3]	X			
[4]				X
[5]			X	
[6]	X			
[7]				X
[8]			X	
[9]			X	
[10]	X			
[11]				X
[12]	X			
[13]				X
[14]			X	
[15]	X			
[16]			X	
[17]				X
[18]	X			
[19]	X			
[20]				X
[21]				X
[22]			X	
[23]		X		
[24]		X		
[25]		X		
[26]				X
[27]				X
[28]		X		
[29]	X			
[30]				X
[31]				X
[32]	X	-	-	-
[33]	-	X	-	-
[34]	-	X	-	-

For the actual scope of this literature review the ones that were included are the records that are focused on the traceability and donation scope.

Starting the review with Maia e Coutinho et al. [3], in the Studie, it is explored the use of Blockchain technology to enhance the transparency and traceability of crowdfunding campaigns. The study presents an architecture using Ethereum Blockchain and smart contracts to track the flow of funds and analyze the financial costs and transaction times in crowdfunding. This architecture aims to provide

investors with clearer insights into how their funds are being utilized, consequently increasing trust and efficiency in crowdfunding activities. The research includes experiments and performance analysis to evaluate the practicality and cost-effectiveness of implementing Blockchain solution in real-world crowdfunding scenarios.

He et al. [6] details an Ethereum-based system designed to boost food bank operations through smart contracts and traceability. It focuses on improved accountability and transparency, thanks to Blockchain technology. The system leverages Ethereum's platform for secure and efficient food distribution, introducing stakeholder trust and addressing food insecurity effectively.

The work of Ugaz-Burga et al.[10] discusses the development of a Blockchain-based system to enhance the transparency and traceability of donations. The first addressed challenges were the lack of control and traceability in donation management. The solution proposed was created using a private Ethereum-based Blockchain with a Proof of Work (PoW) consensus protocol and smart contracts. This solution aimed to track donations from the donor to the beneficiary, ensuring transparency and accountability. The key aspects of this work are aligned with this thesis and it included creating a Blockchain network, developing smart contracts, and integrating mobile applications for the end users. The implementation: demonstrated feasibility and effectiveness in managing and tracing donations.

The solution used the Servir Group, which is the managing entity, as the central role on managing the donations and ensuring that the intended beneficiaries are reached.

Results demonstrated the potential of Blockchain and smart contracts in improving donation traceability and management.

Almaghrabi et al [12] discusses a blockchain-based framework designed to enhance transparency and traceability in charity donation processes. This system, built on the Ethereum platform, allows all parties involved—from donors to recipients—to track the progress of donations in real time.

A major strength of the system is its ability to provide real-time, transparent tracking of donations, which helps restore donor confidence. It is also approached scalability issues, and its substantial energy consumption raising sustainability concerns. Despite these challenges, the framework promises significant improvements in how charitable donations are managed and tracked

Looking at the impact of Blockchain technology on the motivation to donate, the research by Baudier et al. on Can Blockchain Enhance Motivation to Donate [15] done on the context of USA's charity organization specifically investigates how different religious beliefs moderate the acceptance and use of Blockchain in donations, applying theories of reasoned action and planned behavior. It

addresses a novel intersection of technology and charity as well as it incorporates a diverse set of important factors like age, gender, and religion and their impact on the donation process. Although it is geographically limited to USA and focused primarily on religion it emphasizes transparency significantly impacts the donation process.

The document of Eliang et al [18] outlines a blockchain-based smart contract system for enhancing the operations of food banks, utilizing the Ethereum platform for improved traceability and accountability in food distribution. This approach aims to ensure transparency for food banks that manage resources from various sources and distribute them to those in need. The system uses Ethereum's smart contracts to automate processes and record each transaction on a decentralized ledger.

In this approach it is enhanced the transparency and accountability, which can build trust among donors, food banks, and recipients by ensuring that all transactions are recorded and traceable. This solution can potentially reduce waste and fraud, ensuring that resources are used efficiently and reach those truly in need. Additionally, the use of smart contracts automates many operations, potentially reducing administrative costs and errors associated with manual processes.

Recently on 2023 Klug e Prinz et al. [19] discussed the development of a data-based transparency system directed at ensuring fair pricing in the agriculture and food sector. This system was designed to provide authenticated, traceable, and irreversible data about food origin and production processes, with a focus on Blockchain technology for data verification. The paper includes a study conducted in collaboration with stakeholders, exploring technical possibilities and creating a reference model for the system. The reference model integrates decentralized registers and data cooperation concepts, emphasizing Blockchain as a key component for data traceability and irreversibility. The study contributes to research on Blockchain applications in governmental systems and examines stakeholder concerns and roles in the governance of this Blockchain-supported data space. It aimed to provide reliable information about food origin and production processes. This work includes the use of advanced Blockchain technology for data traceability and the collaboration with stakeholders to understand technical possibilities.

The document of Javhad et al [29] discusses a blockchain-based platform designed to enhance transparency, traceability, and security particularly focusing on corporate social responsibility (CSR) and scholarships. It highlights the growing demand for accountability in the philanthropic sector and proposes a system that leverages permissioned blockchain networks to manage donations more

efficiently. The platform integrates a comprehensive database of scholarships and CSR activities facilitated through NGOs to support financially disadvantaged students.

One of the main strengths is the reduced operational costs that it offers by its resource allocation processes. This efficiency is achieved through the automation of transactions and the use of smart contracts that ensure secure monetary transfers. Additionally, the immutable and decentralized nature of blockchain provides a verifiable record of all transactions, which helps in building trust among stakeholders and enhancing the accountability of charitable contributions. The system also supports a wide range of participants, including CSR-indexed companies, government scholarship programs, non-profit organizations, and the recipients to leverage the scope and the impact these donations.

UpHaaR, which is a work from Saraswat et al. [32] is a comprehensive analysis and proposal of a Blockchain-based system designed to enhance transparency and security in charity donation processes. The scheme, aims to address common issues in traditional charity donation systems, such as fraudulent activities and lack of traceability, by utilizing Blockchain technology. Key features of UpHaaR include the use of smart contracts, certificate-less cryptography, and signcryption to ensure the security and privacy of users. The system was designed to provide a reliable and efficient platform for charity donations, mitigating risks associated with fake fundraisers and ensuring that donations reach their intended beneficiaries. It also covers a new problem as it discusses the social concern raised by fake charity fundraiser schemes and highlights the need for a trusted and auditable approach to manage the reputations of charity organizations.

While previous research has left a strong foundation, my thesis builds upon it by introducing fresh tools and concepts to the scientific community. I aim to explore deeper into expanding the field of blockchain for donation traceability, proposing different solutions to increase transparency and trust. Additionally, this work, in addition to the previous ones, recognizes the growing importance of the circular economy and its role in sustainable practices.

By incorporating these elements, I present a new perspective on how serialization and smart contracts can be implemented to optimize donation management, enhancing both efficiency and reliability. This comprehensive approach not only expands upon existing knowledge but also covers the way for further research in these crucial areas.

Chapter 3

Blockchain Donation Framework

This Framework outlines a detailed process for the donation of items through Non-Fungible Tokens (NFTs). In addition to outlining the donation process it also aligns with the principles of a circular economy by encouraging the reuse of items. This approach benefits the environment and the society by extending the life cycle of products, reducing waste, and promoting sustainable consumption. It starts by identifying the problems and requisites, defining donor personas and highlighting different motivations and privacy preferences. The framework includes detailed steps to be done by the actors, emphasizing the use of Blockchain, NFTs and Decentralized Applications. It suggests a process to create the digital asset (NFT) involving minting it on a Blockchain, ensuring it includes detailed metadata and unique identifiers. The framework also describes how to setup smart contracts for transaction records and ownership transfer and discussing the importance of traceability. All of this guaranteed by the Blockchain protocols.

3.1 Problem identification and requisites

3.1.1 Problem identification

One of the most significant issues nowadays is the waste of fully functional products. A large number of items in good condition are discarded each year, even though they could serve the needs of others. This waste is not only environmentally unsustainable, but it also represents a lost opportunity to help those in need. One of the reasons for this wastage is the lack of an effective mechanism to connect donors with recipients.

Also, because of lack of reuse, there is an ongoing cycle of unnecessary production and consumption. New items are continually manufactured, consuming substantial resources, even when there are still products underused that could answer to the same needs. This cycle of producing new items, many of which could be replaced by already available used items, leads to a significant environmental and economic inefficiency.

At last, the lack of trust in the donation process can block the circle of donation caused by insufficient traceability and transparency in the donation journey. Potential donors often have reservations about participating in donation activities due to uncertainties about the destination and destination of the donated items. Without a reliable tracking system, it is challenging to ensure that donations are managed responsibly and can reach their intended destinations.

These problems highlight the need for a solution that can ensure the efficient redistribution of usable items, reduce unnecessary production and consumption, and build trust through transparent and traceable donation processes. A Blockchain based framework stands out as a solution to address these issues, leveraging this technology's strengths in traceability, transparency, and security.

3.1.2 Solution requisites

To ensure that the stated problems can be properly addressed some requisites must be achieved to mitigate the identified difficulties.

For this, the framework to be developed must prioritize ease of use, especially in creating donations. It must enable users to list items for donation effortlessly, with a straightforward process. This simplicity is key to encourage more people to participate in the donation process, thus increasing the variety and volume of items available.

Secondly, a major requirement is the development of a simple yet effective user interface. The platform should be designed to be used by people with different levels of technology expertise. This includes intuitive navigation and a clear layout. The goal is to provide an engaging experience that guides users smoothly through each step of the donation process, reducing errors and increasing user satisfaction.

Last, but not the least, security cannot be overseen. The framework needs to ensure the safety and integrity of the entire donation process, from the listing process of an item to its final delivery. Using Blockchain technology, the system should offer a secure, transparent, and tamper-proof record of all transactions. Strong user authentication methods should be in place to protect personal data and prevent unauthorized access and the decentralized solution must ensure data availability and protection to cyber security issues.

