The University of Hong Kong

COMP4801 Final Year Project

Final Report

# Blockchain in Supply Chain

**Analyzing the Pros and Cons of Blockchain in Supply Chain Management and Demonstrating a System**


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# Abstract

The globalization and rapid growth of global supply chains have led to a rising need for transparency. This focus on transparency aims to ensure product safety and enable effective inventory tracking. However, the current method of enhancing transparency relies on voluntary information disclosure by companies. To tackle this problem, this project proposes a blockchain-based solution that allows all stakeholders to participate in a decentralized network, granting them access to verified information. Through application demonstrations, various practical challenges have been identified and addressed, unveiling the advantages and disadvantages of integrating blockchain technology into supply chain management.

## Acknowledgements

I would like to thank my supervisor, Dr. Qian Chenxiong, for providing so many valuable guidance and support throughout this project. His expertise, feedback, and dedication have been instrumental in shaping the direction of my research.

# Abbreviations

**BCT** Blockchain Technology

**IPFS** InterPlanetary File System

**CID** Content Identifier

**DApp** Decentralized application

**NGO** Non-governmental Organization

**PDA** Program Derived Address

**P2P** Peer-to-Peer

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# Chapter 1

# Introduction

This chapter provides an introduction to the background of the project, followed by an exploration of the motivation and objective.

## 1.1 Background

With the advent of globalization, the ability to produce and purchase products on a global scale has become increasingly prevalent. However, this expansion has also brought about a heightened public focus on the transparency of supply chains. This emphasis is driven by a growing demand for greater assurances regarding the safety, quality, and ethical standards of the products and services being offered(1). A study conducted on consumer habits in 2016 revealed that 94% of customers expressed a desire for transparency within the food supply chain, specifically seeking comprehensive information on the production process(2). By providing such transparency, businesses can establish and foster trust and confidence among consumers, enabling them to make informed decisions regarding whether or not to purchase a product. Additionally, prioritizing transparency contributes to a positive brand reputation, allowing companies to stand out and attract more customers(3).

On the other hand, several industry-leading companies have endeavored to enhance their supply chain transparency to improve sustainability. A notable instance occurred in 2005 when Nike faced accusations of providing inadequate working conditions in its global factories. In response to public scrutiny and to protect its brand reputation, Nike opted to disclose detailed supplier information, including names and addresses(4). These examples highlight the increasing significance of transparency, which yields numerous advantages for both the public and the companies involved.

## 1.2 Motivation

The conventional method of enhancing supply chain transparency involves companies voluntarily disclosing detailed information. However, these disclosures are dependent on a single source of trust and may encounter challenges such as data loss, data manipulation, and reduced trustworthiness. To address these issues, the emergence of blockchain technology (BCT) offers a potential solution through decentralized application (DApp) for managing the supply chain. Leveraging the characteristics of blockchain and smart contracts, all uploaded information becomes immutable and can be accessed and verified by stakeholders. This enables companies to establish a decentralized system that enhances transparency, increases trust among stakeholders, and mitigates risks associated with centralized data sources (5).

## 1.3 Objective

This project aims to thoroughly analyze the advantages and disadvantages of implementing blockchain technology in supply chain management. Moreover, it seeks to develop a decentralized blockchain solution specifically designed for recording and managing crucial product information across the entire supply chain. The proposed system will be accessible to all stakeholders, including suppliers, logistics companies, and customers, allowing them to actively participate in and access shared data.

The project workflow commences with suppliers inputting detailed product information through the utilization of smart contracts. To ensure data integrity, a chain of trust mechanism is implemented, granting modification rights exclusively to the responsible parties involved in the inventory flow until the products reach the end consumers. Throughout the development of this prototype, numerous challenges were encountered, and corresponding suggestions for overcoming these obstacles will be thoroughly discussed and examined.

