Blockchain-Based Organ Procurement System: Challenges and Software Engineering Analysis

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***Abstract*—This article explores the unique use of Blockchain and software engineering in organ supply chain management. The paper offers a Blockchain-based system to solve organ procurement and distribution transparency, accountability, and efficiency issues. The framework carefully examines software engineering approaches, focusing on the Spiral Model. This research advances Blockchain applications in healthcare and shows how the Spiral Model can be used strategically to construct and improve the organ supply chain structure. The study examines the synergies between Blockchain and software engineering to show how cutting-edge technology and proven process models can transform organ transplantation and create a more secure, transparent, and ethical supply chain.**

***Index Terms*—Blockchain, Smart Healthcare, Etherium, Public Blockchain, Organ Donation, Supply Chain**

I. Introduction

Originally proposed in 1999 by British scientist Kevin Ashton, the Internet of Things (IoT) has developed into a worldwide network linking numerous gadgets and items to the Internet. The Internet of Things (IoT) includes gadgets that can interact with people or other machines to carry out certain activities. Numerous advantages have been gained by both people and organizations, including home automation for higher living standards and lower costs, industrial applications for equipment monitoring and maintenance, and medical breakthroughs for illness prediction and remote health monitoring. The potential of IoT is further increased by the advancement of AI and communication systems, and the upcoming 5G network is expected to change communication rates, notably in the medical industry. The use of wearable technology and smart services in healthcare facilities has enhanced patient care as a result of the IoT's integration with the sector. In the near future, this revolutionary change is anticipated to lead to more precise diagnoses and improved treatment outcomes. [1]

The combination of AI and cloud technology is undergoing a significant shift in the healthcare sector. AI-driven apps with previously unheard-of precision and efficacy transform patient care, diagnosis, and treatment planning. Machine learning algorithms may examine a variety of medical data, including imaging scans and patient records, to spot trends, diagnose ailments, and even suggest individualized treatment regimens. Additionally, the cloud architecture is supporting telemedicine services, enhancing patient record accessibility, and enabling seamless data exchange and cooperation among healthcare practitioners. The fusion of AI and cloud computing is improving medical decision-making while reducing administrative processes, ultimately enhancing patient outcomes, lowering costs, and shifting healthcare delivery toward a more patient-centric model. The healthcare sector is at a turning point when innovation has the potential to completely transform how patients are cared for and how medical research is conducted.

The ability to save countless lives and vastly enhance the quality of life for those in need makes organ donation of the utmost significance. Numerous people experience organ failure or life-threatening illnesses every year, and for many of them, organ transplantation is their last chance of survival. People can provide others in serious need of a second shot at life by donating organs including the heart, lungs, kidneys, liver, and more. The receivers of organ donation not only live longer but also recover their health and vigor, continuing to pursue their goals and make contributions to society. Additionally, it promotes a feeling of cohesion and compassion throughout communities by illuminating the profound effect that the altruistic act of organ donation may have on people's relationships with one another. Encouragement of organ donation aims to foster a culture of compassion, empathy and shared responsibility for the welfare of other people as well as to save lives.

Software engineering is a pillar in the field of intelligent healthcare systems, providing a wide range of essential contributions. The large amounts of medical data produced by these technologies are first managed and integrated, assuring accuracy, security, and accessibility for healthcare practitioners. Interoperability is a priority for software developers, who develop standards and other tools to enable seamless data interchange across various parts of the healthcare system. Additionally, to improve the entire user experience, they implement strong security measures, deploy powerful analytics and AI algorithms for diagnostic and predictive healthcare, and concentrate on user-friendly interfaces. These experts are also essential in the creation of telemedicine and remote monitoring systems, assuring their scalability, dependability, and adherence to stringent healthcare laws.

Software engineering is fundamental to the development of smart healthcare systems. Providing them with the instruments and technology necessary to enhance patient care, expedite healthcare delivery, and increase accessibility to healthcare services, particularly in rural locations, equips healthcare personnel. Software engineers are at the vanguard of the healthcare sector transformation, encouraging interoperability, data security, and sophisticated analytics, eventually leading to more effective, efficient, and patient-centric healthcare solutions.

In order to enhance organ availability, the study in [2] investigates how supply chain management techniques are applied to the organ transplantation procedure in the USA. However, it raises worries that the problem of organ scarcity may make already-existing gaps in access to treatment worse. Ensuring fair access is difficult due to the spatiotemporal dispersion of transplant facilities, donors, and recipients. Healthcare is creating standardized, data-driven systems to speed up organ delivery and procurement, but these systems are modeled after business supply chains, which may benefit patients who already have advantages. The study contends that while these technologies shouldn't be opposed, they should be modified such that universal access takes precedence over financial success.

By offering a mathematical model for the location-allocation of organ harvesting and transplant sites, this work [3] tackles a crucial element of health and hygiene. The main goal is to reduce the overall system expenses as well as geographic disparities in the distribution of these centers. The model uses a two-objective nonlinear mathematical programming technique to take into account the ambiguity of quantities like cost and transit time, which are represented as fuzzy sets. The study employs the -constraint technique to solve problems and focuses on creating an Organ Transplant Supply Chain (OTSC), using Iran as a case study. Specifically, the data provide precise criteria for satisfaction and viability rates for operation consideration, emphasizing the relevance of patient family satisfaction above organ viability rates in deciding the frequency of successful transplant procedures.

Given the lengthy waiting lists for organ transplants, this article [4] tackles the crucial problem of cutting down on organ transplant travel time. It tries to identify the locations of transplant facilities and shipping agents inside a nation in order to create a complete model that maximizes transport efficiency. With an emphasis on lowering cold ischemia time while taking financial restrictions or non-binding time covering constraints into account, the issue is presented as a mixed integer programming (MIP) problem. The work conducts extensive numerical experiments and applies this model to the setting of organ transplantation in Belgium. The outcomes point to the centralization of transplant centers as a result of optimizing the factors impacting cold ischemia duration, and the MIP model has fast calculation times overall, with the exception of situations when there are a lot of possible shipping agents.

Although maintaining the safety and integrity of the organ supply chain is crucial, there are a number of complex difficulties involved. First, there are worries about illicit organ trading and organ trafficking, which call for strict security measures to stop the exploitation of weak people. To reduce ischemia time, organs must be transported securely and effectively, but logistical difficulties like traffic jams, bad weather, and logistical mistakes can endanger the viability of the organs. Protecting patient confidentiality also depends on ensuring the privacy and security of private patient information and medical records across the supply chain. The supply chain for organs is also becoming more and more vulnerable to cybersecurity risks, since hacks on healthcare systems have the ability to threaten patient safety and disrupt daily operations. The last issue in organ transplantation is ensuring an equitable distribution of organs while minimizing potential security threats and guaranteeing the traceability of organs along the supply chain. This requires striking a fine balance between accessibility and security. Addressing these complex issues is essential to preserving the credibility and dependability of the organ supply chain and ensuring the health of both donors and recipients.

II. Related Work

Although the practice of transplanting organs has a long history, it really took off in the 20th century because to ground-breaking developments including the first successful kidney, lung, pancreatic, liver, and heart transplants. Organ transplantation underwent a paradigm shift with the 1970s discovery of immunosuppressive drugs, most notably cyclosporine, which led to a greater acceptance and success of the medical procedure. The Organ Procurement and Transplantation Network was founded in the United States in 1984 as a result of the organ scarcity issue brought on by the rising demand for organs. A nationwide register for organ matching was maintained by this network, which also made it easier to gather thorough information on solid-organ transplants. [5]

In [6] they indicated that the healthcare industry is changing, with an increased demand for efficiency, in part because of an older and more mobile population. The COVID-19 pandemic highlighted the significance of telemedicine and real-time information exchange. The development of Internet of Things (IoT) devices, particularly the Internet of Medical Things (IoMT), has contributed to the recent change in healthcare trends toward electronic (eHealth), mobile (mHealth), and universal (uHealth) healthcare. However, these developments also bring with them new difficulties, chief among which is the security of mobile and IoT devices as well as the underlying infrastructure for healthcare information. Secure data sharing, consensus management for record changes, and a variety of consensus algorithms, including proof of work (PoW), proof of concept (PoC), proof of stake (PoS), proof of space (POS), proof of activity (POA), practical Byzantine fault tolerance (PBFT), and redundant Byzantine fault tolerance (RBFT), are some of the potential benefits of blockchain in the healthcare industry. The need for better security and interoperability in healthcare systems is what motivates the use of blockchain in that industry.

In [7] they indicated that blockchain, a widely used distributed ledger technology, has enormous potential for the healthcare and medical industries. Without the requirement for centralized management, it functions as a decentralized database system that is chronologically updated by consensus nodes. Decentralization, verifiability, and immutability are key characteristics that are essential for medical record administration, including safe facility transfers and patient visit validation. A decentralized database that allows users access to stored data is fundamentally what a blockchain is. Each block in a data transaction consists of data, timestamps, and connections to blocks that came before it. To increase security, each block has a distinct, encrypted digital identity. Blocks are individually stored by nodes within the network, guaranteeing the content's durability and immutability. Only data addition is permitted since changing one block compromises the integrity of the entire chain, protecting against hacker efforts to modify data.

In [8] they indicated that with several studies acknowledging its potential, blockchain technology has lately emerged as a transformational force in the healthcare industry. Through the facilitation of decentralization and digitalization, supported by Information and Communication Technologies (ICTs), it promises to transform conventional healthcare systems and enterprises. Patient record management, claims processing, medical IoT security, research data validation, financial auditing, and transparency are all examples of blockchain uses in the healthcare industry. These applications utilize real-time changes on a blockchain ledger that is encrypted and decentralized, improving data security and control. Access controls are made easier by this technology, protecting private healthcare data.