3.2 Design Specification

The image 3 represents a structured framework that highlights the circular donation process of eye lenses. It begins with the registration of donors and recipients; it establishes a validated ecosystem where both parties are securely logged into the system. A validation hub then ensures the accuracy of the lens's specifications updating the digital asset information. This digital representation serves as a unique identifier ensuring the traceability with a digital fingerprint in the shape of a serial number. Following serialization for unique identification, these digital assets are recorded on the blockchain, offering an immutable ledger that details each item's provenance and ownership. This allows searching capabilities within the blockchain, ensuring that stakeholders can verify and trace the donation.

Completing the cycle, shipping traceability is integrated, allowing the physical journey of the lenses to be monitored, consequently closing a loop in the donation process and ensuring the integrity of each transaction from start to finish. New loops can start as soon as the receiver wants to re-donate de lenses supporting the base concept of the circular economy.

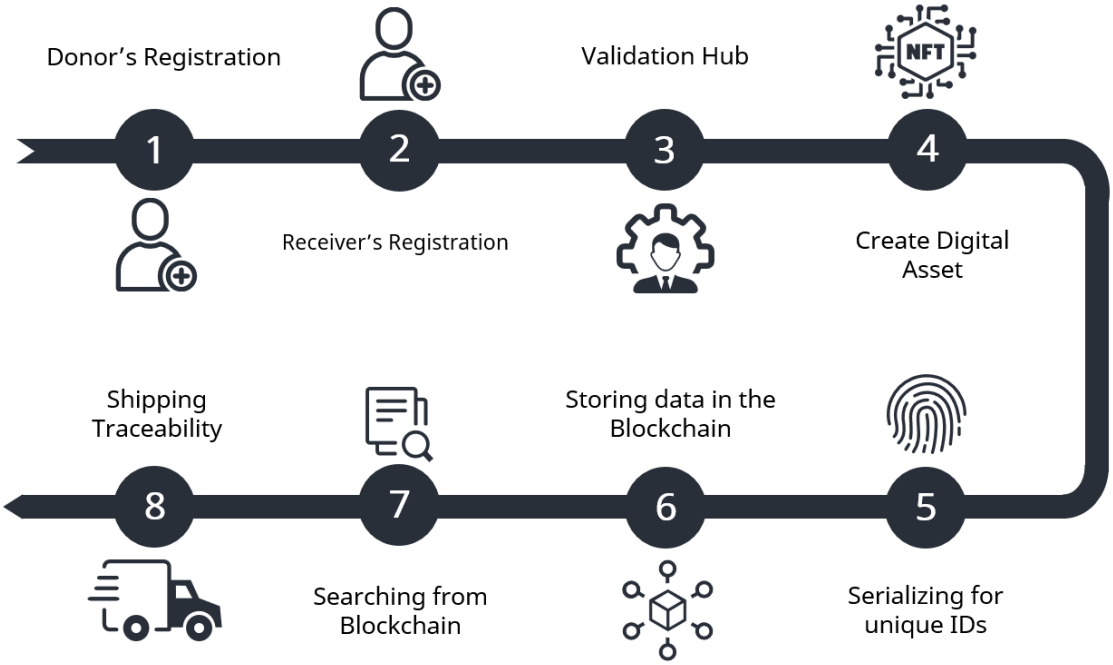

Figure 3 - Circular Donation Process Schema

3.2.1 Actors

3.2.1.1 Donors

For the donation process to begin there is a need to have a donor and this is the main subject on the donation process. It is a must have for the chain to be initiated.

To have a better understanding of the donor's profile it were defined a few personas that represent different types of donors. There can be more profiles, but for the matter of this work it is assumed the ones below:

1. **Anonymous Philanthropis**t: This donor values privacy and wishes to remain completely anonymous throughout the donation process. He is motivated by a genuine desire to help others and contribute to charitable causes without seeking recognition, so they want to keep their identity hidden.
2. **Community Officer:** This donor is actively involved in the local community or in a specific cause. He wants to make a positive impact and he is comfortable that a third-party manages

the donation between him and the NGOs or individuals in need. He is open to share some personal details but wants to control when and what information is shared.

3. **Corporate Social Contributor:** This donor represents a company or organization interested in social responsibility. He seeks opportunities to support charitable causes and often make larger donations. He wants to share publicly his donations and contributions for branding and Public Relations purposes.
4. **Legacy Giver:** This donor is planning to leave a legacy through his donations. He wants his donations to preserve his memory and contributions for the future. He would like to share personal stories or messages with their donations and does not want to keep his profile private.

In the charitable giving process, donors take a main figure and they bring diverse motivations and values. Whether they prefer to remain anonymous, actively engage in their local communities, represent corporations, or aspire to leave lasting legacies, donors offer a wide range of perspectives and intentions. This diversity enriches the charitable landscape, allowing for a vast number of causes and projects to receive support.

In this framework donors have the autonomy to choose their level of privacy. Some can decide to the complete anonymity, while others can openly share their giving journey. This flexibility must provide a way for donors to align their charitable activities with their personal values and comfort levels.

In essence, donors are not just simple contributors, they are the primary subject behind the positive circle of giving subjects that can leave a footprint for a better world.

Taking in account these values this process needs to be transparent ensuring traceability from end to end without the possibility to misrepresent or fabricate data.

3.2.2 Receivers

As well as the donors, receivers play an important role in this framework. Typically, receivers are individuals or groups in need, but this is not a must. Receivers may be part of a process that helps reducing waste by reusing available items.

Interacting with the donation platform, receivers need an interface that is intuitive and easy to navigate, enabling them to find what they need efficiently. Security and privacy must also be in place to ensure that their personal information is kept safe.

After all, the impact of receiving donations on these individuals or groups is profound. Beyond the obvious benefit of receiving items they need, the act of receiving can bring a sense of community

support and connection. It is not just about the items received it is also about the feeling of being cared for and supported by others. This emotional and psychological experience is an essential aspect of the donation process.

3.2.3 Validation Hub

In this landscape of a donations, the Validation Hub stands as an extreme valuable intermediary, ensuring the smooth transition of items from donors to receivers.

The this entity has the critical role of receiving donations from various donors, organizing them and coordinating their shipment to the receivers. This approach includes verifying the quality and condition of the donated items, categorizing and storing them safely until they are requested to be dispatched.

These entities should have professionals skilled to execute the verification, logistics and inventory management. Incorporating technology, particularly the Blockchain aspect of the framework, the Validation Hub maintains and feeds a transparent and traceable system. This system allows both donors and receivers to track the journey of the donations.

The entity also plays an important role in communication and coordination. They act as the point of contact for both donors and receivers. This role is essential in maintaining a smooth and responsive flow of operations.

Their work goes beyond transactional interactions, they are the key to build and sustain the ethics around giving and receiving.

3.3 Blockchain Selection

To develop this framework, it becomes essential to understand the nuances of different Blockchain platforms, particularly when considering their suitability for such purposes.

In the work of Dinh et al. [35] "Untangling Blockchain: A Data Processing View of Blockchain Systems" it is provided a broad analysis of blockchain technologies from the perspective of data processing capabilities. It offers a detailed examination of different systems in terms of distributed ledger technology, cryptography, consensus protocols, and smart contracts.

The authors introduce BLOCKBENCH, a benchmarking framework that helps understand the performance of private blockchains in handling data processing workloads. They perform evaluations on major blockchain systems like Ethereum, Parity, and Hyperledger Fabric, showing various designs and performance gaps compared to traditional database systems.

Furthermore, the authors propose several research directions aimed at enhancing blockchain technology to bring its performance closer to that of established database systems, thereby making it more efficient and suitable for broader applications.

Recognizing that Ethereum [36] as a significant advancement in blockchain technology, primarily due to its introduction of smart contracts and the capability to support decentralized applications (dApps) enabling a wide variety of applications across different sectors. Ethereum's flexibility in allowing developers to write complex business logic directly into the blockchain is highlighted as a key innovation.

Understanding that Ethereum has lower speed and high transaction fees a Layer 2 solution, can be a solution for this without sacrificing Ethereum's security, leveraging Ethereum’s existing infrastructure and compatibility.

For this combination of improved performance and security Polygon [37] can be an attractive option for developers and users seeking more efficient blockchain transactions while still connected to the Ethereum ecosystem.

Also, for this specific use case the cost is a key factor to succeed with a donation’s framework that may not have many financial resources available, so Polygon can bring the lower costs as a solution to implement a less expensive environment.

Being aware of the differences between Ethereum and Polygon is important to determine the most effective and efficient way to use the Blockchain technology for this philanthropic use case.

Ethereum, often referred as a pioneer Blockchain and smart contract platforms, has established itself as the primary choice for decentralized applications (dApps) and non-fungible token creation. Its main strength lies in its robust security and extensive decentralization, which is the result of its consensus mechanism and node distribution. However, these features come with certain trade-offs. The most notable is the high transaction fees, commonly known as "gas fees". Additionally, transaction processing on Ethereum can be relatively slower compared to newer Blockchains, which can be a limiting factor for some applications, but for this use case it should not be a problem.

On the other hand, Polygon was developed to address these specific challenges. It operates as a layer-2 solution for Ethereum, seeking to provide faster and cheaper transactions while it still maintains a high degree of security. By operating as a sidechain to Ethereum, Polygon achieves higher transaction throughput, significantly reducing the time and cost associated to those. This makes it an attractive platform for those who are looking for a cost-sensitive or require faster transaction speed for their applications.

Another key difference lies in their consensus mechanisms [38]. While Ethereum currently uses a proof-of-work (PoW) system, contributing to its high energy consumption and slower transaction times, Polygon utilizes a proof-of-stake (PoS) mechanism. This not only makes transactions on Polygon more energy-efficient[38] but also contributes to its ability to process transactions more rapidly.

In addition to this, Polygon's architecture is designed to be highly compatible with Ethereum. It allows developers to easily integrate their Ethereum-based applications to Polygon with minimal changes. This interoperability is a significant advantage for developers looking to leverage the benefits of Polygon while still maintaining the ability to interact with the Ethereum ecosystem.

Assuming that the primary differences between Polygon and Ethereum lie in their approaches to consensus mechanisms, cost, and speed. Ethereum, with its strong focus on security and decentralization, remains a foundational Blockchain platform but often has high transaction costs and slower speeds. Polygon, on the other hand, offers a more efficient and cost-effective solution for users and developers, particularly those requiring faster transactions and lower fees, all while maintaining a close relationship with the Ethereum network.