## 1.4 Outline

The remaining sections of this report are organized into four chapters. Chapter 2 provides an overview of the workflow of the blockchain solution and elaborates on the key technologies that will be employed throughout the development process. After that, Chapter 3 provides a detailed implementation and usage of the proposed application. Next, Chapter 4 explains the practical challenges faced by the application and offers corresponding solutions. Then, Chapter 5 analyzes the advantages and disadvantages of applying BCT in supply chain management. Finally, Chapter 6 provides a conclusion for this project.

# Chapter 2

# Methodology

This chapter provides an overview of the workflow of the application and implementation of this project.

## 2.1 Implementation

This section provides an explanation of each technology used in the project and justifies the choice of these technologies.

### 2.1.1 Blockchain: Solana, Rust

Solana is chosen for this project based on several compelling factors. One of the key reasons is its exceptional performance and eco-friendliness, which stems from its innovative consensus algorithm known as Proof of History (PoH). This algorithm enables Solana to process an impressive number of transactions, reaching up to 710,000 per second (6). This high transaction throughput is essential for effectively managing and tracking a large volume of transactions within a supply chain context.

Another noteworthy advantage of Solana is its cost-effectiveness. With transaction fees as low as approximately $0.00025, the expenses associated with creating and updating record can be kept minimal. This affordability is particularly advantageous for a logistics system that requires frequent interactions and updates on the blockchain.

Furthermore, Solana supports the utilization of Rust, a powerful systems programming language, for the development of smart contracts. With Rust, developers can leverage its robustness and safety features to create secure and efficient smart contracts on the Solana network. (7).

### 2.1.2 Front-end framework: React.js

The front-end development of the management system is carried out using React.js, a widely adopted JavaScript framework known for its versatility and extensive community support. Leveraging React.js, we can create a dynamic, responsive, and user-friendly interface that meets the requirements of the project. With the availability of libraries specifically designed for interacting with crypto wallets and the Solana network, we can seamlessly integrate wallet connectivity, transaction handling, and data retrieval from the blockchain.

### 2.1.3 Decentralized file storage: InterPlanetary File System (IPFS)

IPFS, a peer-to-peer (P2P) content-addressed file system, guarantees the preservation of data integrity, security, and privacy. As direct storage of images on the Solana blockchain may not be practical, IPFS plays a pivotal role in storing essential documents such as quality check reports, receipts, and other pertinent files. To facilitate this process, the React.js ”ipfs-http-client” package can be employed to upload these documents to IPFS. Subsequently, a Content Identifier (CID) will be generated, serving as a reference to the uploaded documents. This CID will be stored on the blockchain, enabling retrieval of the associated documents using the same CID (8). By integrating IPFS, the system achieves efficient and secure storage of documents while mitigating the risks associated with single points of failure.

## 2.2 System workflow

Users are required to employ their digital wallets to engage with the network. Based on the user's desired actions, such as registering, initializing a product, adding a record to an existing product, or viewing existing records, they will be directed to different windows within the system. Each window is specifically designed to facilitate the corresponding task, ensuring a seamless user experience.

Figure 1 illustrates an overview of the system workflow, while Figure 2 depicts the workflow specifically related to submitting data to the blockchain. In the following sections, each action will be thoroughly explained, providing comprehensive details and clarity.

### 2.2.1 User Registration

For service providers in the supply chain, who are responsible for product initialization and adding records, it is necessary for them to register an account on the blockchain network. To complete the registration process, these parties will be required to provide their name and submit relevant identification documents as a means of verifying their identity. Following successful verification, a user program derived address (PDA) will be generated. This ensures that only authorized and authenticated individuals or entities can participate in the system and perform these specific tasks (see Figure 1 step 1).

### 2.2.2 Product Initialization

Once registered, suppliers can initiate a product by invoking the function within the deployed smart contract on the network. This function call will trigger the initialization process, resulting in the creation of a corresponding product PDA. The PDA will be initialized with vital information such as the product name, unique ID, and supplier details. This step establishes the initial state of the product within the system, enabling subsequent tracking and management throughout the supply chain (see Figure 1 step 1).