In [9] they mentioned that with systems like electronic medical records (EMR) and electronic health records (EHR) striving to improve treatment quality, patient-centric services, and data security, health IT has become fundamental to the healthcare industry. The investigation of new technologies is prompted by the persistence of interoperability and data integrity problems. Solutions for maintaining and transferring patient information are provided by blockchain, a decentralized, transparent ledger that addresses issues with security, privacy, and healthcare waste. Despite its promise, blockchain adoption in healthcare is still modest, with many initiatives failing because they were started at an early stage or had scalability issues. Adoption is further hampered by hesitation, a lack of understanding of blockchain's potential, and organizational preparedness, making business problems just as important as technological ones.

In [10] they have discussed the challenges regarding the management and secure retrieval of enormous volumes of individual health data, which are frequently kept in non-standardized, inaccessible systems, provide difficulties for the healthcare sector. Recent public health crises have brought attention to the industry's vulnerabilities, which are further exacerbated by interoperability problems, unavailable medical records, and data security issues. The healthcare industry is still in the early stages of establishing dependable, secure infrastructure for integrating various data sources, despite the push toward patient-driven interoperability. With little current study, blockchain technology is emerging as a viable answer to these problems. As blockchain applications proliferate, it is vital to evaluate their influence on healthcare outcomes and the easing of major industry problems, such as patient data security and accessibility.

In [11] they have discussed the challenges that with a rising need for transplants globally, the lack of organ donors poses a serious issue to the healthcare sector. Organ transplant programs are essential for the sustainability of healthcare, but they encounter a number of difficulties, such as complex supply chain problems, data inaccessibility, and security issues. Despite considerable studies on supply networks for organ transplants, nothing has been done to examine how these problems are interconnected. It seeks to offer a thorough knowledge of the obstacles impeding organ transplant supply chains, their connections, and their possible effects. The study makes use of interpretative structural modeling (ISM) to provide insights for theory and practice, improving the optimization of the organ transplant supply chain in underdeveloped nations.

In [12] they have discussed the difficulties that arise throughout the contribution procedures for charities, highlighting the value of openness and traceability. To increase confidence among stakeholders, guarantee gifts reach their intended beneficiaries, and remove uncertainties in the charity sector, it proposes a blockchain-based donation tracking system. The framework uses the security and decentralization capabilities of blockchain to provide a safe and open contribution system. It has a web-based testing method that has shown to be successful in removing middlemen and safeguarding transactions. The paper makes a contribution by stressing the value of traceability, outlining a workable blockchain-based solution, and fusing theoretical ideas with real-world uses. Through distributed ledgers and smart contracts, it provides backward and forward traceability, authentication, and privacy protection, with implications for software engineering features of blockchain technology in the charity sector.

In [13] they have discussed that According to IEEE standards, the discipline of software engineering entails a systematic approach to software creation, operation, and maintenance, with several approaches directing the process. These approaches are crucial for gathering requirements, creating complicated software systems, testing them, and keeping them up to date. The selection of a technique is influenced by things like technical proficiency, management, quality evaluation, and cost. While tried-and-true methodologies like Waterfall, Agile, and DevOps have worked well for traditional software development, the rapid advancement of technologies like blockchain, AI, and quantum computing raises doubts about the necessity of new methodologies that take advantage of these developments. The decentralized, secure, and transparent ledger system offered by blockchain, in particular, has gained popularity and has the potential to be useful in many other fields.

In [14] they have discussed the privacy challenges related to the development of web-based liver transplantation registries (WLTR) has become more crucial to improving patient care and research since liver transplantation is a crucial life-saving procedure. These registries lower expenses while providing real-time data updates and accessibility. However, protecting patient privacy and data security is essential when digitizing medical information. Patients' adherence to therapy and follow-up care can be influenced by their faith in these systems, which can have an impact on post-transplant survival and disease control. WLTR privacy problems have not received much attention despite the rising significance of health outcome registries.

In [15] they have written about the practice of posthumous medical data donation (PMDD) is a charitable initiative that is presently not supported by any legal or regulatory frameworks that would allow people to give their medical data for legitimate, non-profit medical research. This essay illuminates this comparatively uncharted area of law by providing a comparative review of the legal environments around PMDD in the US and the UK. While academics in the social sciences and humanities have widely highlighted the advantages of PMDD, highlighting its potential to promote cutting-edge medical research, individualized treatment, and data-driven solutions to urgent medical problems, legal literature in this field is still scarce. In order to support PMDD and balance privacy concerns with the general public's interest in medical research, existing evaluations indicate to the necessity for specialized regulatory regimes and offer options for harmonizing data protection regulations and putting into place dynamic data governance frameworks.

In [16] they have discussed that Smart Contracts are self-contained computer protocols that allow for the execution of contracts between parties and provide benefits like increased security and lower transaction costs. By using Blockchain technology, these contracts ensure flawless execution and preserve a transparent transaction history. They operate on a decentralized peer-to-peer network that enables the exchange of value and information. With the idea that ”code is law” at its core, smart contracts automate contractual duties. Starting with pseudo-code, a structured representation of program logic, might be a useful strategy for legal professionals wishing to use this technology. In order to help Cloud Computing providers comply with GDPR, this chapter attempts to give a pseudo-code template for Smart Contracts, highlighting the significance of smart disclosures.

In [17] they have discussed the Blockchain-based alternatives for organ donation systems are being investigated in light of recent technological breakthroughs since they provide more transparency, security, and efficiency when compared to centralized systems. This paper offers a network model for organ donation systems using the Hyperledger Fabric architecture, in contrast to prior research which mostly focused on Ethereum-based blockchain solutions. A client application for user interaction was also launched together with a smart contract prototype system utilizing Amazon Managed Blockchain Service. With peak transaction speeds of up to 508.4 TPS for reading records and 389.1 TPS for producing new records, performance evaluation using the Hyperledger Caliper benchmarking tool showed encouraging findings. Future work will focus on improving system performance and finding suitable managers and endorsers inside this regulated blockchain network.

In [18] they have mentioned the potential of blockchain technology in the field of healthcare has attracted a lot of scholarly attention in recent years. Electronic health records (EHRs) are envisioned to benefit from better security, transparency, and patient-centered control provided by blockchain, which is seen as a potential solution to issues with health data storage and interchange. Theoretical uses of blockchain in healthcare and its projected advantages, such as better clinical decision-making, effective administration, and increased medical research, are widely discussed in the literature. Despite the widespread discussion about the potential advantages, there are surprisingly few scholarly investigations of the actual application and impact of blockchain in healthcare settings. This gap emphasizes the necessity for thorough evaluations of blockchain's real-world applications and the difficulties it could face in the healthcare industry.

In [19] they have explained that the Interest in blockchain technology has grown as a result of the expanding demand for secure patient data access and integrated healthcare information. Healthcare data standards, interoperability, and accessibility issues can be solved with blockchain, which provides a decentralized and secure transaction ledger. By doing away with the requirement for a reliable middleman, it improves efficiency, security, and privacy. There are two sorts of blockchains: permissionless and permission, and each offers a distinct form of governance. Blockchains with permissions, such as consortium blockchains, let healthcare stakeholders share restricted amounts of data. Blockchain's potential in healthcare is being actively investigated by researchers, who are concentrating on interoperability, privacy, security, data integrity, and openness. The implications for patient involvement, provider access to patient data, and medical research are highlighted in this systematic assessment of blockchain healthcare research's advancements and obstacles. Additionally, it points up obstacles and recommends lines of further investigation.

In [20] they have explained that Massive electronic patient records have been created as a result of the healthcare industry's fast digitalization, calling for reliable data protection solutions. A possible solution to the problems of data privacy, security, and integrity in healthcare is blockchain technology. For peer-to-peer digital data transfers, blockchain provides a secure, decentralized ledger that supports data storage and verification. Additionally, smart contracts are included, allowing for decentralized, automated interactions between parties. Data interoperability, secure electronic health record (EHR) sharing, medicine supply chain management, and other uses of blockchain in healthcare are included. These programs might improve patient outcomes, data management, compliance, cost-effectiveness, and supply chain security for the medical industry.

III. Framework

The typical procedure for organ donation and transplantation is shown in Fig. 1. The transplant staff at the hospital first evaluates the donor. A brain death test is carried out if the donor is deceased; for living donors, a comprehensive medical evaluation is carried out to guarantee appropriateness. The procurement organizer then receives all medical data, reviews them to determine the donor's eligibility, and makes sure the donor is properly registered in the healthcare system. The organ transplant coordinator receives the information from the procurement coordinator if the donor meets the requirements and agrees to an anonymous donation. The latter creates a sorted list for transplant surgeons by matching patients on the waiting list with eligible donors. Based on the recipient's medical history and donor information, the transplant surgeon determines whether the organ is a good fit. After the organ is accepted, the donor's surgeon removes it, transports it to the patient's hospital, and gives it to the transplant surgeon. When living donors give to known recipients, the transplant surgeon receives the data directly so they may do the surgery.

We go into great detail in this part explaining our blockchain-based organ donation and transplantation methodology. Fig. 2 depicts the system architecture and shows how two smart contracts are used: one for organ donation and the other for organ transplantation. Through a decentralized application (DApp) frontend connected by an application programming interface (API), participants can engage with these smart contracts.

Each smart contract has distinct functionalities that are accessible only to pre-approved participants. The individuals who are permitted permission to access data kept on the blockchain encompass many professionals, such as physicians, members of the hospital transplant team, procurement coordinators, organ matching coordinators, transporters, and transplant surgeons. The individuals can analyze events, logs, and transactions. The establishment of a waiting list is followed by the approval of donors through medical examinations, and thereafter, the Organ Donation Smart Contract promptly matches them with recipients. The Organ Transplantation Smart Contract, however, is responsible for overseeing all aspects of the transplant process, encompassing the extraction of organs from the donor, their transportation to the recipient, and their subsequent implantation. The entire process is meticulously recorded and stored on the blockchain for subsequent examination and verification purposes.