For this reason, this use case was performed assuming that the whole process is supported on polygon because of its lower cost, lower gas fees and its energy efficiency because of its consensus mechanism.

The table 2 preforms a comparison and quick overview of how Polygon and Ethereum differ in some key features.

Table 2 - Polygon versus Ethereum feature comparison.

FEATURE	POLYGON (MATIC NETWORK)	ETHEREUM
TRANSACTION FEES	Lower fees due to layer-2 scaling solutions.	Higher fees, especially during network congestion.
TRANSACTION SPEED	Faster transaction processing.	Slower compared to Polygon, due to network load.
SCALABILITY	High scalability due to off-chain processing.	Limited scalability in current state (Ethereum 1.0). Ethereum 2.0 aims to address this.
SECURITY	Relies on Ethereum's security but less decentralized.	Highly secure, benefiting from a large and decentralized network.
DECENTRALIZATION	Less decentralized compared to Ethereum.	Highly decentralized.
COMPATIBILITY	Compatible with Ethereum (EVM compatible).	Native platform, sets standard for compatibility.
ENERGY EFFICIENCY	More energy-efficient (uses Proof of Stake).	Less energy-efficient in current state (uses Proof of Work). Transitioning to Proof of Stake with Ethereum 2.0 (occurred in April 2023).

DEVELOPER ECOSYSTEM	Growing developer community. Supports Ethereum tools and dApps.	Large, established developer community. Extensive range of tools and dApps.
MARKET REACH	Increasingly popular, especially for applications needing lower fees.	Broad market reach and recognition. Preferred for high-value and security-critical applications.

3.4 Framework development

3.4.1 Donors Registration

As stated before this donation process assumes that there is an application where the users make their interactions with the system. The authentication phase must be done using a Decentralized Identifier (DID) [39] to ensure user confidentiality. The use of a DID, in contrast to centralized identifiers, empowers users with a Self-Sovereign Identity (SSI) [40]. This means that users have complete control over their digital identity, as opposed to relying on a third-party provider who might have access to their personal details.

Instead of a traditional identifier such as emails or social media credentials that are owned, provided and maintained by a third party who has access to the user information details, the DID is a Self-Sovereign Identity which allow the individuals to control and manage their own digital identity.

The user must already have a DID to register, or the application must be able to create a DID for the cases where the user does not have one yet, or wants to create a new one for this specific purpose. For the cases that the user already have an identification, the authentication can be performed using an existing DID stored in the user's Wallet[41].

Still on the registration process is important to ask the user to review and accept the terms of service and privacy policy. This is a document that needs to be created based on the specification of each donation platform, but should be always performed to ensure that the user is aware and validates the defined policy.

Depending on the donor's persona the profile customization may be, or not updated, this is an optional step. For the cases where the user wants to share all the profile information these parameters should be filled out at this moment. For the users who want to keep full privacy and share no other information this should not be recorded.

The user should be able to update his profile whenever he wants, and his privacy definition can also be updated whenever he wants to do it.

This registration process must provide the users with the certain that user data is collected securely and ethically, in compliance with privacy regulations having the clear understanding of the donation platform terms and policies.

3.4.2 Receivers registration

Likewise of the approach taken for donor registration, the registration process for donation receivers is designed with a strong emphasis on user confidentiality and self-sovereignty. This process begins with the authentication phase, where receivers are also required to use a Decentralized Identifier (DID) that is part of their privacy goal.

For the authentication step, if a receiver already has a DID, they can conveniently use this existing identifier, which is typically stored in their digital Wallet. However, recognizing that not all users may have a pre-existing DID, the solution should also provide the functionality to create a new DID. This feature is particularly useful for those who are either new to the concept of SSI or wish to have a separate DID for their interactions on this platform.

As part of the registration, receivers are asked to review and accept the terms of service and privacy policy of the platform. This step is essential to ensure that receivers are fully informed and agree to the platform's policies, particularly regarding how their data is handled. The terms and policies should reflect the specificities of each donation platform, emphasizing transparency and user awareness.

Regarding profile customization, receivers have the option to share as much or as little information as they are comfortable with. This aspect of the registration should be completely optional, satisfying to those who wish to share their profile details and those who prefer to maintain their full privacy. Importantly, the platform must provide receivers with the flexibility to update their profile and privacy settings at any time, providing them with ongoing control over their personal information.

Lastly, the registration must rely on the commitment of data security and ethical compliance. It must assure receivers that their data is being collected in a secure and ethical manner, consistent with the latest privacy regulations.

This approach warrants that receivers have a clear and comprehensive understanding of the platform's terms and the measures in place to protect their data.

3.4.3 Validation Hub

The Validation Hub is the entity that can validate the specifications of the of the donated items ensuring that the act of giving translates into effective help for those in need.

This entity serves as a central point of coordination, efficiently managing the items, sorting and distribution of donations.

They establish trust with donors by maintaining transparency on how donations are used and ensuring that all items meet the necessary quality standards. Handling logistics is a significant part of their role as they handle storage, transportation, and timely delivery of goods.

Additionally, they facilitate communication among all parties involved, bringing side by side donor's intentions and recipient needs.

In summary, the Validation Hub is the centre figure in transforming individual acts of generosity into a coordinated, impactful response to those in need.

3.4.4 Creating the digital asset

Taking advantage of the emergence of Non-Fungible Tokens (NFTs) [42] physical items can be represented digitally and stored in a Blockchain. NFTs play a key figure in this donation process as the main concept is to create a digital representation of an item that a user would like to donate. Originally the ownership of physical items has been proved through proof of purchase, certificates or by simply physical possession using an NFT it is possible to combine a set of parameters pre-defined and combine them with some pictures, certificates, invoices and other documents into a Token that merges all this data together creating the NFT object that can be stored into a Blockchain.

Creating the NFT is the first step towards its traceability. Its digital certificate encapsulating ownership and the donation intent for the physical item can be securely stored on a Blockchain and then represent the physical handover to another person or entity by recording these transactions on a Smart Contract [43] and adding blocks with additional information connected to the original one.

It is very important to create a Unique Identification of the NFT. It can be created a serial number that links directly to the physical item or, if the item already has a serial number, it can, and should, be used for the purpose.

It is also important to include comprehensive metadata in the NFT, such as make, model, year of manufacture, condition, and any other relevant details about the article that is being tokenized. All this data becomes immutable once the NFT is created and stored in the Blockchain. Although the data stored in the blockchain is immutable it is important to keep in mind that new data can be added to the upcoming blocks and new transactions can be added to the existing smart contract linked to the NFT according to the Smart Contract predefined functionalities. The process of storing a unique digital item on the Blockchain is defined as minting [44]. In the next sections it is described with more detail this minting process.

3.4.5 NFT Traceability Storing data into the Blockchain

Minting the digital asset allows it to become an NFT. Before minting it is necessary to have a crypto wallet compatible with the intended Blockchain. This wallet stores the native token [45] of the Blockchain and the NFT once minted.

Depending on the chosen Blockchain (like Ethereum, Polygon, Solana, etc.), it is necessary to acquire the native token for the selected Blockchain, for example, for Ethereum the token is the ETH and for Polygon the token I MATIC. This token is used to pay for the transaction fees associated with minting the NFT.

Minting the digital asset involves uploading the digital representation to the chosen platform, filling the comprehensive metadata and then executing the minting process.

This process effectively registers the digital asset on the Blockchain, making it an NFT.

3.4.6 NFT Traceability

Creating a robust system for ensuring the traceability of the NFT is a goad approach, because it not only enhances the integrity of the donation process but also provides donors and recipients with assurance about the authenticity and the history of the donated item.

There are a few ways to enhance traceability. These are some possible solutions that could be used for this specific framework:

1. Detailed and immutable metadata
    a. Assign a unique identifier to the NFT (like a serial number) that links directly to the physical item. This could be based on the item's existing serial number, or a unique code generated for this purpose.
    b. Include comprehensive metadata in the NFT, such as make, model, year of manufacture, condition, and any other relevant details about it. This data becomes immutable once the NFT is minted. Although, as indicated before this data can be updated if the smart contract that regulates the transactions allows the update of these details. Anyway the historical data is always kept in this book of records.

2. Integration of Physical and Digital Verification
    a. Attaching tamper-proof, smart tags, like RFID or NFC chips, to the item. These tags should store or link to the NFT's unique identifier.
    b. Utilizing QR codes or NFC tags that link directly to the NFT's data on the Blockchain. When scanned, these should display the NFT's details, ensuring that the physical item is the one represented by the NFT.

3. Blockchain technology

    a. Utilizing a public Blockchain for transparency and immutability. This way transactions and transfer of ownership can be publicly verified.

    b. Ensuring the NFT's smart contract records for every transaction or transfer of ownership. This includes donations, acceptance by institutions, and claiming by recipients.

4. Regular updates and verification

    a. Implementation of mechanisms in the smart contract to update the NFT's metadata if needed. This should be used, for example, when there is a change in the condition of the item. This should ensure that all changes are recorded on the Blockchain.

    b. Setting up periodic verifications of the physical item's condition and ownership and update the Blockchain record accordingly.

5. Digital certificates of authenticity

    a. Issue a digital certificate of authenticity with the NFT, which can be updated and verified against the Blockchain record.

These are some possible solutions to ensure traceability. The usage of one or more of these depends on the type of items that are being donated.

3.4.7 Query data from the Blockchain

Interacting with an NFT on the Blockchain involves the interaction with the decentralized ledger to obtain the verifiable information as determined by the smart contract's logic.

This process includes interactions with the smart contract associated with the NFT, and most likely querying its metadata.

Accessing this data involves connecting to the Blockchain network to retrieve its current status or historical records. The Blockchain's assurance that once data is recorded it remains unchanged provides donors with a reliable record of the NFT’s history and characteristics, an essential aspect of the donation process.

From the receiver's perspective, engaging with an NFT on the Blockchain means interfacing with a distributed and unchangeable ledger to acquire verified, secure information, as per the smart contract's guidelines.

This involves interactions with the smart contract linked to the NFT and its metadata.

Accessing this data means logging into the Blockchain network to gather the latest or the historical information recorded in the ledger.