### 2.2.3 Appending record

When a product is shipped to a logistics company or other intermediaries, the ownership of the product is transferred from the sender to the receiver. This transfer of ownership authorizes the receiver to add a record to the product object, documenting the receipt and any relevant information for the next stage of the supply chain. Both the sender and receiver can verify each other's identities, ensuring that the product only passes through trusted parties. This process is repeated as the product moves through various intermediaries until it reaches the retailers. As a result, a chain of trust is established, providing a comprehensive record of the product's journey and ensuring transparency and accountability within the supply chain (see Figure 1 step 2 & 3).

### 2.2.4 Data Fetching

Users have the ability to retrieve data from the blockchain and display it on the front-end at any given time. They can access a list of products that have been recorded on the blockchain and examine them in detail. This functionality allows users to view the stored information and gain insights into the recorded transactions and events associated with each product.

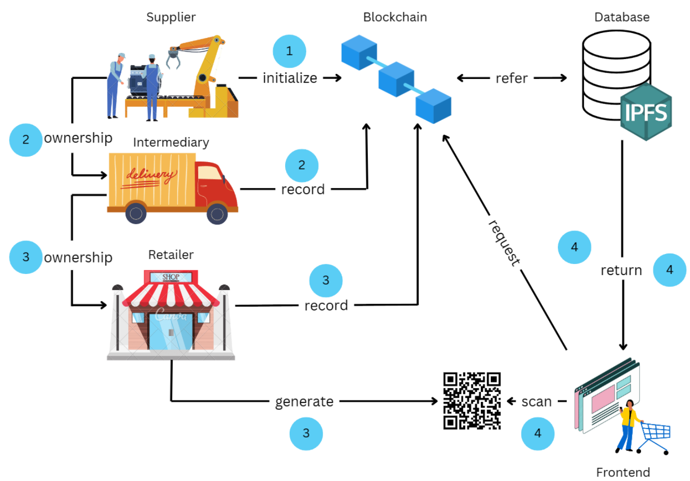


Figure 1: System workflow

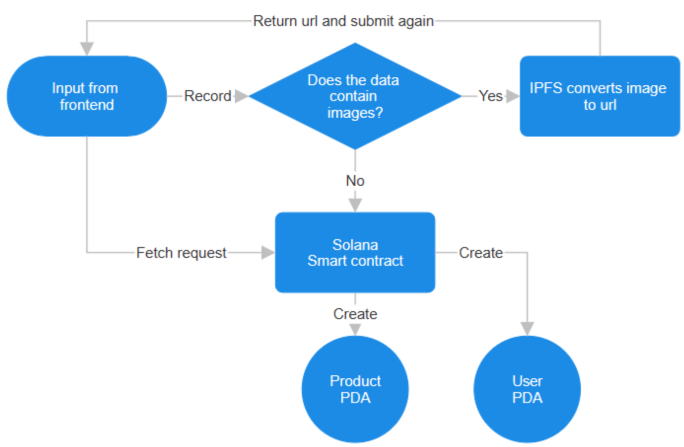


Figure 2: Program Flowchart

# Chapter 3

# Application Demonstration

This chapter provides a comprehensive explanation of the implementation details of the demonstration DApp. It covers the step-by-step process of developing and deploying.

## 3.1 Smart Contract Deployment

Our project relies on the utilization of smart contract. A smart contract is a self-executing contract with the terms of the agreement directly written into code.

In our application, we establish a static program ID (5BvpCr5tAWHDTFemNihrBE5L2k2EzokTh3jMVteYuppK) on Solana devnet, which serves as a unique identifier for the deployed smart contract. This program ID ensures that our application exclusively interacts with the specified smart contract on the Solana blockchain.

## 3.2 Home Page

When users open our application, they are presented with the home page. To begin using the application, users can click on the "Connect" button located in the top right corner of the interface to connect their wallet.