Furthermore, the system uses a private permissioned Ethereum blockchain to guarantee authorization, secrecy, and privacy.

A. Integration on the blockchain

Our developed smart contracts must be available at all times, but it is not ideal to have them deployed on the main network while they are being tested. Therefore, to test the Ethereum-based smart contracts, it is advised to utilize a test network, a virtual machine such as the JavaScript-based Virtual Machine, or a local blockchain configuration. We created these contracts in our solution using the REMIX IDE, then we installed them on the Remix Virtual Machine. Testing is made more efficient by this environment, which enables isolated Ethereum nodes running directly in the browser. The smart contracts can be put into use on Ethereum's mainnet to evaluate their performance in the real world once they have undergone extensive testing and confirmation. Crucially, these contracts ensure deterministic behavior by yielding consistent results regardless of the operating node.

B. Smart contracts:

Organ Donation Smart Contract:
Four major parties are involved in the organ donation smart contract: the procurement organizer, the matching organizer, a member of the hospital transplant team, and the patient's

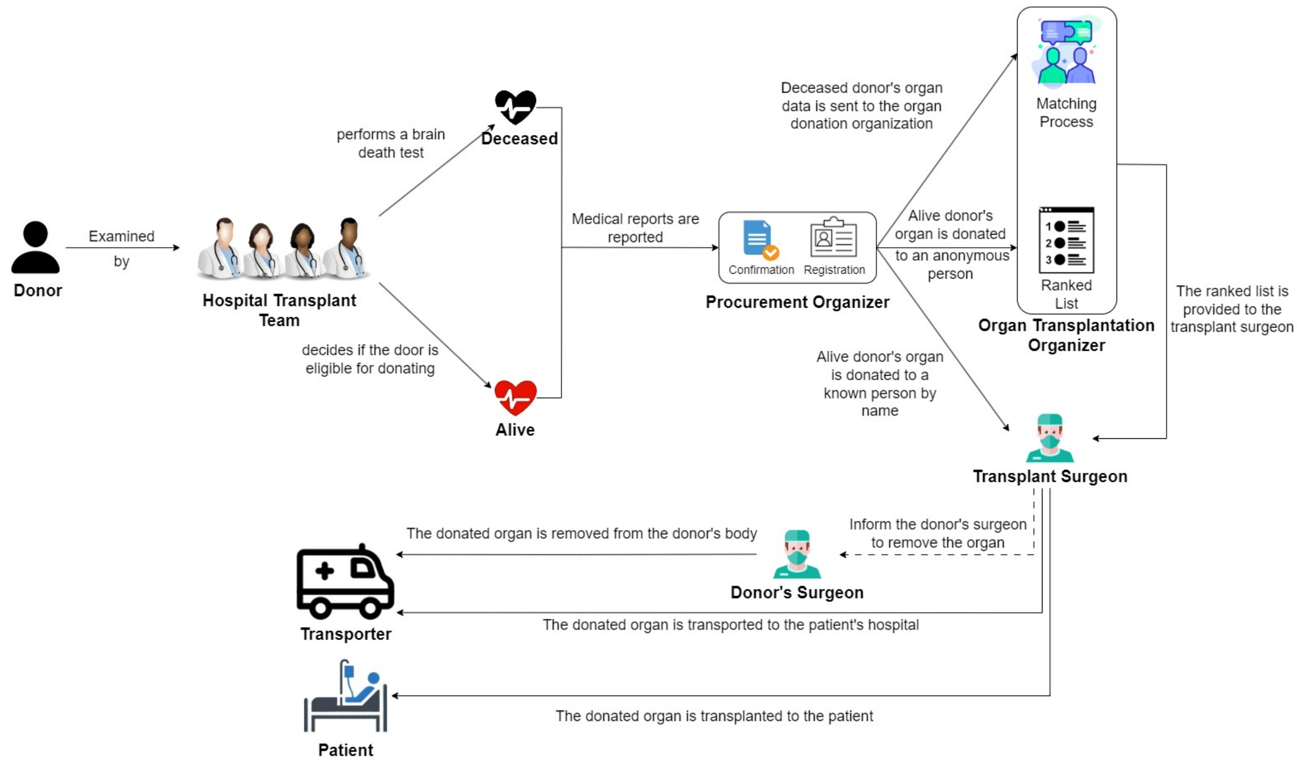


Fig. 1. **Flowchart of the traditional framework**

physician. Every participant has a distinct Ethereum address that they use to communicate with the smart contract's features. This contract uses a variety of variables of different kinds. First of all, certain entities such as the procurement and matching organizers are linked to Ethereum addresses. Second, a mapping system ensures authorization for operations such as transplant surgery and patient validity checks by connecting Ethereum addresses to predetermined criteria. Furthermore, listing variables such as 'BloodType' and 'OrganType' denote distinct blood kinds and organs, hence streamlining data processing.

The procurement organizer becomes the contract's owner, assigns the matching organizer's Ethereum address, and starts the smart contract's deployment. Patients are added to the waiting list by a licensed physician, and all participants are informed of this. Members of the medical team then perform tests and declare the results acceptable. Donors are registered by the procurement coordinator, who also specifies the type of organ given. The next step is a computerized matching procedure that matches patients with potential donors based on factors like age, blood type, BMI, and waiting period. Information about the matched patient and donor is kept for further use.

Organ Transplantation Smart Contract:
The transplant surgeon, the transporter, and the surgeon who performed the donation are the main players in the organ transplantation smart contract. They carry out particular tasks in order to communicate with the contract. A variety of variables are included in the contract, such as the donor's and the transplant surgeons' public Ethereum addresses. In order to approve transporters to transfer donated organs from the donor hospital to the recipient hospital, it also has a mapping system. There's also an enumerated variable named 'OrganStatus,' which lists the possible states in which the given organ can be.

The transplant surgeon deploys the smart contract, defining the initial condition of the removed organ and the Ethereum addresses of the donor's surgeon. The transplanting process begins when the approved transporters are designated after deployment. The organ is first removed by the donor's surgeon, and it is then transported from the donor's location to the receiving hospital by a licensed transporter. The delivery procedure is tracked from the beginning to the end. The transplant

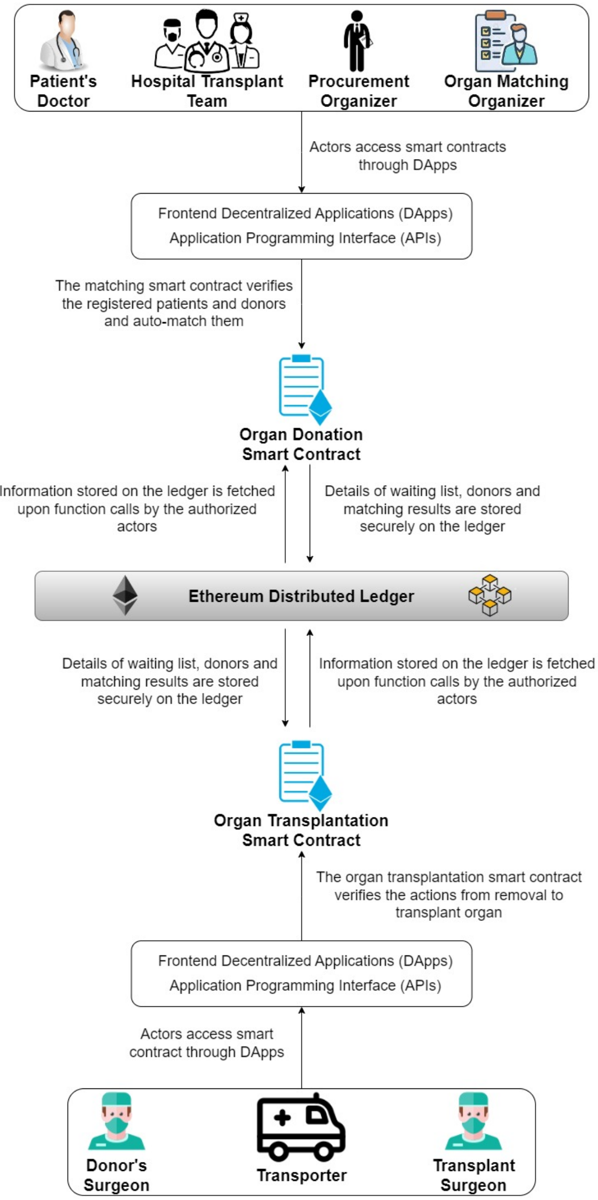


Fig. 2. **An overview of the proposed blockchain-based solution for organ donation and transplantation.**

surgeon then starts the transplant process after verifying that the organ has been received. At last, the specifics of the transplant, such as the patient's ID, the time, and the date, are recorded and declared.

The entity-relationship diagram that summarizes the primary characteristics and functionalities of any smart contract is shown in Fig. 3. We identify unique Ethereum addresses as the single procurement organizer and matching organizer in our architecture. Because the patient's physician, a member of the transplant team, and patient validity appear more than once in the system, they are represented as mappings. Since there are several types of blood and organs, they are enumerated. The organ donation smart contract's main features are MatchingProcess, AddingNewPatient, TestApproval, and RegisteringNewDonor.