The decentralized structure of the Blockchain, where data is distributed across various nodes, offers significant benefits. For the donor, this ensures the integrity and security of the data associated with their NFTs. Since the information is not centralized, it is less vulnerable to hacking or corruption, consequently preserving the authenticity and value of their digital assets.

For the receiver, the decentralized nature of the Blockchain means they can trust the information they receive about an NFT. The permanence and consistency of data across multiple nodes guarantees that the NFT's history and attributes are accurate and reliable for their acceptance.

For both the donor and receiver, the process of retrieving data from the Blockchain can be done using a mobile app or web application developed for this matter. Both the donor and the receiver rely on the app's interface to interact with the Blockchain network and get the detailed data they need to view.

This system provides both parties with confidence in the transparency and immutability of the transactions of the assets that are being donated.

3.4.8 Shipping Traceability

Implementing the shipping process for NFTs, must consider the integration with shipping companies APIs (Application Programming Interface) and the intent to store tracking information within the NFT and must consider a series of interconnected steps. Initially, the donor prepares the item for shipment and obtains shipping details, including a tracking code. This is made possible through the shipping company's API, which allows real-time tracking of the shipment.

Once the shipping details are received in the donation platform, these, especially the tracking code, are embedded into the metadata of the smart contract that is linked to the NFT. This integration ensures that the physical shipment is consistently linked to its digital representation on the Blockchain.

The smart contract associated with the NFT plays a crucial role here; it must be designed to recognize the delivery confirmation as a critical event. This could mean, for example, facilitating the transfer of ownership upon the item's successful delivery and updating the NFT's status to reflect the change in possession.

Both the donor and receiver must have the capability to monitor the shipping process through the platform that is handling the NFT.

Once the item reaches its destination, the receiver must confirm its reception. This confirmation could be done via a direct integration with the shipping service to ensure the data is written into the

metadata without human errors. The acknowledgment of the reception is then pushed into the smart contract, triggering the predefined actions and completing the process.

This structured approach not only ensures a smooth transition of physical items linked with NFTs but also maintains the full traceability and security throughout the process bonding the physical logistics with the digital assurance provided by the Blockchain technology.

Chapter 4

Donation Framework Use Case

4.1 Use case description

In the evolving landscape of digital technology, the use of Blockchain with charitable activities presents a major opportunity to enhance transparency and engagement in donations. This chapter investigates the practical application of the "Blockchain Donation Framework," initially conceptualized as an abstract model, to a specific scenario - the donation of eyeglass lenses.

Eyeglasses, often underutilized or discarded, represent a significant resource that, if redistributed efficiently, can have a strong impact for those in need. It can also reduce the waste as per it's reuse instead of disposal. The framework, when applied to this context, not only extends the lifespan of these lenses but also introduces an innovative, sustainable model for charitable contributions.

This chapter is structured to examine the process from two critical perspectives: the donor's and the receiver's perspectives. For donors, it shows the journey from registration on a mobile application, through the creation of a Non-Fungible Token (NFT) representing their donation, to the logistical aspects of pickup, shipment, and tracking. For receivers, it outlines the process of accessing these donated lenses directory, beginning with registration, followed by searching and requesting NFTs, and ending in the reception and feedback submission. Each step is designed to leverage Blockchain technology to ensure a seamless, secure, and transparent process.

For this specific use case the Donations Validation Hub handles the process between the donor and the receiver. This entity is responsible for receiving, controlling and storing the lenses. It is assumed that this entity has the necessary hardware and knowledge to verify and confirm the lenses specifications that might have been previously defined by the donor. Also, when an item is requested this Validation Hub is responsible for initiating the shipping process and ensuring the delivery to the designated receiver.

It is also assumed that the Donations Validation Hub foresees the whole process and owns a digital wallet already with Polygon tokens that are used to pay for the gas fees needed for the Blockchain transactions.

This enables the donor and the receiver to perform their actions without the need to have in their possession tokens to proceed with the donation flow.

The final goal of this chapter is to demonstrate the practical viability of the Donation Framework in a real-world application. By integrating advanced Blockchain technologies within the philanthropic

domain, this chapter aims to not only propose a novel approach to lens donation but also to inspire further exploration into how Blockchain can be connected to revolutionize many other possibilities of reusing valuable items leveraging the circular economy and waste reduction concepts.

As defined below, in Table 2, is represented a structured overview of the roles and actions of the key actors involved in the mobile donation process APP. The actors include the Donor, the ONG Representative (acting as the Receiver), and the Donations Validation Hub. Each actor plays a critical role in ensuring a seamless, secure, and transparent transaction. The Donor initiates the donation by registering and creating the donation. The Donations Validation Hub supervises the logistics, from receiving, verifying and storing the lenses ensuring and, at the end, the delivery to the designated receiver. Lastly, the ONG Representative, responsible for aiding those in need, interacts with the process by identifying and requesting the necessary lenses. The table also outlines some specific actions taken by each actor in this collaborative effort.

Table 3 – Roles and actions of the key actors

ACTOR	ACTIONS TO PERFORM
DONOR	Registration on the mobile application; Creation of a Non-Fungible Token (NFT) that represent their donation; Managing logistical aspects of the shipping process regarding pickup, tracking and delivery of the donation; Feedback submission regarding the logistic process to the Validation Hub; Check the status and details of the donated items, for example like: shipped, received in the warehouse, specification confirmation and delivered to the final receiver.
VALIDATION HUB	Receiving the donated lenses from donors; Controlling and storing the lenses; Verifying and confirming the lenses specifications validating or updating the values defined by the donor; Initiating the shipping process upon request by the ONG representative; Ensuring the lenses delivery to the ONG representative;
ONG REPRESENTATIVE (RECEIVER)	Registration on the platform to access the donated lenses; Searching and requesting for NFTs representing the donated lenses; Matching the needs of the final receiver with the available lenses; Facilitating the reception of the donated lenses for those in need; Submission of feedback regarding the received items and their distribution;

4.2 Use Case Implementation

In this section the Mobile Donation App's Figma design is described. It is a user-centric platform designed to facilitate the donation and receipt of eye lenses. This design addresses the needs of three main stakeholders: donors, receivers, and the Validation Hub. For donors, it offers a simple and rewarding donation process. Receivers benefit from an easy-to-navigate interface to find and request lenses, while the management efficiently handles and distributes the donations. This comprehensive design aims to facilitate an impactful experience for all users involved in the lens's donation journey. The mobile App was named "IseeU" and the link to the design with the most important flows is the following: Figma Design

4.2.1 Donor's Perspective

The Figure 3 outlines the user registration process where the user has the ability to setup the details of his account in order to be able to move forward with the application's feature usage.

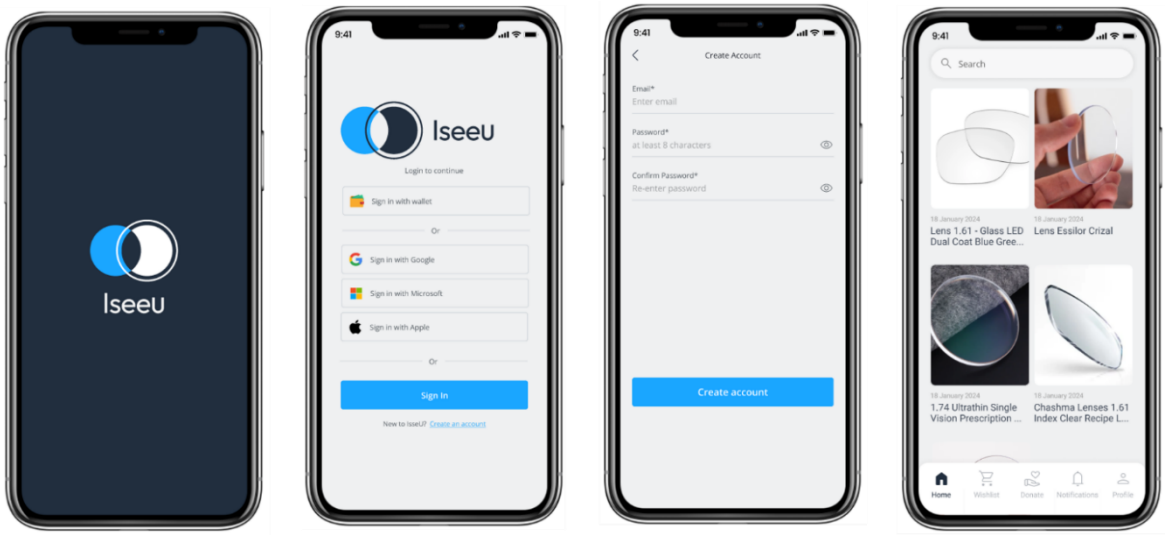

Figure 4 – User registration

The process of registering as a user on the mobile app must be straightforward and user-friendly. This ensures that each donor's experience is tailored to their preferences and requirements.

The mobile app prioritizes a smooth registration process for donors, ensuring a personalized experience based on their preferences. Users can choose their preferred login method, including existing Google, Apple, or Microsoft accounts for a quick signup. Alternatively, for added security, they can opt for Web3 sign-in using their crypto wallet.

Once logged in, users provide basic information like name and contact details to build their profiles if they want to do so.

For transparency, users review and accept the platform's terms and conditions to understand the rules, regulations, rights, and responsibilities of using the app.

Finally, after providing information, selecting their donor type, and accepting the terms, users submit everything to create their account. Upon successful registration, the app confirms account creation via email or within the app itself.

4.2.2 NFT Creation

The illustration of the NFT creation process flow on the mobile app is showed in the Figure 4. This represents the steps from preparing, reviewing, creating, and minting the NFT to the Blockchain.