Our application utilizes the phantomWalletAdapter to establish a connection with the user's wallet. The connection endpoint is set to "Solana devnet," where our smart contract is deployed.

Once the wallet is successfully connected, the application proceeds to identify the user's PDA associated with the public key of the connected wallet. This allows the application to retrieve the user's information and establish their identity within the system.

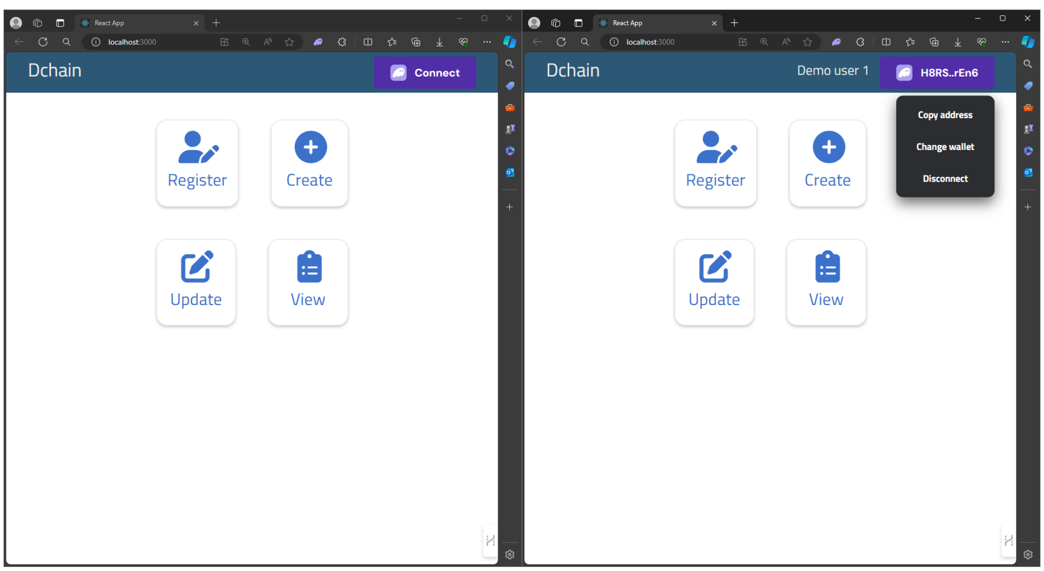


Figure 3: (from left to right) Home page (i) not connected with wallet (ii) connected with wallet

## 3.3 Register Page

Users can input their information, including organization name and essential documents, in the application. After clicking the "Submit" button, they need to pay the transaction fee and the fee for creating their user PDA. The PDA is generated by hashing the following seeds: ["user", the public key of the user's wallet and the program ID]. This hashing process utilizes the SHA256 algorithm to create a unique identifier for the user within the system.

Figure 5 displays an initial dataset stored in a user PDA, which serves as a dedicated storage location for specific information related to the user.

