

# Impact of Blockchain on Vaccine Supply Chains

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**Abstract** - Effective supply chain management is difficult in any industry, but it is especially difficult and dangerous in healthcare, because a harmed supply chain can have a direct influence on patient safety and health outcomes. Blockchain technology is one potential answer for improving the health supply chain's security, integrity, data provenance, and functionality. Blockchain technology has sparked widespread interest, with applications ranging from data processing to banking and finance, information security, IoT, and healthcare sector. As a guarantee of transparency and security, blockchain could be a useful solution for mending supply networks. Even the most basic deployment of blockchain technology might provide significant benefits to the supply chain. The ability to identify the essential data relevant to supply chain management is enabled by registering product transfers on the digital ledger as transactions. The goal of this project is to create and test a blockchain system that will allow for information sharing throughout the vaccination delivery network. We're working on a Decentralized Application (DApp) that will run on smart contracts and will be tested in a simulated network.

**Key Words:** Blockchain, Supply Chain, Vaccine, Smart Contracts, Decentralized Application

## 1. INTRODUCTION

Manufacturers have a vested interest in the vaccine supply chain because their reputations are built on the efficacy of their vaccines at the time of administration. Underperforming supply chains pose a threat to vaccination safety and efficacy, and there is a possibility of future supply disruptions in the event of adverse events. By the beginning of March, 413 million doses of COVID-19 vaccine had been produced. By the end of 2021, it is expected that this number will have risen to 9.5 billion doses [1]. The ability to efficiently distribute COVID-19 vaccines to target groups in accordance with stated immunisation plans depends on supply chain readiness. Vaccine supply management by manufacturers typically ends at shipment or factory exit, and vaccines then begin a long journey to immunization in-country distribution chains that are plagued with obstacles. To reduce the danger of diversion and falsification of COVID-19 vaccines, a robust method for ensuring traceability should be in place, and reverse logistics procedures should be reinforced or established to allow tracking of vaccines during vaccination campaigns [2]. Many of the difficulties

that supply chains face can be quickly addressed with blockchain. This technology has the potential to develop supply chains that are highly adaptable, proactive, reliable, responsive, and accountable. It allows us a lot of data visibility. Because a transaction is certified by many network members, it improves supply chain transparency and the natural and perceived accuracy of transactional data. This research has studied the current industrial applications of blockchain to the trace of supply chain operations of COVID-19 vaccines. The rest of the paper is organised as follows: Section 2 discusses the issues with the traditional supply chain methods. In Section 3, we discuss how blockchain helps overcome these issues. In the remaining sections, we discuss the theoretical foundations and buzzwords pertaining to blockchain: A brief description of Blockchain in Section 4, Smart Contracts in Section 5, Ethereum and Smart Contracts in Section 6, and our Implementation of COVID-19 Vaccine Supply Chain in Section 7. We discuss the scope for improvement and future research directions in Section 8 and close with Section 9.

## 2. ISSUES WITH TRADITIONAL SUPPLY CHAIN METHODS

COVID-19 caught the world off guard, but it has risen to the challenge of a pandemic well. 172 countries are exploring vaccine options for the virus about a year after the outbreak began. Vaccination is one of the most effective ways to prevent and/or control the outbreak of infectious diseases. This medical intervention also brings about many logistical questions [3]. Individual organizations no longer compete as solely autonomous organizations, but rather as supply chains, which is one of the most major paradigm shifts in modern company management, and supply chain can be defined as a network of many businesses and relationships, rather than a chain of businesses with one-to-one, business-to-business interactions [4]. From bench researchers to vaccine manufacturers to epidemiologists, donors, and public health practitioners, many people are concerned about and frustrated by the everyday effort to provide immunizations to communities [5]. As we look at the many stages of the supply chain, we can notice that there are a variety of potential hiccups and bottlenecks at each point [6]. Security Issues, Vaccine Damage, Lack of Transparency, and Counterfeit Vaccines/Drugs are all major concerns in the vaccine supply chain.

## 2.1 Security Issues

The COVID-19 vaccination has been dubbed "liquid gold" by some. There's always the risk of malicious action when you have something of high value, and there are several security concerns around the transfer points at each stage in the vaccine supply chain [6]. Supply chains must be carefully built to respond to the features of each shipment because the COVID-19 vaccinations are very valuable and possibly volatile.

## 2.2 Vaccine Damage

About 28% of sales, or US\$370 billion, are made up of cold chain freight or environmentally sensitive products and temperature-related losses in the business alone amount to US\$35 billion every year [7]. The temperature ranges for storage and transportation may be the same or different; the product manufacturer determines them based on stability data [8]. It is vital to ensure that the cold chain and supply chain freezers can withstand temperature fluctuations and prevent huge quantities of this vaccine from deteriorating.