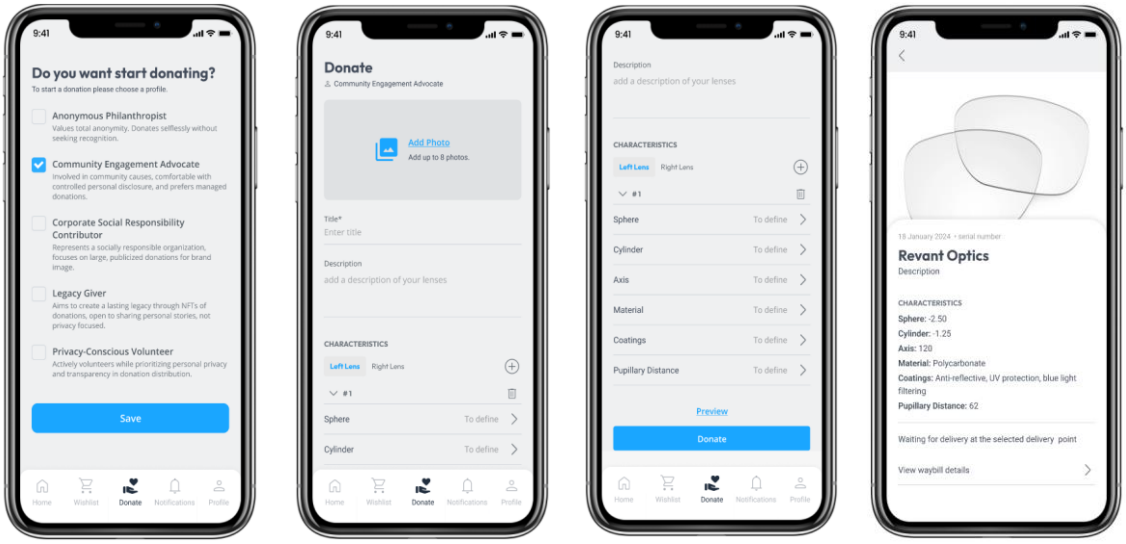

Figure 5 – NFT Creation

When the suer decides to start donating. They are prompt to define their philanthropic approach so they select their donor type. Options may include Anonymous Philanthropist, Community Advocate, Corporate Contributor, Legacy Giver, or Privacy-Conscious Volunteer.

The donation user journey begins with the donor choosing how to provide an image symbolizing the eye lenses. The donor can either select an existing picture from their phone’s gallery or use the phone’s camera to capture a new image. This step allows the app to have a clear and accurate representation of the lenses available for donation.

Once the image is selected or the picture taken, the donor can utilize the app’s editing tool to make the necessary adjustments to the image, such as modifying brightness, contrast, rotating or

cropping. The goal here is to guarantee that the image shows the lenses conditions and allows further visual evaluation.

Then it is needed to add the lenses specifications as metadata. In this important step, the donor inputs detailed data that will be linked to the Non-Fungible Token (NFT) associated with their eye lenses donation. The metadata parameters may include sphere, cylinder, axis, material, coatings, pupillary distance, and other relevant parameters that might be needed to describe the items. These details provide potential recipients with essential information about the lenses' prescription and physical characteristics. The donor should try to provide as accurate and comprehensive data as possible. However, sometimes the donor might not have accurate values for all parameters. In such cases, they are encouraged to provide their best estimate or leave those fields marked as "not available".

Once the previous step is preformed the donor is asked to review all the details and metadata they have provided and if needed they can go back to review these details. Once validated, the donor confirms the transaction and proceeds to mint the NFT. At this moment, and right before the minting process, the application generates a serial number that can be further represented by a Data Matrix which is used as the main reference for the NFT traceability throughout the process. Minting generates the digital information and stores it into the Blockchain, creating a secure and unchangeable record of the donation.

At the same time, the smart contract linked to the NFT is created to record the first transaction which is, in this case, its own creation.

When submitted to the Blockchain the donor waits for the confirmation that the NFT has been successfully minted. Once this confirmation is received, the NFT, symbolizing the eye lenses donation, becomes accessible on the Blockchain and is also represented on the donor's NFT app page.

4.2.3 Shipment and Tracking

The logistics involved in picking up the lenses from the donor and shipping them to the destination is shown in Figure 5. At this time smart contracts are used to automate and verify the steps of the process, ensuring transparency and efficiency.

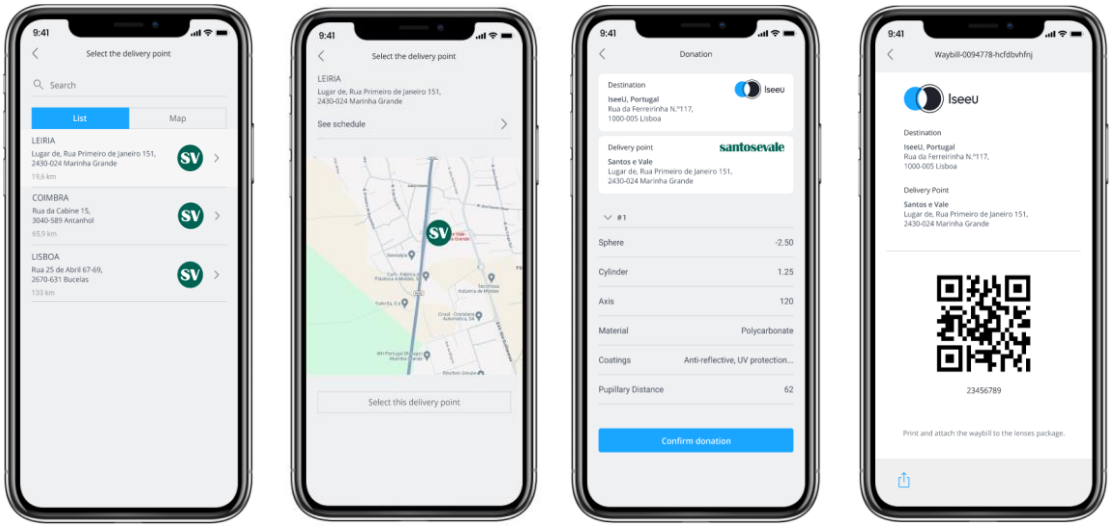

Figure 6 – Pickup and Delivery Process

It starts with donors being guided through the pickup and delivery process of eye lenses using the mobile app, ensuring that their generous donation reaches the Validation Hub's warehouse efficiently and securely.

From the list of available NFTs the donor must select one, or more, items to ship. The first step is to request a pickup through the APP as it interfaces with various available shipping providers via their API. The donor selects the preferred shipping provider based on convenience by searching for the nearest pickup point. Upon selection, the app automatically generates a waybill for the package. This waybill is essential as it contains all the necessary shipping details and serves as a receipt for the transaction.

At this time, the smart contract gets updated by a new transaction with two very important parameters. The first one the tracking code provided on the waybill the second one is the receivers blockchain address, which in this case is the Validation Hub's address.

After generating the waybill, the donor's next step is to prepare the package and to take it to the designated pickup point. This could be a drop-off location specified by the shipping provider or a pickup location where the provider collects the package. All these pickup locations must be shown in the web APP according to the shipping provider selected. The donor ensures that the package is securely sealed and labelled with the correct waybill information.

Once the package is on its way, the donor can actively track its progress. This can be done either through the mobile app or directly on the shipper's platform using the tracking code. The app integrates with the shipper's API to provide detailed tracking information. This feature enables the donor to monitor the shipment's journey, offering real-time updates on the package's status.

The final step in the process is the confirmation of the package's successful delivery. This confirmation is done by the Donations Validation Hub, when receiving the package. Once the package arrives, the entity verifies its contents against the waybill and records the delivery.

The process of receiving the package should execute the smart contract function that confirms the transfer of ownership. After this process is finished the donor is notified of the completion of the first journey of their donation.

4.2.4 Notifications

The mobile app ensures that donors are kept informed about the journey of their donated eye lenses, as this is one of the main goals of this framework. It is important to ensure, from the moment of shipment to the final delivery to the receiver that the notification process is triggered for specific events.

These events may include the following:

1. Package Received at the Validation Hub's Warehouse

   Notification Trigger: As soon as the donated package arrives at the Validation Hub's Warehouse, the donor receives a notification.

   Notification Content: This notification confirms the safe receipt of the package and may include the date and time of arrival as well as the information of the person who received it.

2. Validation or Update of Lens Specifications

   Notification Trigger: When the Validation Hub validates or updates the specifications of the donated lenses, a notification is sent to the donor.

   Notification Content: This includes information on the validation process and any updates or changes made to the lenses specifications previously defined in the NFT's metadata.

3. Receiver's Item request

   Notification Trigger: The donor is notified when their donated item is requested by the receiver.

   Notification Content: This notification may detail the intended recipient details and the expected timeframe for delivery, keeping the donor involved in the process.

4. Item Reaches the Receiver

Notification Trigger: Upon successful delivery of the item to the receiver, the donor receives a notification.

Notification Content: This message confirms that the lenses have reached the intended destination, including the date and time of delivery as well as additional details of the receiver.

5. Receiver's Feedback

   Notification Trigger: When the receiver provides feedback on the donated lenses, the donor is notified.

   Notification Content: This crucial notification includes the feedback given by the receiver, offering the donor an insight into the impact of their donation and the satisfaction level of the recipient.

In figure 6 there are two examples of notifications shown to users depending on which step of the process they are at a specific moment.

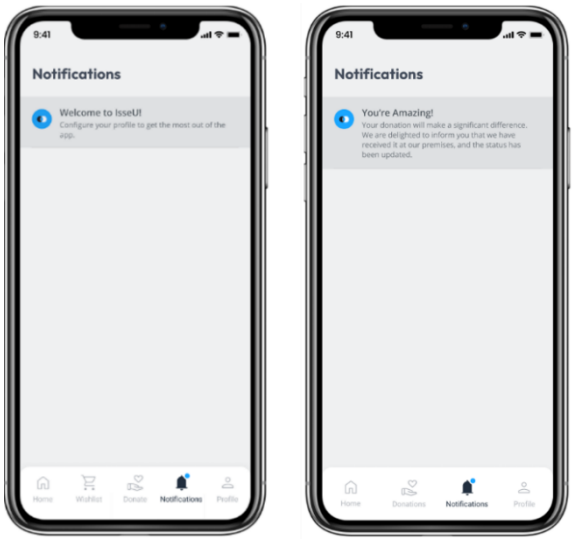

Figure 7 - Notifications

4.3 Validation Hub

4.3.1 Reception

This process explains the process flow done by the Validation Hub upon the receipt of donated eye lenses. It ensures that each donation is handled properly, keeping the donor informed at every stage.