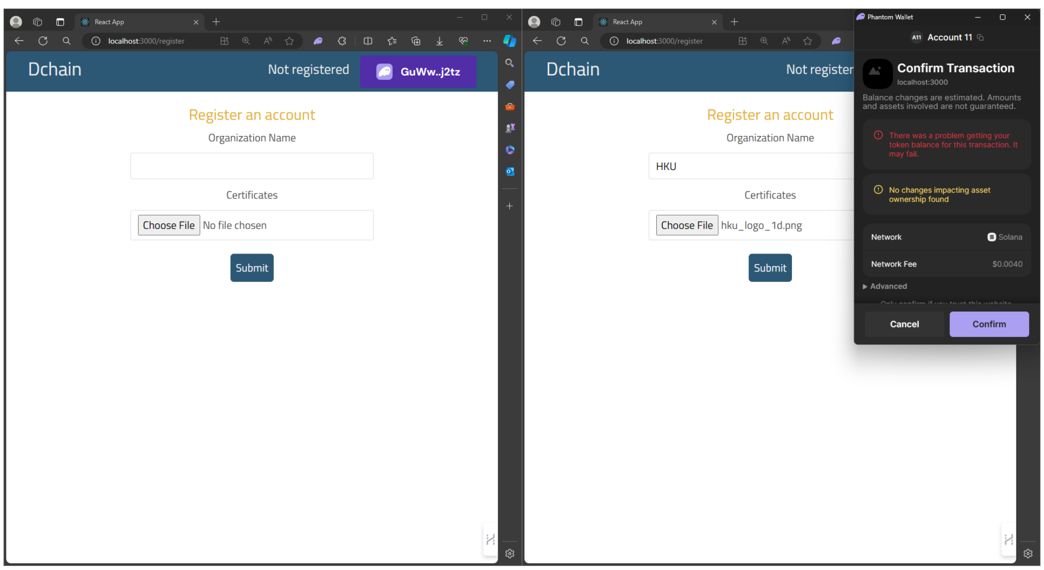


Figure 4: (from left to right) (i) Register page (ii) confirm transaction

```json
{
  "publicKey": "67TJXREymPxvkV2G2zCmeUgKk3XAXoQsMuCcH2oEoAEt",
  "account": {
    "address": "GuWwssMWpZnDDZT5ZripsUKfYLf2i5nrtMjfSEk7j2tz",
    "certificate": "https://gateway.pinata.cloud/ipfs/QmW7UjqGs4uJb6m2NxkbSpHiJ7H6Vrq1X8xWwJWch6L52P",
    "role": "HKU",
    "productId": 0
  }
},
```


Figure 5: Initial data in a user PDA

## 3.4 Create Page

Users can input the name of a product.Upon submission, they are required to pay the transaction fee and the fee for initializing a product PDA. The PDA is generated by hashing the following seeds: ["product", the public key of the user's wallet, the user's product ID (which is recorded within their user PDA), and the program ID]. This hashing process utilizes the SHA256 algorithm to create a unique identifier for the product within the system.

Figure 7 displays an initial dataset stored in a product PDA.

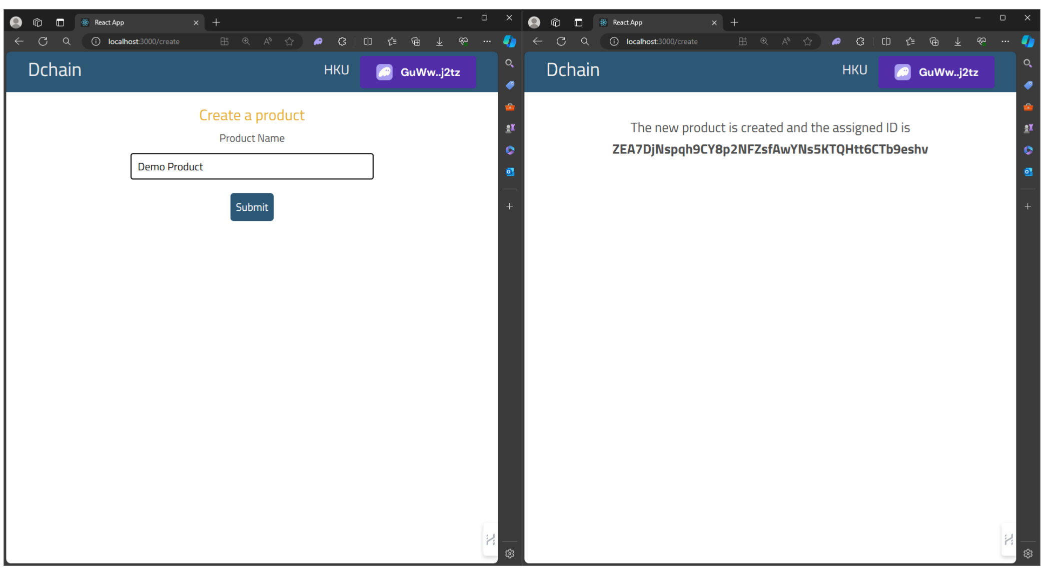


Figure 6: (from left to right) (i) Create page (ii) after creation

```
{
  "publicKey": "ZEA7DjNspqh9CY8p2NFZsfAwYNs5KTQHtt6CTb9eshv",
  "account": {
    "record": [],
    "recordCount": 0,
    "productName": "Demo Product",
    "productOrigin": "GuWwssMWpZnDDZT5ZripsUKfYLf2i5nrtMjfSEk7j2tz",
    "organization": "HKU"
  }
},
```