## 2.3 Lack of Transparency

Once the vaccines are distributed by the manufacturer, their present state and location are unclear, and there is no clear traceability or chain of custody throughout the process. The fundamental issue is that there is no method to verify that the vaccine was obtained from a proper source. As a result, there's a possibility they'll end up in the hands of someone who will sell them on the black market.

## 2.4 Substandard and Counterfeit Vaccines/Drugs

According to the World Health Organization (WHO), one out of every ten medical items, such as medications, vaccinations, and diagnostic kits, is substandard, false, or fabricated in low- and middle-income nations [9]. According to WHO estimates, counterfeit medications worth US\$79.26 billion are marketed each year [10]. During the COVID-19 pandemic, the significance of combating counterfeit and phony medications, as well as other sorts of fraud, was underlined in particular. Interpol discovered an 18 percent increase in the seizures of illicit antiviral medication during its annual Operation Pangea, which took place from March 3 to 10, 2020, compared to the same period in 2018 and the discovery of more than 34,000 counterfeit and substandard masks, "corona spray," "coronavirus packages," and "coronavirus medications" is just the tip of the iceberg in terms of this new counterfeiting trend [11].

The use of blockchain to trace the whole supply chain, from raw ingredients to completed goods distributed by pharma producers to hospitals and end consumers, might be the most effective method to solve these problems. Healthcare has been identified as one of the top priority

industrial areas for blockchain implementation in major countries throughout the world, which is unsurprising.

## 3. WHAT IS BLOCKCHAIN?

A blockchain is a collection of blocks that hold data. This technique was first described in 1991 by a group of researchers, and it was designed to timestamp digital documents so that they could not be backdated or tampered with.

Basically, a blockchain is nothing but a database. It is different from a typical database in the way it stores information i.e a blockchain stores data in blocks which are chained together. It could be seen as a distributed ledger, a chronological chain of 'blocks' where each block contains a record of valid network activity since the last block was added to the chain [17]. A block may be defined as an encrypted piece of information which is linked together.

Each block consists of 3 things: 1) Some data, 2) Hash of the block, 3) Hash of a previous block. You can compare hash to a fingerprint. It uniquely identifies a block and all of its contents, just like a fingerprint. This effectively forms a chain of blocks, and it is this mechanism that ensures the security of a blockchain.

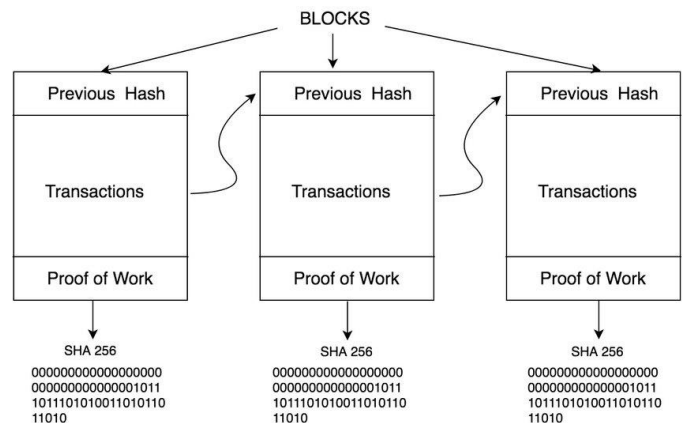


Fig -1: Chain of blocks in a blockchain(Source : [19])

The blockchain has an interesting property i.e, once some data has been recorded inside a blockchain, it becomes nearly impossible to change it. This allows the participants to audit and verify transactions independently and relatively cheaply [14]. A peer-to-peer network and a distributed timestamping server are used to operate a blockchain database independently [21].

Trust among a distributed network is achievable in a normal blockchain interaction because of the validation or mining process, in which each new transaction is confirmed by the entire network before being added to a blockchain.

Mining is the process of adding new blocks of data to the ongoing chain through validation by each network node known as a 'miner.' A miner can add a new block only after solving some mathematical/cryptographic algorithm,

which must be accepted as valid data by the majority of the nodes. The miner is then rewarded by the network for adding a new valid block to the chain by some credit. This credit incentivises the miners to constantly validate and keep the consistency of the data throughout the network. A miner is usually an independent entity and no single miner is capable of removing, adding, or changing the data.