The new phase of the journey of the donated lenses begins with their arrival at the Validation Hub. Once the package containing the donated eye lenses is received, the entity's staff takes responsibility for it. This initial step marks the transition of the lenses from the donor to the hands of the entity as per the smart contract execution.

Upon receipt of the package, the next action is to update the tracking status. This update is done automatically using the shipper's API reflecting in both, shipper and donation APP, the real-time status ensuring transparency in the process. The tracking information is updated through a shipper's API call triggered by the receiving function available in the donation APP. The person receiving the item package has also to accept the reception by pressing the "Receive" button in the inbound order list.

After the tracking status is updated, a notification is promptly sent to the donor. This notification serves as an acknowledgment and appreciation for his contribution. It confirms that the donated lenses have been successfully received by the Validation Hub, providing valuable information to the donor and closing the loop on the first shipment phase.

The final step in the reception process involves storing the donated item in the warehouse for further technical review to assess their condition, specifications, and suitability for future use.

As per figure 7 it can be observed a few screens that represent the perspective of the Validation Hub, which is responsible to handle the items after donation, but before the shipping process.

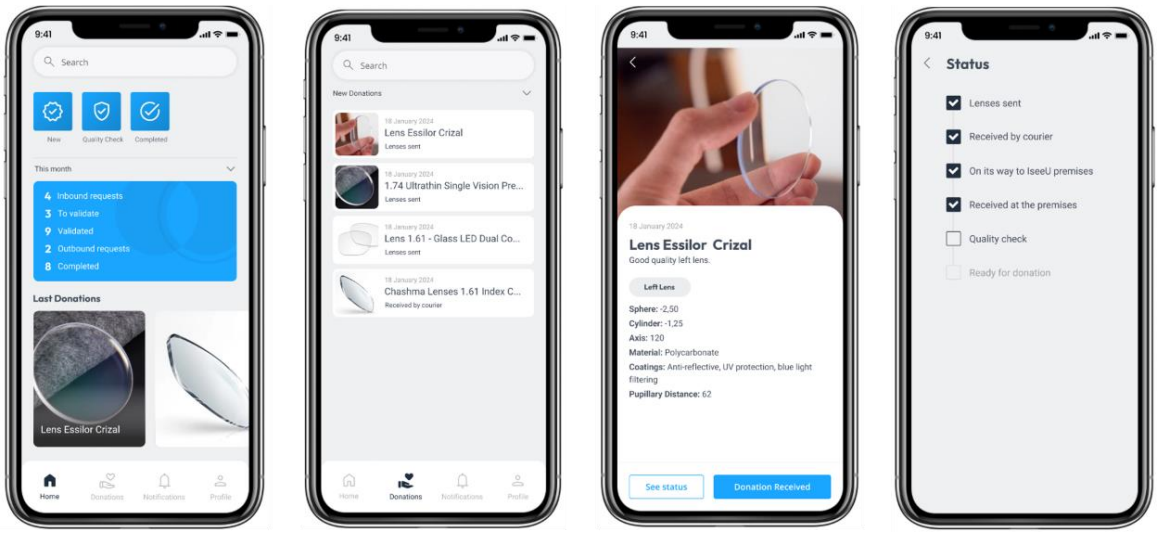

Figure 8 - Receiving Cockpit

4.3.2 Retrieving & Updating Specifications

This process provides the details for reviewing and updating the specifications of donated eye lenses, ensuring that they have the correct specifications before being matched with a receiver's request. The process is carried out by a technician at the Validation Hub's warehouse and involves a detailed examination of the lenses using proper hardware for the task. The traceability is done by the Serial Number previously generated and stored in the NFT's metadata.

It begins with the technician retrieving the donated lenses from a reserved area within the warehouse. This area is specifically designated for newly arrived donations waiting for review.

Once the lenses are retrieved, the technician performs a complete control check of the lenses parameters. This includes verifying, for this matter, sphere, cylinder, axis, material, coatings, and pupillary distance among others that may be available. This control check is a critical step, as it assesses the physical and optical characteristics of the lenses.

After completing the control report, the Technician then verifies the values obtained by their measurements against the lenses NFT Metadata. This comparison is made to ensure consistency and accuracy between the physical item and its digital representation. If discrepancies are found, or if any additional details are noted, the technician updates the NFT Metadata accordingly by executing the update parameters transaction on the smart contract and submitting them through the APP. This update reflects the most current and accurate information about the lenses.

The final step involves marking the lenses as reviewed and ready to be shipped. This status update is done in the system once the lenses are confirmed to meet the quality standards and have all the parameters specified in their NFT Metadata. These lenses are now available to be searched by a user indicating that they are prepared for the next stage in their journey – delivery to a individual who needs them.

4.3.3 Receive Lenses Requests

This process details how receivers can request donated lenses through the mobile app and how these requests are fulfilled by the Validation Hub. It ensures an effective matching of donated lenses with the needs of recipients.

It all starts when receivers search for lenses in the app using specific parameters, such as sphere, cylinder, axis, material, coatings, and pupillary distance. This search allows them to find lenses that match their specific requirements, ensuring that the lenses are suitable for their needs. This search is done through the smart contract updated lens parameters.

Once receivers find lenses that meet their criteria, they can place an order directly from the warehouse through the app. This order indicates their commitment in obtaining the specific lenses they have identified.

Upon the order placement, a shipping request is automatically generated in the Validation Hub's system. This request initiates the process of preparing the lenses for shipment to the individual who ordered them.

At the same time, the donor is notified that their donated item has been requested. This notification serves as an update and acknowledgment of their contribution, keeping them informed about the status and the positive impact of their donation.

The logistics technician, at the Validation Hub, then takes action by requesting a pickup from one of the available shipping providers. The technician receives the waybill, generated by a request made to the shipping provider's API, that is used as of the package identification, which includes all necessary shipping details and serves as a tracking document for the journey of the lenses to the receiver. This process is similar to the shipping process done by the donor in the first phase.

The technician retrieves the ordered lenses from the warehouse and prepares them for shipping. This involves ensuring the lenses are securely packaged and labeled with the correct waybill information, ready for transit.

Finally, the technician selects the most suitable pickup location of the shipping provider and delivers the package there. This step marks the beginning of the second part of the lens's donation journey – their transit to the receiver.

4.4 Requester's Perspective

4.4.1 User Registration and Login

The registration process on the mobile app for beneficiaries must follow a similar process to the donor's registration as they are both application users.

The process is identical to the donor one. The remaining profile is the same and the user can update it later with new information.

4.4.2 Search

The process of searching for lenses on the mobile app is designed to be user-friendly and allowing receiver to quickly find lenses that match their specific needs.

It starts with the user accessing the search button on the app. This button is prominently displayed for easy access, ensuring that the receiver can begin their search with minimal effort.

Upon clicking the search button, the user is presented with the search screen. It inputs for various lens parameters, such as sphere, cylinder, axis, material, coatings, and pupillary distance. These inputs allow them to specify the exact criteria they are looking for.

The user then inputs the parameters as per their prescription into the provided fields. Once all the relevant data is entered, they perform the search. The app processes these parameters to find matching lenses in the database.

Based on the input parameters, the app displays a list of lenses that match the search criteria. Each item in the search results represents lenses that meet the specifications entered by the user.

If no exact matches are found, the app informs the user that there are no lenses matching all the specified parameters, but it may also suggest lenses with parameters that are close to the selection. This feature helps receivers explore alternative options that might still meet their needs.

When clicking on any item from the search results, the user is shown all the detailed information about the lenses. This includes comprehensive data like the full specifications, condition, any additional notes provided by the donor as well as warehouse location. This step allows the user to have a better understanding about the lenses and decide if they are suitable for their requirements.

On each detailed item card there is a specific button to add the item to the Wishlist which facilitates the ordering process.

In figure 8 it is shown a brief overview of how search can be performed on the APP using the details that were updated previously in the NFT related smart contract.

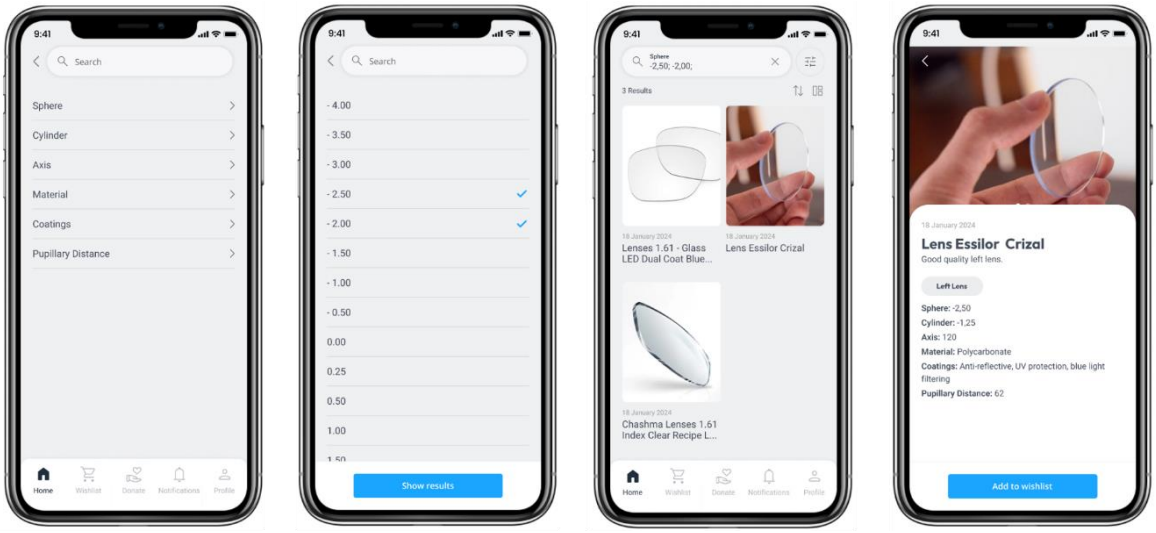

Figure 9 – Search view details

4.4.3 Item Request

The steps of requesting lenses via the mobile app are performed in the search screen, as per Figure 9. It should ensure a smooth experience for those looking for ordering lenses.