Certain attributes define the transplantation process in the Organ Transplantation smart contract. Just one surgeon—designated as an Ethereum address—is in charge of the

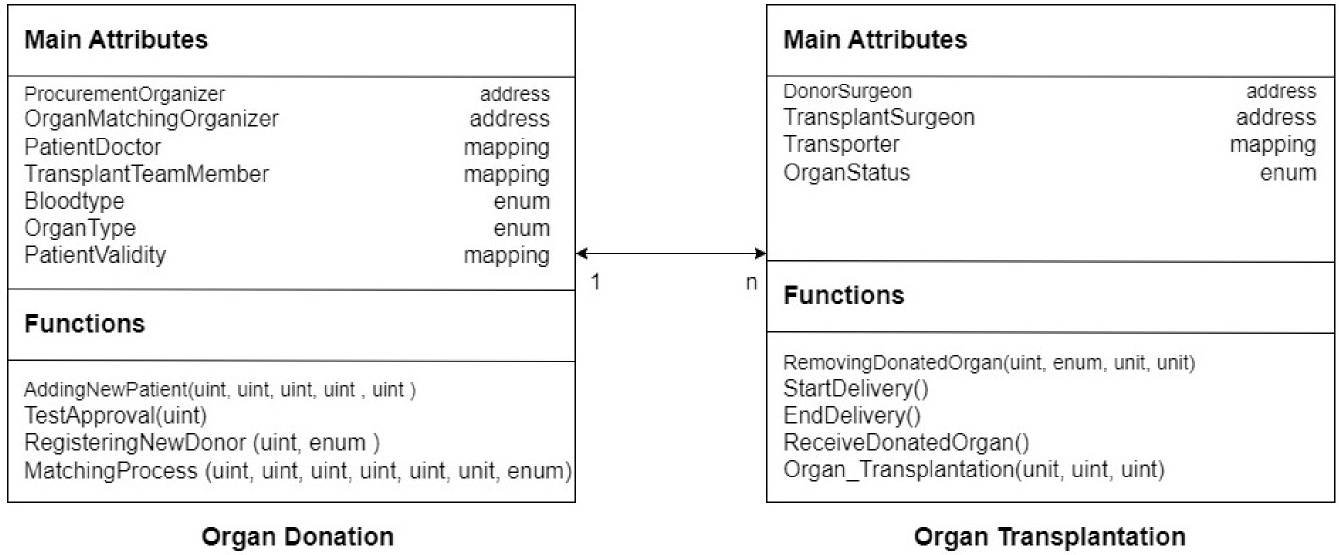


Fig. 3. **Entity-Relationship diagram of smart contracts**

transplant from the donor's perspective, and another surgeon handles the surgery for the receiver. Since there can be more than one transporter, they are shown as a mapping. Functions including RemoveDonatedOrgan, StartDelivery, EndDelivery, ReceiveDonatedOrgan, and Organ_Transplantation are included in the smart contract.

Furthermore, the relationships between the transplantation and organ donation smart contracts are 1:n. While numerous transplantation smart contracts may exist for different donation methods, each organ donation smart contract may cover all patients.

IV. Software Engineering Perspective

A. ViewPoint Hierarchy

The several important viewpoints and related stakeholders related to the creation and execution of a blockchain-based organ procurement system are delineated in this viewpoint hierarchy table (Fig. 4). The interaction of strategic, operational, and structural factors that must be taken into account to guarantee the effective and moral operation of such a system is discussed in the table.

1) The Indirect Viewpoint: The strategic Level approach explores the wider moral, legal, and regulatory issues surrounding the use of blockchain technology in healthcare and organ procurement. The legal and ethical issues of organ procurement are crucially addressed, and regulatory standards are upheld, by stakeholders including legal professionals, ethicists, policy makers, government regulatory agencies, and healthcare compliance officers. Furthermore, when it comes to promoting societal acceptability and privacy protection in relation to organ donor data, public health advocates, privacy activists, and patient advocacy groups are essential. To guarantee long term funding and the financial sustainability of organ procurement programs, financial analysts, hospital administrators, and government organizations also provide their skills.

2) Interactor Viewpoint (Operational Level): This perspective focuses on improving the usability and user experience for a range of stakeholders, such as healthcare professionals, organ donors, and receivers. When designing user-friendly interfaces that promote smooth interactions and expedite the procurement process for medical professionals, surgeons, medical practitioners, and nurses play a pivotal role in the process. The focus is on developing an inclusive system that meets the requirements of a wide range of people, therefore concerns of accessibility and use for donors and receivers are equally crucial. IT administrators, privacy officers, and data security specialists are also essential in resolving security and privacy issues for all parties involved. The seamless functioning of the system depends on the participation of medical educators, training facilities, and medical societies in the provision of thorough training and education programs for healthcare professionals.

3) Domain Viewpoint (Structural Level): This point of view concentrates on the technical features of the system, including supply chain management, data management, blockchain architecture, and integration of procurement protocols. Experts in cybersecurity, cryptography, and blockchain development play a crucial role in creating a strong, safe blockchain architecture that enables safe, transparent transactions. The experience of system integrators and health information management specialists is put to use in the smooth integration of blockchain technology with organ procurement processes. Organ donation data management and validation is a crucial task for health information technologists, database managers,

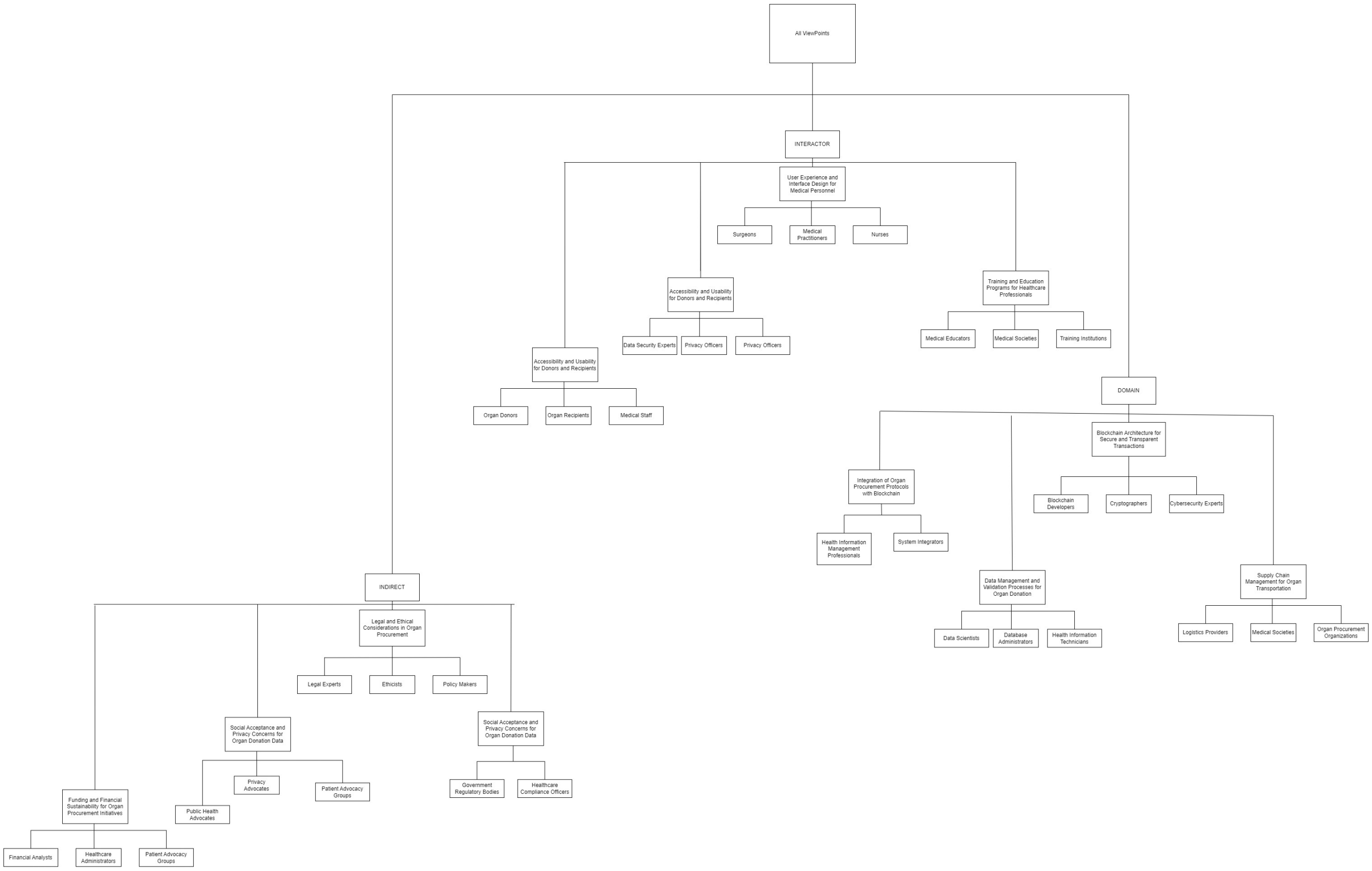


Fig. 4. **ViewPoint Hierarchy**

and data scientists. Lastly, efficient supply chain management for the transportation of organs is ensured by logistics companies, transportation authorities, and organ procurement groups, guaranteeing prompt and safe delivery.

The multifaceted nature of the difficulties and factors to be taken into account in the creation and execution of a blockchain-based organ procurement system is shown by this extensive perspective hierarchy chart. This framework attempts to direct the effective development and operation of the system while maintaining the highest standards of ethics, security, and efficiency by acknowledging the importance of diverse points of view and involving pertinent stakeholders.

B. Requirement Engineering

Undoubtedly, the Requirement Engineering process entails several systematic steps meant to pinpoint, examine, record, and confirm the requirements and limitations of a software system. Requirement engineering is essential in a blockchain-based organ procurement system as it guarantees that the system takes into account the particular difficulties and demands of the healthcare industry. It requires an all-encompassing strategy that includes the following crucial steps:

1) Feasibility Study : **Define the Scope:** After taking into account the potential and obstacles presented by the current organ procurement methods, determine the precise aims and objectives of the blockchain-based organ procurement system.
Analyze Technical Feasibility: Take into account variables including data security, scalability, and interoperability as you evaluate the technical capabilities and limitations associated with integrating blockchain technology in the organ procurement system.
Evaluate the Economic Viability: Examine the financial ramifications of creating, implementing, and maintaining the blockchain-based system, taking into account both one-time costs and ongoing operating expenditures.
Assess Legal and Ethical Feasibility: Make sure that the application of blockchain technology in organ procurement complies with ethical and regulatory requirements by looking into the legal and ethical issues surrounding it.