Figure 7: Initial data in a user PDA

## 3.5 Update Page

To add a new record, users need to input several fields, including the product ID (i.e., the product PDA), the wallet public key of the next owner, the address, and any relevant documents. Once the transaction is confirmed and payment is made, the smart contract then locates the product PDA and verifies its current ownership. If the signer of the transaction is confirmed as the rightful owner, a new record is appended to the product's ownership history.

Figure 9 shows the updated dataset stored in a product PDA.

## 3.6 View Page

Upon connecting their wallet, users can access a list of products in the application. The product list is ordered by last access, allowing users to easily find recently updated or viewed products. Users can click on a product or search for a specific product ID to view detailed information about a particular product.

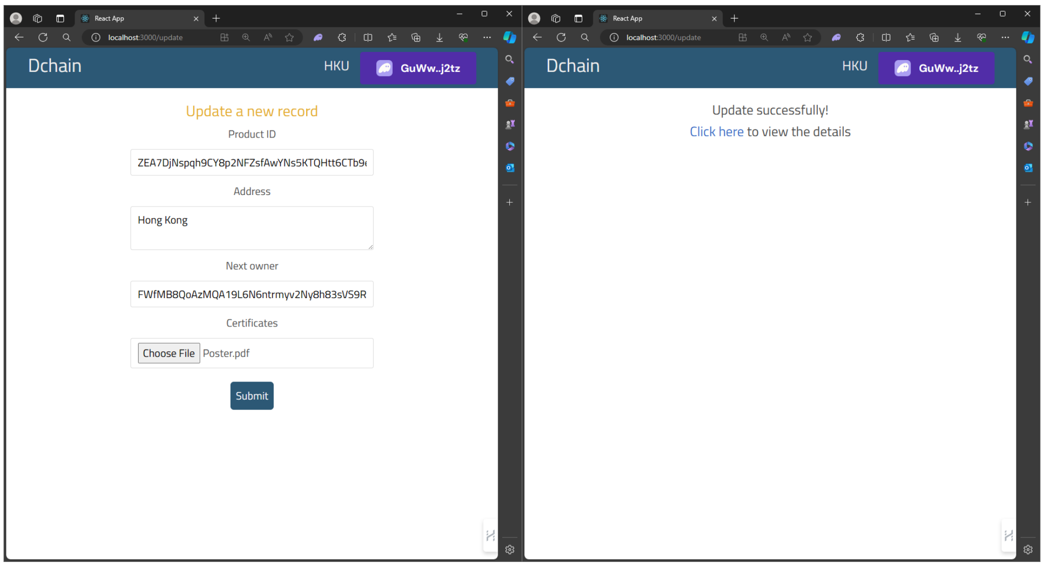


Figure 8: (from left to right) (i) Update page (ii) after updating


Figure 9: Updated data in a user PDA

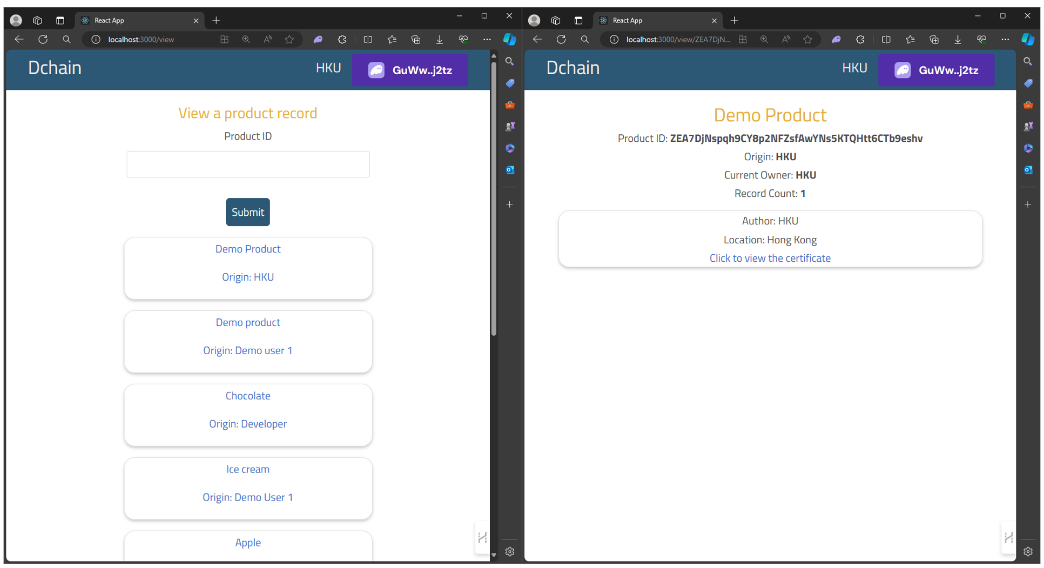


Figure 10: (from left to right) (i) View page (ii) showing details

# Chapter 4

# Challenges

This chapter outlines the main challenges encountered by our application and provides the corresponding solutions to address them.

## 4.1 Documentation

This presented project showcases a simplified blockchain solution for supply chain management. However, in a real-world application, it's crucial to have mechanisms in place to verify the authenticity and credibility of the documents uploaded by upstream stakeholders. This verification process can involve government supervision and the issuance of official certificates to enhance trust among the parties involved. Regulations can be established to ensure compliance with social, environmental, and legal requirements. By supervising and monitoring the activities of stakeholders involved in the supply chain, governments can help maintain transparency and accountability. Besides, various non-governmental organizations (NGOs) such as the Business