After searching and finding the desired lenses, the user needs to add these items to their Wishlist, as stated in the previous section. This is done by clicking the 'Add to Wishlist' button available on the lens item card. This action places the item in a saved list for future reference, allowing the user to continue browsing through other available lenses without losing track of their initial selections.

Once added, the item remains in the Wishlist, and the user is free to either continue searching for more lenses or proceed to the next step. The Wishlist serves as a holding area where users can review and reconsider their choices before finalizing their request.

To complete the request for lenses, the user must navigate to their Wishlist. Here, they can review their selected items and make any necessary changes or removals. Once satisfied with their selections, they choose the 'Create Order' option. This action initiates the formal request process for the selection.

When the order is created by the receiver, a shipping request is automatically generated in the warehouse's shipping pipeline. This step triggers the alert for the logistics team at the warehouse to prepare the order for dispatch.

Simultaneously, a notification is sent to the donor, or donors, of the ordered items. This notification informs them that the lenses they donated are now on their way to satisfy a request, and this function is meant to provide them with a sense of fulfilment and connection the donation process.

Finally, the user receives a confirmation message with the order number and details of their request. This message serves as a receipt and provides essential information such as the expected timeline for shipping and any other relevant details.

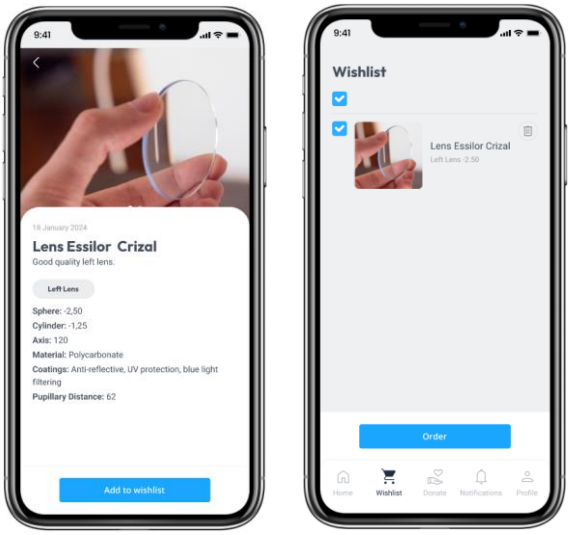

Figure 10 – Item Request

4.4.4 Order Tracking

The first step for a user looking to track their order is to navigate to the order screen within the app. This is typically accessed through the button 'My Orders'. This section is designed to provide a centralized location for all order-related information.

Once on the order screen, the user is presented with a list of all their placed orders. Each order is displayed with the order number, date of order, and most importantly, the current delivery status.

This status provides an at-a-glance update on where the order is in the delivery process – whether it's still in the warehouse, in transit, or if it has been delivered. Figure 10 is meant to give an overview of how status can be checked by users upon the shipping or delivery process.

For more in-depth information, users can click on any individual order to see detailed information about that specific order. The detailed view includes the estimated delivery date, tracking number, order delivery status and list of items in the order.

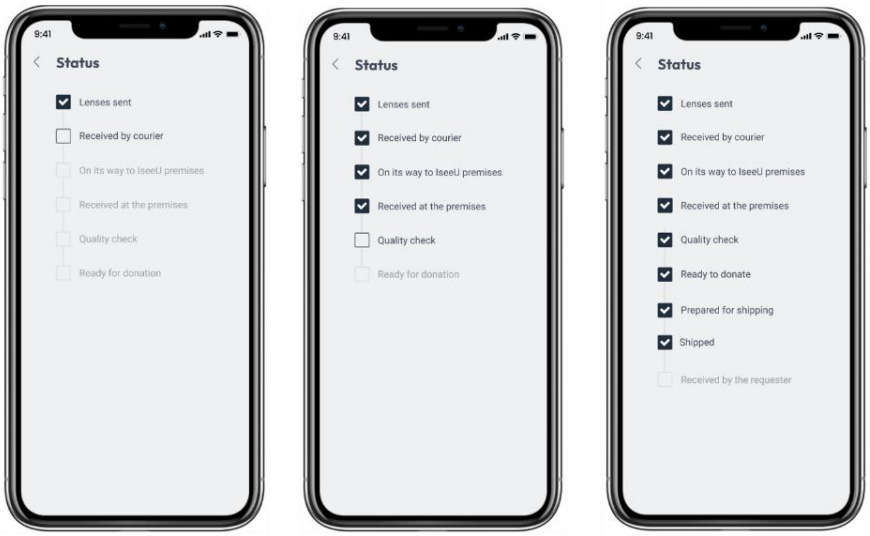

Figure 11 - Tracking screens

4.4.5 Feedback System

The feedback mechanism is in place to ensure transparency and satisfaction in the lens's donation process. This process allows receivers to provide feedback once their order is delivered, enhancing the experience for both donors and receivers.

When an order is marked as delivered by the shipper's API, a feedback record is automatically created in the donation app. This record shows the receivers that it is time for their acknowledgement of order reception and to provide their feedback on the experience.

The receivers are prompted by the app to acknowledge the reception of the order and submit their feedback. This request is an essential part of the donation process, ensuring that the receiver's experience is heard and valued too.

To submit their feedback, the receivers must navigate to the feedback area within the app. In this section, all orders that have been delivered but have pending feedback are displayed. This organization helps the receiver to easily identify and select the relevant order for feedback.

After selecting an order, the receivers are asked to rate the process. This rating can cover various aspects such as the condition of the lenses, the efficiency of the delivery, and overall satisfaction with the process.

The receivers are then encouraged to write a thank you note. This note is an opportunity to express gratitude and any additional thoughts about the donation. It is a personal touch that adds value to the feedback expresses appreciation to the donor.

Once the rating and thank you note are complete, the receiver submits the feedback through the app which triggers a new transaction on the smart contract. This step finalizes their input regarding the donation process.

Following to the feedback submission, the donor, or the donors, receive a notification. This notification includes confirmation of the successful delivery and the thank you message from the receiver. It is meant to provide closure and satisfaction to the donor, knowing their donation has been well-received and appreciated.

Finally, with the submission of feedback, the order is marked as received in the app. This action officially closes the loop on that specific donation, marking the end of the transaction and ensuring that all parties are informed of the successful conclusion – this closes one loop of the positive circle of giving.

4.5 Use Case Evaluation

4.5.1 The discussion group

To discuss the framework an informal group was created and bringing a diverse wide of thoughts and insights to this donation framework use case. Their personal and professional roles and backgrounds enabled a comprehensive evaluation of the system from multiple perspectives.

The group was composed by friends, family and coworkers with background in web design , full stack development, teaching, engineering and social volunteers.

Together, this group was well-positioned to test and provide feedback. Their diverse needs and insights helped evaluating the solution and brought different scenarios for discussion, leading to a more robust and user-centered platform that effectively integrates the desired functionalities and expected user experience.

This blend of personal and professional perspectives was very important for creating a system that aims to enhance the donation process.

4.5.2 First Iteration of the DSRM Methodology

The initial iteration of the DSRM methodology in the framework highlighted a significant limitation regarding the profiles of donors and receivers. It was possible to identify that individuals who wished to engage in both donating and receiving items faced an inefficient system, as they were required to manage two separate profiles – one for each role.

This setup proved to be impractical and counterintuitive, as it did not accommodate the necessary flexibility in such model. This led to the insight that a more unified, user-friendly approach was needed, allowing participants to switch between donating and receiving within a single profile.

It was also identified that the absence of a dedicated Validation Hub for verifying, in this case the lenses parameters could probably led to potential mismatches between donated items and the needs of the requesters. The incorporation of a Validation Hub would bring substantial benefits like:

1. Precision Matching: Ensuring that each donated item, especially lenses with specific parameters, accurately meet the requirements of the recipient, maximizing utility and satisfaction.

2. Resource Optimization: By preventing mismatches, it avoids the wastage of resources, including time, effort, logistics and the actual items involved.

3. Enhanced Efficiency: Restructuring the process of matching donations to needs boosts the overall efficiency of the donation cycle.

4. User Trust and Engagement: With a reliable verification process in place, both donors and recipients are more likely to trust and engage with the system, enhancing participation rates.

5. Sustainability: By ensuring that items are effectively used, this entity contributes to the sustainability goals of the circular economy model, reducing unnecessary waste by using all the resources effectively.

Integrating a Validation Hub for checking the items parameters and handle the logistics of the process enhances the solution's effectiveness and aligns it more closely with the principles of a circular economy.

4.5.3 Second Iteration of the DSRM Methodology

In the second iteration of the DSRM methodology, it was concluded that establishing a network of pickup locations with pre-defined shipment providers would greatly streamline the process of collecting donations. This network would provide convenient, accessible points for donors to drop off

their items, ensuring a more efficient and organized collection process. By partnering with established shipment providers, the system could ensure the timely and secure transportation of donations, further simplifying logistics for both donors and the Validation Hub. This approach not only enhances the user experience but also contributes to the effectiveness and sustainability of the donation process within the circular economy model.

Still in this iteration of the DSRM methodology, a significant change was found and implemented in the handling process of lens donations.

It was observed that serializing each individual lens, rather than the entire package or the set of lenses on the frame, was a more effective approach.

This decision was determined by the understanding that a set of lenses requested from the warehouse often are composed by lenses from various donors. Therefore, assigning a unique identifier to each lens ensures accurate tracking and management. With this method the framework's ability to match specific item requirements with the diverse inventory accumulated from multiple donors improves the overall efficiency and effectiveness of the donation process.

4.6 Block and Smart Contract Example

The Smart contract is also a key in this donation process as this will be the historical ledger of the changes occurred for one serial number. On figure 11 it is represented the blockchain based on the current use case and it gives a better perspective of the block creation and smart contract updates throughout the process.