2) Requirement Elicitation and Analysis: **Determine Stakeholders:** Speak with important parties, such as physicians, organ donors, recipients, regulators, and IT specialists, to learn about their needs and viewpoints.
Hold interviews and workshops: To get information on the precise features and functionalities needed in the organ procurement system, arrange workshops and interviews with

a focus on both the technical and operational elements.
Conduct Analysis of Data: Examine current information on organ procurement procedures to find any holes, inefficiencies, or possible opportunities for blockchain-based improvement.
Prioritize Requirements: Sort and order the needs that were elicited according to their importance, urgency, and compatibility with the overarching aims and objectives of the system.

3) Requirement Specification: **Document Functional Requirements:**The system's functional needs, such as organ monitoring, data sharing guidelines, and blockchain platform transaction management, should be clearly stated in the document.
Record Non-essential Conditions: Indicate non-functional needs, such as compatibility with current healthcare information systems, system scalability, privacy protection, and data security.
Make scenarios and use cases: Provide thorough use examples and scenarios that emphasize the relationships between various stakeholders and the blockchain-based platform, demonstrating how the system will operate in practical settings.
Create a document outlining the requirements: Make sure that the requirements specification document is clear and accessible to all parties involved in the development process by compiling all the information that has been gathered into one.

4) Requirement Validation: **Conduct Walkthroughs and Reviews:** To find any ambiguities, inconsistencies, or discrepancies in the recorded requirements, arrange for regular walkthroughs and reviews of the Requirement Specification Document with the project team and stakeholders.
Carry out simulations and prototyping: Create simulations and prototypes to test the functionality of the suggested system and confirm that it can successfully satisfy the criteria.
Get Input from interested parties: To make sure that the finished system meets the expectations and needs of all stakeholders, get their input on the defined requirements and take into account their comments and recommendations.
Verify Compliance Standards: Check to see if the stated criteria adhere to the legal, moral, and regulatory requirements of the procurement of organs and the handling of patient data in the healthcare sector. The development team can methodically analyze, record, and validate the fundamental requirements for the blockchain-based organ procurement system by following these Requirement Engineering steps. This will guarantee that the final solution satisfies stakeholders' needs and complies with all applicable legal and ethical requirements.

C. Process Model Selection

Rationale behind Process Model Selection:
The integration of Blockchain technology into organ procurement networks is a revolutionary move that will improve security, traceability, and transparency in the medical field. But because of the inherent complexity of the organ supply chain and Blockchain technology, a flexible, risk-averse, and iterative development methodology is required. The following paragraphs will explain why we chose to use the Spiral model for our project and why it is essential to the successful deployment of a Blockchain-based organ supply chain system.

1) Project Complexity and Uncertainty: The organ supply chain is by its nature complex, comprising several parties, a wide range of regulatory requirements, and sophisticated logistics. Furthermore, additional levels of complexity are brought about by blockchain technology, particularly in the areas of data integrity, consensus methods, and smart contract features. The intricacy is further compounded by the uncertainty surrounding the emerging standards for Blockchain technology and organ transplantation processes. The iterative nature of the Spiral model offers an organized framework for handling this complexity.

2) Continuous Risk Assessment and Mitigation: Companies involved in the organ supply chain have a number of hazards to deal with, from non-compliance with regulations to data breaches. This difficulty is well aligned with the Spiral model's emphasis on risk assessment and reduction. Proactive decision-making is made possible by the Spiral model, which regularly assesses the risks related to the adoption of Blockchain. A strong and secure organ supply chain system is ensured by early detection of possible dangers and the mitigation techniques that follow, protecting sensitive patient data and adhering to ethical norms.

3) Iterative Prototyping for Stakeholder Alignment: Involving stakeholders is essential to the success of any project involving the organ supply chain. The iterative prototyping technique of the Spiral model facilitates ongoing stakeholder interaction, including medical professionals, organ donors, recipients, and regulatory agencies. Stakeholders may see how the system is changing through iterative prototypes, offering insightful feedback. By ensuring that the produced system closely matches stakeholders' expectations, this iterative feedback loop promotes cooperation and trust.

4) Adaptability to Evolving Blockchain Standards: Blockchain technology is always evolving, with new consensus methods, protocols, and standards appearing on a regular basis. Following a strict development plan can make it difficult to incorporate state-of-the-art Blockchain innovations. These quick changes in technology are made possible by the flexibility and adaptability of the Spiral model. Our project maintains its agility by adopting the Spiral model, which facilitates the smooth integration of the most recent Blockchain standards and guarantees the organ supply chain system's competitiveness and relevance in the rapidly changing

technological landscape.
When it comes to developing Blockchain-based organ supply networks, the Spiral model makes the most sense. Its capacity to successfully engage stakeholders, handle complexity, support ongoing risk management, and adjust to new technologies makes it an invaluable asset. Utilizing the Spiral model, our initiative optimizes the potential of Blockchain technology to transform organ supply chain management while simultaneously minimizing risks. We are confident that our Blockchain-based organ supply chain effort will be successful since the Spiral model is the most reasonable and persuasive option.

D. How Spiral Model be helpful?

By selecting the spiral model, we will get mainly get 3 advantages: Managing Complexity and Uncertainty, Continuous Stakeholder Engagement and Feedback, and Flexibility to Embrace Emerging Technologies.

The Spiral Model is a perfect fit for developing a Blockchain-based organ supply chain system since it works incredibly well for projects in unpredictable and complex situations. The supply chain for organs is complicated, with many parties involved and strict legal restrictions. Blockchain technology simultaneously adds new layers of complexity to security, consensus methods, and data integrity. Because the Spiral Model is iterative, these issues can be systematically explored and resolved. The development team may gradually improve the Blockchain framework with each iteration of the Spiral Model, tackling particular obstacles and uncertainties along the way. This iterative process results in a more durable and dependable organ supply chain management system by allowing for early risk detection and mitigation in addition to guaranteeing that the developing system complies with project objectives.

Involving stakeholders is essential to the success of any software project, but it's especially important in delicate areas like organ supply chains and healthcare. The iterative cycles of the Spiral Model encourage ongoing stakeholder input and interaction throughout the development process. Healthcare providers, organ donors, recipients, and regulatory agencies should all be involved in every iteration of the Blockchain-based organ supply chain to guarantee that the system satisfies their unique requirements and conforms with rules and laws. Frequent feedback loops allow stakeholders to see how the system is changing, offer insightful comments, and recommend essential changes. This cooperative method guarantees that the finished product satisfies the practical needs of the stakeholders in the organ supply chain while also fostering transparency and trust, two qualities that are crucial in the healthcare industry.

Blockchain technology is constantly changing as new features for smart contracts, consensus algorithms, and protocols are created quickly. Because of its flexibility, the Spiral Model is very useful for discussing new technologies such as Blockchain. The development team may evaluate the most recent developments in Blockchain technology and smoothly incorporate them into the organ supply chain system as the project moves through iterative cycles. This adaptability makes the system competitive and inventive in the ever-changing field of healthcare technology, as well as future-proof. Adopting the Spiral Model gives the project the flexibility it needs to fully capitalize on Blockchain developments, producing an innovative and highly advanced organ supply chain structure.

E. Process Model Explanation

Within the domain of healthcare technology, the creation of the Organ Donation and Transplantation System requires a methodical and well-organized approach. The Spiral Model, because of its iterative and adaptive characteristics, is considered the most optimal selection. This model offers a customized framework that is in accordance with the distinct problems and demands of the medical community, guaranteeing the development of an advanced and adaptable system.

1) Customer Communication: The initial phase of the Spiral Model implementation for our Organ Donation and Transplantation System entails extensive engagement with healthcare experts, organ procurement coordinators, and prospective recipients. It is of utmost importance to comprehend the distinct requirements and preferences of individuals. By conducting comprehensive interviews and workshops, we acquire valuable insights into the complexities of organ donation protocols and transplant operations, thereby influencing the fundamental structure of the system.

2) Planning:: Upon analyzing the comments obtained from client interactions, the process of initiating comprehensive project planning is commenced. In our specific context, the planning phase encompasses the process of clearly delineating the boundaries and objectives of the system. This encompasses the delineation of capabilities such as the process of patient registration, the criteria used for evaluating potential donors, and the algorithms employed for matching organs. The integration of collaborative planning sessions including transplant surgeons and hospital transplant teams facilitates the harmonization of the system with practical medical procedures.

3) Risk Analysis:: Due to the inherent sensitivity of healthcare data and the crucial need of timely organ donations, risk analysis assumes a central role. We do a thorough assessment of potential hazards associated with the security of patient data, the scalability of the system, and compliance with legal requirements. The implementation of continuous risk assessment, which incorporates the expertise of legal professionals and cybersecurity specialists, serves to fortify the system against potential threats and assure compliance with rigorous healthcare standards.