& Human Rights Resource Centre and the International Labor Organization can also conduct investigations and assessments of multinational companies to evaluate their adherence to ethical practices (4). NGOs' findings and certifications can serve as additional layers of trust and assurance within the supply chain (9).

## 4.2 Cost Distribution

When creating product PDA in Solana, the signer is required to pay rent based on the size of the PDA. In our application, the product PDA includes an empty vector for future records, which necessitates the supplier to pay the maximum space rent of 10MB. Specifically, in our application, the supplier needs to pay 0.07 SOL to initialize a product PDA, while no additional cost is incurred by others. However, this cost should not solely fall on the supplier, as intermediaries also play a role in the process. This can potentially impact the supplier's economic benefit.

To address this issue, it is advisable for the middleman to contribute a certain amount of tokens during the update process, and the refund functionality of Solana's PDA account can be utilized. Once the product reaches its final destination, such as the retailer, the PDA can release the excess rent back to the supplier. However, prior to that, the supplier still needs to provide a larger initial deposit, which which could impose short-term economic stress.

## 4.3 Access Control

Since Solana is a public blockchain, anyone is able to modify record history inside the product PDA by invoking the smart contract. This can pose a risk to the reliability and trustworthiness of the application.

To prevent unauthorized modifications, implements a mechanism to determine the current owner of a product, who is allowed to append record to the product. If there are no existing record histories, the creator of the product is considered the owner. However, if there are previous records, the owner is determined based on the information provided in the latest record (see figure 11). This mechanism ensures that the product can only be transferred among trusted parties.

By establishing a chain of trust, this mechanism helps maintain the integrity of the product information. If the upstream party in the chain is not deemed trustworthy, the receiver can evaluate the product information with caution.