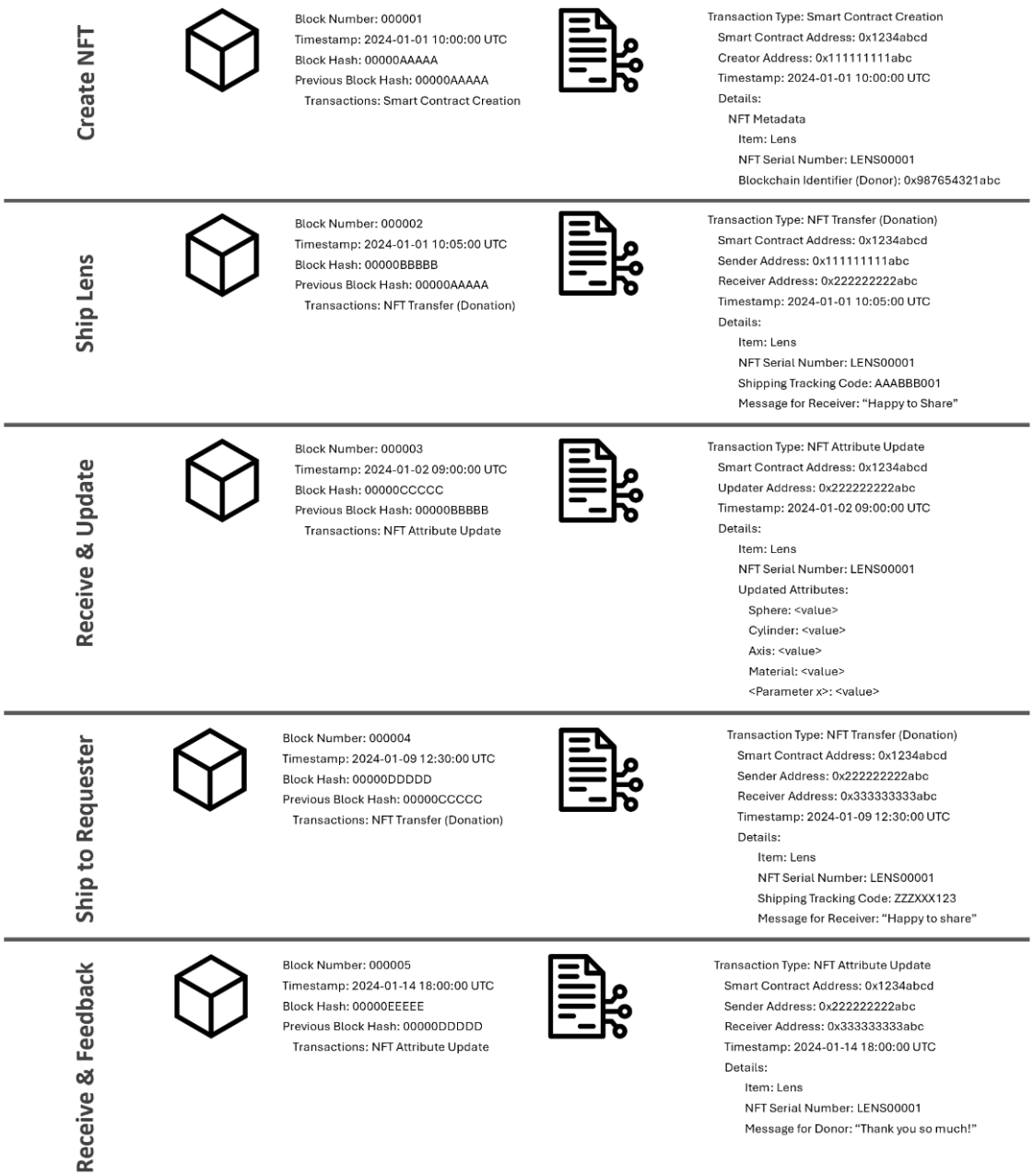

Figure 12 – Lens blocks and smart contract transactions

In the context of this donation process, utilizing blockchain technology and smart contracts is essential for the process transparency and integrity. This schema, presented on figure 8, shows how Blockchain can be implemented to provide the immutable ledger where all these transactions related to the lens's lifecycle, from creation to final donation, are permanently recorded. This allows for a clear and chronological record of the history, which is key for auditability and trust.

On the other hand, smart contracts are key to define and enforce the rules governing the donation lifecycle. They automate the execution of these rules, ensuring that each step of the process follows to the predefined protocols. Also, smart contracts manage the state of the NFT, keeping track of its

current attributes and ownership as these attributes are the key details to ensure the correct lenses are delivered according to receiver’s specification. Additionally, by facilitating features like attribute searchability within the smart contract, the system enhances the user experience at the same time as it ensures that all data is stored in a transparent manner.

Overall, the combination of blockchain's immutable ledger and smart contracts' logic and state management capabilities creates a robust framework for a transparent and secure donation process. This setup not only increases trust among participants but also ensures that every detail of the NFT's journey is recorded transparently and remains verifiable throughout its lifecycle.

Chapter 5
Conclusions & Future Work

5.1 Conclusions

In this thesis, it was investigated how blockchain technology could enhance transparency and trust in the philanthropic sector, particularly in the context of donation traceability.

The research involved the development of a framework for transforming donated items into Non-Fungible Tokens (NFTs), with the aim of embracing the principles of sustainability and the circular economy. This framework was demonstrated through a case study involving eyeglass lens donations, demonstrating its practicality. Additionally, an analysis of blockchain platforms was preformed, specifically Ethereum and Polygon, to evaluate their suitability for this specific use case taking in account aspects that were more relevant for this matter like transaction fees, scalability, security, and energy efficiency.

The adoption of blockchain technology in donation traceability significantly addresses concerns of potential donors who are hesitant due to doubts about the proper use of their contributions. Blockchain's inherent transparency and immutability offers a powerful solution to this issue. By recording transactions on a blockchain, donors can see exactly how and where their donations are being utilized, developing a greater sense of trust and accountability. This increased transparency is likely to encourage more donations, particularly from those who previously held back from doing it due to doubts about the effective use of their goods. The research highlights blockchain's potential in not only restructuring the donation process but also in enhancing donor confidence, expecting to potentially increase the overall philanthropic contributions.

This document also demonstrates the practical applicability of using blockchain to convert donated items into NFTs and how this interface with smart contracts. This approach ensures that each donation is uniquely identifiable and traceable, addressing common concerns about the misuse or misallocation of goods. The transparency provided by blockchain technology allows donors to track the lifecycle of their donations. This could lead to increased donor engagement and a higher potential of repeat donations, revolutionizing the traditional donation models.

The development of a Figma design for the web application brings an innovative and user-centric perspective to the donation process. This design enhances the overall user experience, making the process more accessible and engaging. It also facilitated a revaluation of the user interface (UI) and user experience (UX), allowing the improvement of the process flow. This ensures a more intuitive and efficient interaction for users, required for an extensive adoption.

The application of the conceptual framework to a real-life scenario with eyeglass lenses provides a tangible example of its effectiveness. This use case demonstrates the practicality and feasibility of the approach, reinforcing its applicability. This specific use case addresses a relatively underexplored area – the reuse of lenses. There are not many initiatives worldwide focusing on this, and the implementation of this use case can significantly contribute to this cause. By applying blockchain technology to track and authenticate reused lenses, the research helps preparing a way for more sustainable practices in lens donation and recycling, potentially inspiring similar initiatives globally. This approach demonstrates how innovative technology can be leveraged to promote sustainability in areas that are traditionally disregarded in philanthropic efforts.

The research has prepared a groundwork for the development of a real-life mobile application. This foundation is fundamental for moving from theory to practice, highlighting the readiness for the next stages of implementation.

On the other hand, the research presented in this thesis also encounters certain limitations. The lack of a fully operational mobile application in the research is a significant limitation. This holds back the ability to collect real-time data and user feedback, which are essential for validating the practicality of this blockchain application approach in a real-world setting. Real data is crucial for assessing the system's performance, user acceptance, and overall impact on donation traceability.

Blockchain's complexity brings challenges in terms of both development and user acceptance. Specialized knowledge is required for effective implementation, potentially raising the barrier to find developers with such knowledge. This complexity also may be translated into higher costs and longer development times, making the implementation of such work more resource intensive compared to solutions using conventional web technology.

The general public's limited familiarity with blockchain can be an obstacle to general adoption. Users may feel apprehensive about engaging with a system based on a technology they do not fully

understand. This lack of understanding could lead to resistance or a slower adoption rate, as trust and comfort with new technologies are essential for their successful integration into daily use.

When looking for possible Blockchain platforms this thesis reflects on the use of Ethereum and Polygon. eventually choosing Polygon for this specific framework. Ethereum, known for its security and widespread adoption, faces challenges with high transaction costs and scalability issues. Polygon, on the other hand, offers a balance of efficiency, scalability, and lower costs, making it more suitable for the proposed framework. Although it may offer slightly less security compared to Ethereum, Polygon's advantages in handling larger volumes of transactions at a lower cost make it an optimal choice for this application.

In addition Polygon stands out for its energy efficiency, which aligns well with the thesis's focus on leveraging circular economy principles. Polygon's lower energy consumption translates to reduced CO2 emissions, which is an important consideration given the increasing importance of environmental sustainability in technology choices. This aspect of Polygon makes it particularly suitable for applications like the proposed framework, where environmental impact is a key as well as technical performance.

5.2 Future Work

To expand the insights and contributions of this thesis, there are potential directions for future research and development. These paths aim to further leverage Blockchain technology in enhancing the transparency and efficiency of donation systems. These areas of development not only aim to improve the conceptual framework but also seek to address practical implementation challenges and expand the scope of the research. The following areas are possible next steps for this work:

1. The development of a real-life mobile application is a critical next step. This development phase can make the transition from the theoretical framework into a practical tool, enabling real-world application and user testing. Challenges such as user interface design, backend integration, and real-time data handling should be addressed during this phase.

2. Partnering with NGOs may provide precious insights into the real-world applicability of the framework, specifically on this use case application. Their feedback can guide improvements, ensuring it meets the practical needs of both donors and recipients. This collaboration can also facilitate pilot testing and iterative enhancements based on user experience.

3. A deeper exploration into the utilization of RWAs (Real World Assets) in contrast to NFTs can reveal insights into the advantages and potential limitations of digitizing physical donations. This study could focus on aspects such as ease of transfer, legal implications, and the real value of digital versus physical assets.

4. A comprehensive approach to addressing security, especially in private key management, is essential. This could involve developing advanced security protocols, exploring decentralized identity solutions, and user education to enhance security awareness. Research in this area could greatly contribute to the reliability of the system.

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