4) Engineering:: The engineering phase within the Organ Donation and Transplantation System encompasses a series of iterative development cycles. Specialized teams

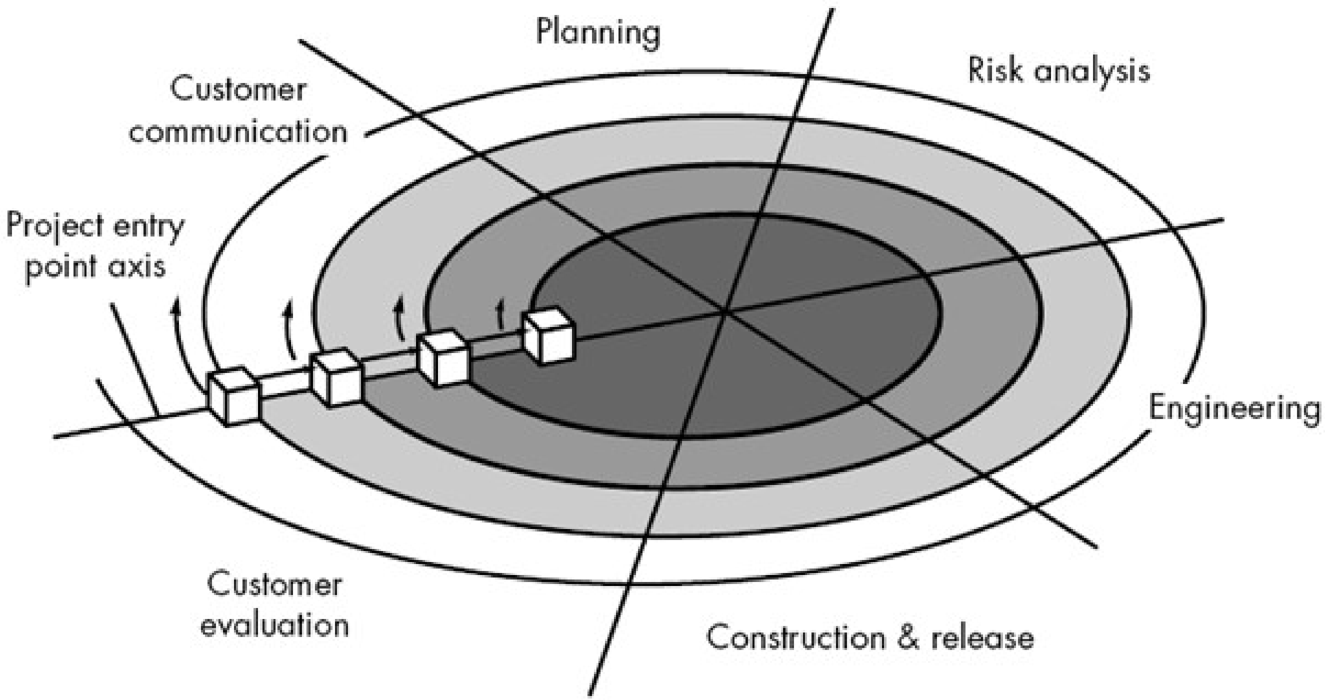


Fig. 5. **Spiral Process Models**

work in collaboration with healthcare professionals to develop modules that facilitate the assessment of patients, registration of potential donors, and matching of organs. The implementation of continuous feedback loops involving transplant coordinators is crucial to guarantee that the organ donation system adapts to the ever-changing demands of the operations involved.

5) Construction and Release:: During this stage, the system is subject to a rigorous building process, which involves the integration of insights obtained from the engineering phase. Rigorous quality assurance processes, such as penetration testing and performance reviews, are utilized. After satisfying the predetermined requirements and receiving approval from transplant surgeons and hospital authorities, the system is deployed for practical application.

6) Customer Evaluation: After being deployed, the system proceeds to the critical evaluation phase. Transplant surgeons, organ procurement organizers, and medical administrators engage in significant interactions with the system, whereby they assess its usability, accuracy, and efficiency. The input provided by individuals is of great value, as it serves to guide and facilitate the process of making incremental changes. The ongoing involvement guarantees the agility and adaptability of the Organ Donation and Transplantation System, enabling it to effectively respond to the dynamic requirements of organ transplantation procedures.

Reiteration of Phases:

Within the framework of the Organ Donation and Transplantation System, the Spiral Model is characterized by its continuous and iterative process of improvement. The steps of customer communication, planning, risk analysis, engineering, building, and evaluation are not discrete entities, but rather interwoven processes that exert ongoing effect on one another. The utilization of an iterative approach in this context guarantees the organic evolution of the system, allowing for the incorporation of the intricacies associated with medical processes, legal frameworks, and user preferences.

The incorporation of the Spiral Model into the development process of the Organ Donation and Transplantation System demonstrates our dedication to designing a system that accurately reflects the complexities of the actual medical environment. The implementation of a customized strategy, which is based on continuous engagement with relevant parties and flexible development processes, ensures the provision of a system that not only fulfills but beyond the anticipated requirements of the medical field. The Organ Donation and Transplantation System is a remarkable example of the harmonious integration of advanced technology and empathetic healthcare approaches, as seen by its iterative development.

V. Engineering Analysis

A. Availability

The requirement for availability in the context of the Blockchain-Based Organ Procurement System pertains to the software application's uninterrupted operation and consistent accessibility. This non-functional requirement underscores the criticality of the system maintaining consistent accessibility for all stakeholders, including regulatory authorities, medical professionals, organ donors, and recipients.

The implementation of strategies that mitigate outages and maximize the system's uptime is required to ensure high availability. This encompasses the utilization of resilient hardware and software infrastructure, the establishment of efficient disaster recovery protocols, and the implementation of redundancy measures. By ensuring uninterrupted accessibility, the system can effectively facilitate the procurement of organs in a timely and efficient manner, thereby providing vital support to healthcare practitioners and patients participating in organ transplant procedures. The non-functional requirement of availability can be further divided as follows :

1) System and Operating System Compatibility: Compatibility requirements for the software developed for the Blockchain-Based Organ Procurement System should encompass contemporary operating systems, such as macOS, Windows 7 and later, and diverse Linux distributions. This guarantees uniformity in access across diverse computing environments that are frequently employed within healthcare organizations and facilities.

2) Database Requirements: The system must possess the capability to seamlessly integrate with widely used database management systems (DBMSs), including MySQL, PostgreSQL, or MongoDB, to facilitate the storage, retrieval, and administration of data efficiently. This feature guarantees smooth integration with pre-existing healthcare information systems and guarantees the ability to scale in response to the increasing quantity of organ donation data.

3) Network Infrastructure: This should be a consideration when developing the software, ensuring that it can operate seamlessly across wide area networks (WANs) and local area networks (LANs), to promote instantaneous data exchange and communication among regulatory authorities, healthcare facilities, and organ procurement organizations. Secure data transmission protocols, including HTTPS and SSL/TLS, should be supported to guarantee the preservation of confidentiality and integrity of sensitive organ donation information while it is in transit.

4) System Resource Requirements: To ensure optimal performance in healthcare computing environments, the software must be optimized to utilize standard CPU, memory, and storage configurations. By doing so, the system guarantees the ability to efficiently oversee the storage and processing of substantial quantities of organ procurement data, all while preventing any adverse effects on system performance or stability.

5) Backup and Recovery Mechanisms: To maintain uninterrupted availability and data integrity, the software must integrate resilient backup and recovery mechanisms. These mechanisms should facilitate the automated and routine transfer of critical data to secure off-site locations. This feature enables efficient data restoration in the case of unforeseen emergencies, natural disasters, or system malfunctions, thereby reducing the likelihood of outage and data loss.

By attending to these particular prerequisites regarding software availability within the framework of the Blockchain-Based Organ Procurement System, institutions can guarantee the system's continued accessibility, dependability, and responsiveness. Consequently, this will facilitate the smooth and effective administration of organ donation procedures, all the while maintaining the utmost levels of data security and system performance.

Therefore, our Blockchain-Based Organ Procurement System has been carefully crafted and developed to satisfy the rigorous non-functional criteria for availability. This guarantees the system's accessibility, dependability, and uninterrupted operation. Furthermore, the software effectively accomplishes all of the aforementioned non-functional criteria for availability.

B. Scalibility

Why this software's scalability is important?
The success of our novel Blockchain-based architecture for the Organ supply chain is largely dependent on its scalability. The capacity to extend our system effortlessly is critical in the healthcare industry, where every second matters and lives are at risk. In the event that unexpected events result in a spike in the demand for organ transplants, our scalable infrastructure guarantees that the supply chain can quickly grow to meet the need. Scalability ensures that our system can manage an ever-growing volume of transactions, facilitating flawless transplant procedures and on-time organ deliveries. It's more than just a feature; it's the glue that keeps our framework adaptable to changing needs in the real world. Scalability gives the organ supply chain the flexibility it requires to meet future difficulties and give hope to people in need of life-saving transplants. In summary, scalability is crucial to our framework's success and has a big impact on the healthcare industry, saving lives with every transaction. It's not simply important.

Certainly, understanding the factors that affect the scalability of a Blockchain-based organ supply chain system is crucial for the success of project. Scalability in this context refers to the system's ability to handle a growing amount of data, users, and transactions efficiently. Here's a detailed explanation of the factors that can either accelerate or decelerate the scalability of your Blockchain-based organ supply chain project.

Factors Accelerating Scalability:

1) Consensus Mechanism: Scalability is greatly impacted by the consensus mechanism selection. Compared to conventional Proof of Work (PoW) methods, algorithms such as Proof of Stake (PoS) and Delegated Proof of Stake (DPoS) are faster and use less energy. You may boost throughput and expedite transaction validation by choosing the right consensus mechanism.

2) Smart Contract Optimization: Scalability can be greatly increased by well-written smart contracts. Smart contracts that are overly complicated or not well-optimized can slow down the system and use too much processing resources. The system becomes more scalable when smart contracts are written with a minimum number of execution steps and gas usage.

3) Sharding: Sharding separates the Blockchain network into more manageable, smaller components known as shards. Because each shard may handle transactions on its own, the total throughput of the system is increased. Sharding approaches allow transactions to be processed in parallel across numerous shards, which accelerates scalability.

4) Network design: The network design influences the speed at which transactions spread throughout the network, taking into account the usage of peer-to-peer (P2P) networks and network protocols. Network scalability is improved by optimizing for low latency and high bandwidth, which speeds up data transmission and ensures quick consensus and validation.