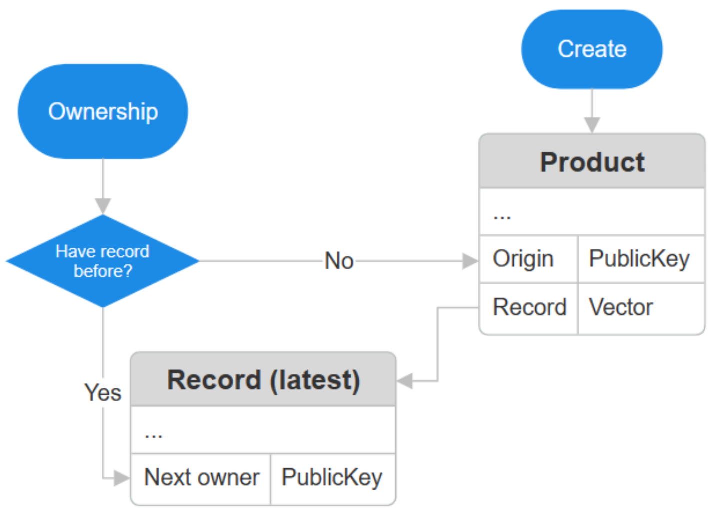


Figure 11: Ownership Determination

# Chapter 5

# Discussion

This chapter discusses about the advantages and disadvantages of integrating BCT with supply chain management.

## 5.1 Advantages

### 5.1.1 Transparency and Traceability

The application operates on a P2P network, utilizing the Solana blockchain network and IPFS. In this setup, all data and transactions pass through the smart contract are publicly visible. The transparent nature of the blockchain network enables easy tracing and verification of product origin, authenticity, and ownership. This helps to combat counterfeiting, as any discrepancies or inconsistencies can be quickly identified and addressed.

### 5.1.2 Efficiency

In a centralized approach involving NGOs, the process of investigating and verifying different parties in the supply chain can be time-consuming and resource-intensive. In contrast, BCT and smart contracts enable the aggregation of data from multiple parties onto a single platform. This allows for efficient verification and validation of data, as the blockchain acts as a trusted and immutable source of information.

### 5.1.3 Security

The use of blockchain technology ensures that once data is recorded on the blockchain, it cannot be altered or tampered with. This immutability of records adds an extra layer of security and trust to the supply chain. Besides, BCT minimizes the vulnerability of the supply chain to cyber attacks, data breaches, and disruptions. If some nodes or participants are compromised in the P2P network, the overall system can continue to function without interruption, ensuring the continuity and reliability of supply chain operations (10).

## 5.2 Disadvantages

### 5.2.1 Cost

Implementing BCT in supply chain management requires significant investment in infrastructure, training, and ongoing maintenance. Additionally, stakeholders, excluding consumers, are typically required to pay transaction fees whenever they invoke smart contracts. These factors can contribute to increased costs per product, which may pose affordability challenges for small and medium enterprises (SMEs).

### 5.2.2 Scalability and Speed

While Solana's mainnet has the capability to process a high number of transactions per second, it is important to consider that this capacity includes all the applications and transactions happening on the blockchain. As the supply chain on the blockchain expands, it can potentially lead to increased congestion and slower transaction processing times, which may impact real-time supply chain operations. This scalability limitation is a factor to be considered when implementing blockchain technology in supply chain management (11).If the scalability limitation of the current blockchain platform is reached, it may be necessary to explore alternative and more advanced blockchain platforms for the system.

# Chapter 6

# Conclusion

This report has examined the major advantages and disadvantages of implementing BCT in supply chain management. While the proposed application shows promise in addressing the issue of supply chain transparency, there are significant challenges that must be overcome for real-world applicability, including the establishment of standard documentation. Nevertheless, this project serves as an stepping stone, providing valuable insights and direction for the development of a blockchain solution in supply chain management. With further refinement and addressing of practical challenges, this technology has the potential to revolutionize supply chain transparency and efficiency in the real world.

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