5) Processing Off-Chain: Not every transaction has to be kept on the Blockchain. The system can operate more quickly by using off-chain alternatives, like state channels or sidechains, for non-critical transactions. This will lighten the pressure on the main chain. Faster off-chain transactions are possible with off-chain processing, which also ensures security and subsequently main chain reconciliation.

Factors Decelerating Scalability:

6) Block Size and Block Interval: In networks with constrained capacity, larger block sizes and shorter block intervals might promote throughput at the expense of slower transaction propagation and validation. Maintaining network efficiency and preventing congestion need careful consideration of block size and block interval balance.

7) Replication and Storage of Data: Scalability may be hampered by storing enormous volumes of data directly on the Blockchain. This data must be replicated by every node in the network, which increases storage needs and slows synchronization. Data replication bottlenecks can be avoided by putting effective data storage solutions, such as distributed file systems, into practice.

8) Consensus Latency: Scalability can be hampered by consensus-building delays, particularly in networks with a large number of nodes. Network congestion or intricate consensus methods might lead to extended consensus latency. This problem can be mitigated by selecting consensus mechanisms like Practical Byzantine Fault Tolerance (PBFT), which provide fast finality and low latency.

9) Resource-Dependent Activities: Certain tasks can require a lot of resources, such as complicated computations inside smart contracts or cryptographic calculations. Transaction validation may be slowed down and system processing capacity may be taxed by these activities. This issue can be resolved by choosing effective methods and optimizing the code, which will increase overall scalability.

10) Sickness in the Network: Transaction propagation and validation delays may result from high network traffic and congestion. If the network is unable to handle an abrupt spike in transaction volume, scalability may suffer. Effective network congestion management can be achieved by putting load balancing and congestion control techniques into practice. Our solution, Blockchain-based organ supply chain system has effectively put a wide range of scalability-accelerating tactics into practice. Our system allegedly guarantees quick transaction processing, low latency, and smooth scalability with its optimized consensus processes, sharding strategies, and effective smart contract design. A high-performance, adaptable, and effective organ supply chain infrastructure that can satisfy the demands of a changing and dynamic healthcare environment is ensured by these solid implementations.

VI. Reliability

Significance of reliability in Organ-Health care:
In healthcare, where every instant counts, reliability underpins our Blockchain-based organ supply chain structure. Imagine a patient awaiting transplantation needs a life-saving organ delivered quickly. Errors and system failures are unacceptable in critical situations. Our platform guarantees reliability by precisely and consistently executing every transaction, data point, and supply chain contact. Our system is reliable because healthcare professionals, patients, and stakeholders can trust it to give accurate, real-time information for timely organ delivery and transplants. Not simply technology—saving lives. Our system's reliability is a commitment to the patients, doctors, and families that depend on it to make life-changing events possible. Our reliable lifeline ensures that every organ arrives safely and every transplant opportunity is taken, delivering hope, healing, and the promise of a better tomorrow.

Factors Affecting reliability:

1) Immutability and Data Integrity: Blockchain's immutability guarantees a tamper-proof record of organ-related information. Immutability ensures data integrity and authenticity throughout the supply chain, improving reliability. Blockchain data is reliable for patients, healthcare practitioners, and regulators.

2) Decentralization and Consensus Mechanism: Blockchain's decentralization eliminates single points of failure. Transactions are validated and agreed upon by several nodes using consensus procedures like PoW or PoS. This decentralized validation mechanism prevents data modification and unwanted access, making Blockchain data trustworthy and safe.

3) Smart Contract Automation: Automate operations in the organ supply chain with self-executing agreements and specified rules. Smart contracts automate organ matching, transit scheduling, and verification, reducing human error.

Automation reduces errors by ensuring important tasks are performed precisely and consistently.

4) Transparent and Auditable Transactions: Blockchain technology enables real-time transaction history viewing for stakeholders. All organ donation and transplantation transactions are transparent. Transparency allows regulators and organizations to audit the entire supply chain process and verify its legitimacy and reliability. Stakeholder trust in transparent and auditable transactions ensures system stability.

5) Distributed Redundancy: Blockchain uses a distributed network with numerous nodes storing copies of the full Blockchain. This redundancy keeps data accessible even if nodes fail or are compromised. Since data is not stored on a single server or location, distributed redundancy ensures system stability. The system can continue running smoothly during network outages, ensuring organ supply chain stability. The reliability of a Blockchain-based organ supply chain relies on interoperability and standardization, which allows different systems to communicate and exchange data. Data formats and protocols are standardized for simple integration with healthcare systems and technologies. Interoperability and standardization reduce data discrepancies and improve stakeholder information interaction, guaranteeing a seamless supply chain data flow.

Our Blockchain organ supply chain system shows rigorous implementation. Our solution offers unrivalled reliability through immutability, decentralization, smart contract automation, transparent transactions, distributed redundancy, and interoperability. From start to finish, a seamless, tamper-proof, and transparent organ supply chain has been designed to build stakeholder trust and transform patient care.

A. Security

Security in the Organ Supply Chain Is Critical because organ transplantation is a sensitive procedure, security in the organ supply chain is crucial. For multiple reasons, it is imperative to guarantee the confidentiality of patient data, donor data, and the actual transportation of organs.

1) Patient Safety: Security lapses put patients' lives in danger by causing misidentifications, organ mismatches, and transplant mishaps.

2) Organ Integrity: To guarantee an organ's viability for transplantation, it is essential to preserve its integrity during transportation. Organ damage or contamination from security breaches could make organs unfit for transplantation.

3) Data Privacy: Maintaining patient privacy is essential. Unauthorized access can result from data security breaches, endangering patients' confidential medical information and infringing their right to privacy.

4) Legal and Ethical Compliance: Healthcare organizations are required to abide by legal requirements as well as ethical norms. Medical organizations' reputations may suffer and there may be legal repercussions from security breaches.

5) Trust and Transparency: Patients, donors, healthcare providers, and regulatory bodies all become more trusting of a secure supply chain. The legitimacy of the organ transplantation system as a whole is increased by secure and transparent procedures.

A number of issues can impact the security of the organ supply chain, including:

6) Centralized Databases: Information on organs and patients is stored centrally, which makes it vulnerable. The entire database may be compromised by a single breach.

7) Human Error: The possibility of errors resulting in misunderstanding and possible security risks is increased when paperwork is handled manually and coordination is done by hand.

8) Lack of Transparency: Inadequate knowledge of the organ supply chain can cause miscommunications, and delays, and make it harder to follow the flow of organs.

9) Unauthorized Access: Weak authentication procedures and insufficient access restrictions can provide unauthorized individuals access to private data, which can result in data breaches.

The following security issues in the organ supply chain are addressed by our smart contracts:

10) Decentralization: Our smart contracts operate on a decentralized blockchain network, which removes single points of failure, lowers the possibility of data breaches, and guarantees the integrity of the system.

11) Immutable Record-Keeping: Every interaction and transaction is preserved in an immutable record using smart contracts. The accuracy and integrity of patient and organ data are guaranteed by the fact that once data is captured, it cannot be changed.

12) Access Control: Robust access control methods are implemented using smart contracts. Unauthorized access to some data is prevented by limiting access to only authorized personnel who are validated using cryptographic keys.

13) Transparency: All activities and transactions carried out via smart contracts are traceable and transparent. Real-time supply chain monitoring by stakeholders ensures accountability and transparency at every turn.

Our solution protects patient lives and maintains the integrity of the whole transplantation process by improving the security, transparency, and efficiency of the organ supply chain through the use of blockchain technology and smart contracts.

VII. Testing and Validation

Within this particular area, we undertake the examination and verification of the fundamental operations pertaining to the organ donation and organ transplantation smart contracts that have been created. The assessment stage is executed utilizing the Remix Integrated Development Environment (IDE). Fig. 6 presents a comprehensive list of the people involved in the testing and validation process, along with their corresponding Ethereum addresses. Furthermore, in relation to the functions, the inputs utilized do not accurately represent actual data; rather, they are only hypothetical assumptions employed for the purpose of testing requirements. The subsequent subsections provide a more detailed explanation of the logs and

	Ethereum Addresses
Patient's Doctor	0xAb8483F64d9C6d1EcF9b849Ae677dD3315835cb2
Hospital Transplant Team Member	0x78731D3Ca6b7E34aC0F824c42a7cC18A495cabaB
Procurement Organizer	0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
Organ Matching Organizer	0x4B20993Bc481177ec7E8f571ceCaE8A9e22C02db
Donor's Surgeon	0xdD870fA1b7C4700F2BD7f44238821C26f7392148
Transporter	0x4B0897b0513fdC7C541B6d9D7E929C4e5364D2dB
Transplant Surgeon	0x583031D1113aD414F02576BD6afaBfb302140225

Fig. 6. The Ethereum addresses of the stakeholders in the testing scenario

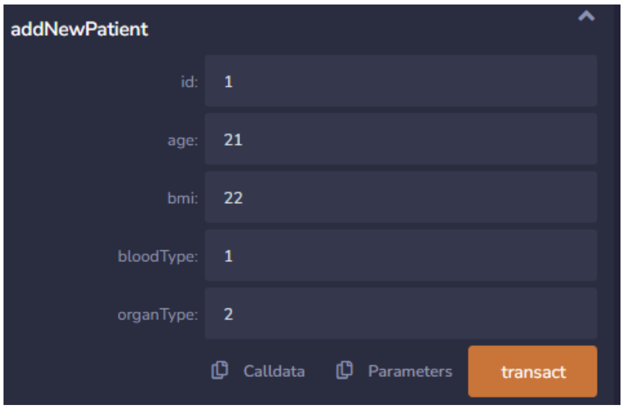


Fig. 7. Snippet of input of addNewPatient function

transactions associated with the primary operations of the smart contract.

Fig. 7 and 8 depict a snippet of input for the addNewPatient function and the logs documenting the successful execution of said function respectively. The addNewPatient function is exclusively invoked by the authorized doctor. Fig. 7 displays the patient's identification number as "1", age as "21", body mass index (BMI) as "22", blood type as "1", and organ type as "2". The enumeration of blood types and organ types is represented as follows: BloodType is an enumeration consisting of the values A, B, AB, and O, while OrganType is an enumeration consisting of the values Heart, Lung, Liver, and Kidney. Regarding patient 1, it has been determined that their blood type is classified as "B" and their organ type requirement is specified as "Liver". Likewise, Fig. 9 depicts a segment of the additional data pertaining to the second patient.

The donorMedicalTestAndRegistration function serves the purpose of incorporating a new donor into the blockchain. It is restricted to be used alone by an authorized member of the transplant team. Figures 10 and 11 illustrate a segment of input

Fig. 8. Logs of successful execution of the addNewPatient function

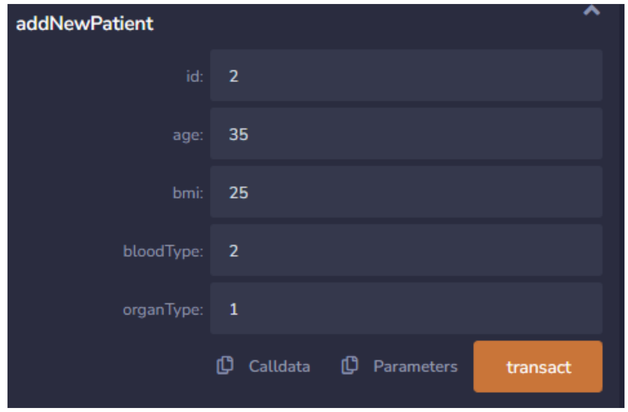


Fig. 9. Snippet of input of addNewPatient function

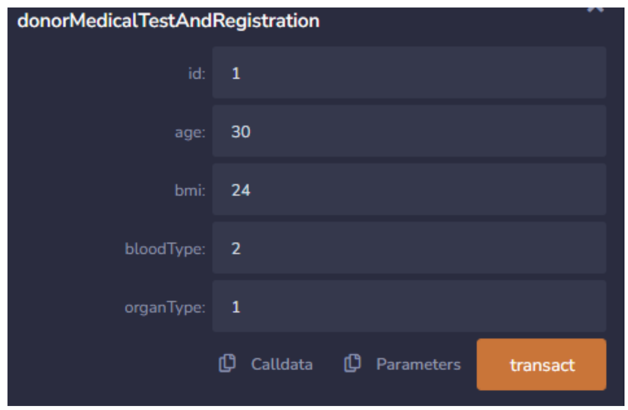


Fig. 10. Snippet of input of donorMedicalTestAndRegistration function

Fig. 11. logs of successful execution of the donorMedicalTestAndRegistration function

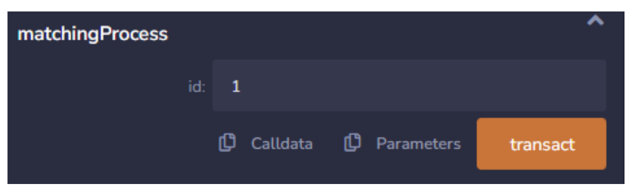
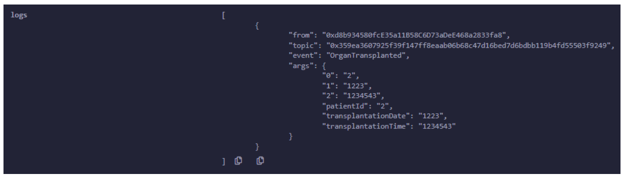


Fig. 12. Snippet of input of matchingProcess function

Fig. 13. Logs of successful execution of the matchingProcess function

logs
[
{
"from": "0xd8b934580fcE35a11B58C6D73aDeE468a2833fa8",
"topic": "0xa925b179dfd4f9e6dd65bd5f9d976ba4175017f46a66d8b238d6238edcf5fb20",
"event": "OrganRemoved",
"args": {
"0": "1",
"1": "1223",
"2": "123432",
"3": "3",
"donorId": "1",
"removingDate": "1223",
"removingTime": "123432",
"organType": "3"
}
},
{
"from": "0xd8b934580fcE35a11B58C6D73aDeE468a2833fa8",
"topic": "0x65fd20fe30dc2300cb5c19d38cdc7066a8e8531be698d53c2e0656c6d31fd8d8",
"event": "OrganReadyForDelivery",
"args": {}
}
]

Fig. 14. Logs of successful execution of the removeDonatedOrgan function



logs
[
{
"from": "0xd8b934580fcE35a11B58C6D73aDeE468a2833fa8",
"topic": "0x359ea3607925f39f147ff8eaab06b68c47d16bed7d6bdbb119b4fd55503f9249",
"event": "OrganTransplanted",
"args": {
"0": "2",
"1": "1223",
"2": "1234543",
"patientId": "2",
"transplantationDate": "1223",
"transplantationTime": "1234543"
}
}
]

Fig. 15. Logs of successful execution of the performTransplantation function

for the donorMedicalTestAndRegistration function, as well as the logs that record the successful execution of said function respectively.

The matchingProcess function is exclusively accessible to the authorized organ matching organizer. When invoked with the donor's ID, this function identifies patients (recipients) compatible with the specified donor. In the illustration provided in Fig. 12, the organ matching organizer initiates the process to find matched patients for the donor with the ID "1". Subsequently, Fig. 13 displays the log entries confirming the successful execution of the function. These logs also reveal the matchedPatient map, wherein the presence of "2" indicates that the patient with ID "2" is identified as a match for the donor.

Likewise, Fig. 14 and Fig. 15 display logs confirming the successful execution of the removeDonatedOrgan and performTransplantation functions.

Fig. 16 and Fig. 17 visually depict the transaction cost and execution cost, respectively, for the fundamental functions embedded within the OrganDonation and OrganTransplantation smart contracts.

VIII. Conclusion

In conclusion, the investigation into the implementation of a Blockchain-driven organ supply chain in the field of software engineering, with a specific focus on the spiral model as the selected operational framework, represents a substantial advancement in the pursuit of improving clarity, tracing capabilities, and effectiveness in the vital domain of organ transplantation. This study not only illuminates the revolutionary capacity of Blockchain technology to revolutionize the procurement and distribution of organs, but also emphasizes the critical incorporation of software engineering principles to guarantee the proposed framework's resilience and flexibility. By employing the spiral model, which is characterized by an iterative and risk-oriented methodology, a strategic decision is made to enable ongoing improvement

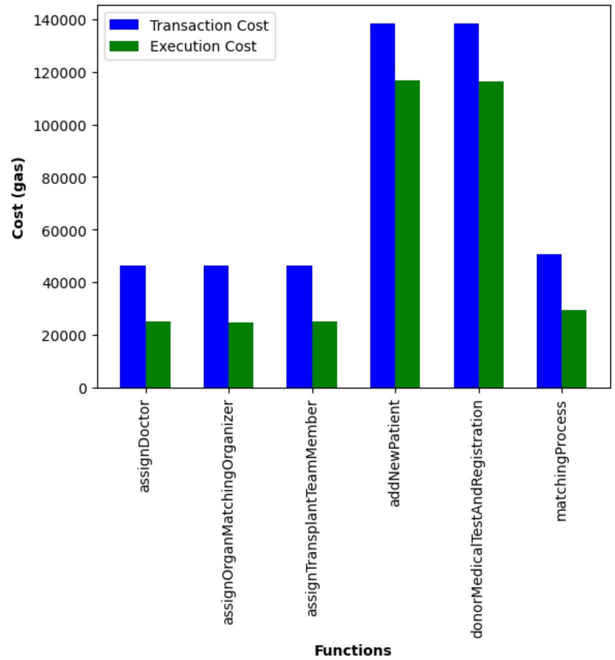


Fig. 16. Cost of primary functions in OrganDonation smart contract

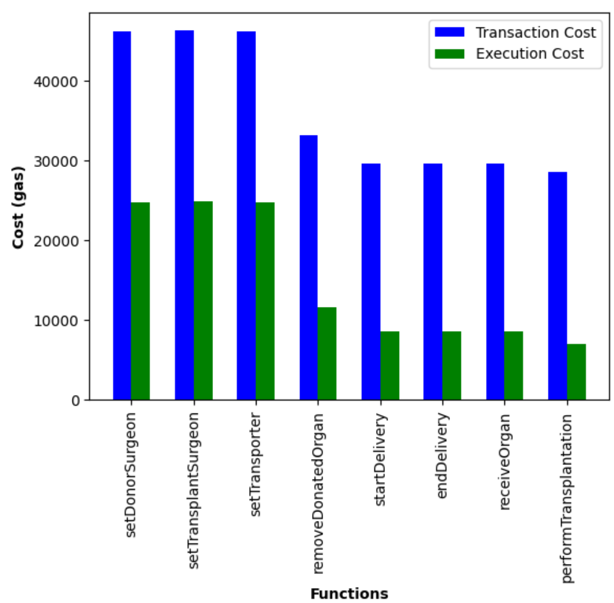


Fig. 17. Cost of primary functions in OrganTransplantation smart contract

and enhancement of the system. This, in turn, facilitates the achievement of an organ supply chain that is dependable, secure, and ethically sound. This research serves as evidence of the interdisciplinary collaboration between software engineering and Blockchain technology in the context of healthcare and organ transplantation. It presents a promising trajectory towards a future in which organ procurement is not only technologically sophisticated but also significantly prioritizes the needs and well-being of individuals.

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