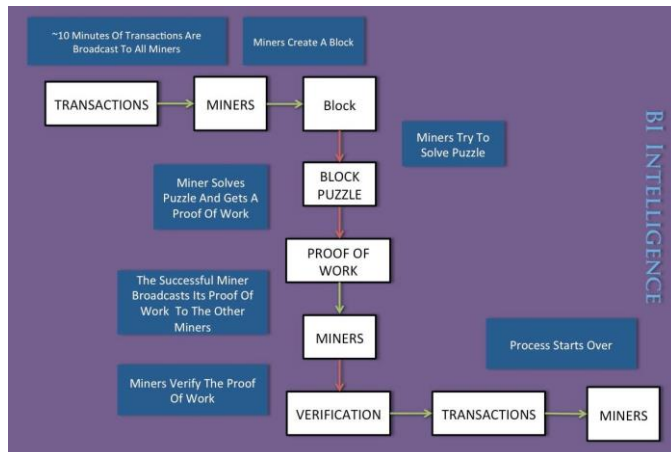


Fig -2: Mining Procedure (Source : [18])

#### 4. TECHNOLOGICAL ADVANTAGES OF BLOCKCHAIN TECHNOLOGY

Users benefit from several key technological advantages that are inherent in blockchain's structural architecture. Some of which including durability, transparency, immutability and traceability are described below.

##### 4.1 Accurate

On the blockchain network, transactions are validated by a network of thousands of computers. This practically eliminates human interaction in the data verification process, resulting in lower human error and more accurate data records.

##### 4.2 Decentralized

Blockchain doesn't keep any of its data in a single location. Instead, the blockchain is copied and spread across a network of computers. Whenever a new block is added to the blockchain, every computer on the network updates its blockchain to reflect the change. Blockchain makes it more difficult to tamper with data by disseminating it across a network rather than holding it in a single central database. Only a single copy of the data would be compromised if a hacker gained a copy of the blockchain, rather than the entire network.

##### 4.3 Transparency

Most blockchains are entirely open-source software. This means that anyone with access to the internet can look at its code. This allows auditors to check the security of cryptocurrencies like Bitcoin. This means that there is no

genuine authority over who controls Bitcoin's code or how it is changed. As a result, anyone can suggest system updates or enhancements. Bitcoin can be upgraded if a majority of network users believe that the new version of the code with the upgrade is legitimate and useful.

##### 4.4 Traceability

If your company works with commodities that are traded through a complicated supply chain, you know how difficult it can be to track an item back to its source. When commodity trades are recorded on a blockchain, you have an audit trail that indicates where an item originated from and where it stopped along the way. This historical transaction data can help with asset validity verification and fraud prevention.

##### 4.5 Reduced Cost

For most businesses, reducing costs is a priority. Because you don't need as many third parties or middlemen to make guarantees using blockchain, it doesn't matter if you can trust your trade partner. Instead, all you have to do is place your trust in the blockchain's data. You won't have to go through as much paperwork to execute a transaction since everyone will have permissioned access to a single, immutable version.

##### 4.6 Immutability

Due to the need for confirmation by other nodes and traceability of modifications, data kept on a distributed public blockchain is practically immutable. This allows users to operate with the highest degree of confidence that the chain of data is unaltered and accurate [13].

However, it went by mostly unused until it was adapted by Satoshi Nakamoto in 2009 to create a digital cryptocurrency Bitcoin. Bitcoin is a peer-to-peer electronic cash system that allows online payments to be transmitted directly from one party to another without the use of a banking institution [12].

#### 5. SMART CONTRACTS

##### 5.1 What are Smart Contracts?

The term 'smart contract' was introduced by Nick Szabo in 1996, when he described it as "a set of promises, specified in digital form, including protocols within which the parties perform on these promises" [20].

Smart contracts are agreements between two or more contracting parties which can be automatically enforced without any intermediaries. These agreements exist as software code on the blockchain network, ensuring their autonomy and self-execution based on established rules [15]. They're frequently used to automate the execution of an agreement so that all parties may be confident of the

outcome straight away, without the need for any middlemen or wasted time. They can also automate a workflow by initiating the following step when certain circumstances are satisfied [16].

The elimination of the need for trusted intermediaries, arbitration and enforcement costs, fraud losses, and purposeful and unintentional exceptions are all goals of smart contracts

### 5.2 How Do Smart Contracts Work?

To make smart contracts function, simple "if(condition)...then..." lines are written into code on a blockchain. When predefined criteria are satisfied and confirmed, the activities are carried out by a network of computers. These actions include transferring money to the relevant people, registering a vehicle, sending notifications, and issuing a ticket. The blockchain is updated after the transaction is completed. That means the transaction can't be modified, and the results are only visible to those who have been granted access [16].

### 5.3 Advantages of Smart Contract

#### i. Speed, Efficiency and Accuracy

When a condition is satisfied, the contract is instantly executed. Because smart contracts are digital and programmed, there is no paperwork to deal with, and no time wasted correcting errors that might occur when filling out documents by hand [16].

#### ii. Trust and Transparency

There's no need to worry about information being tampered with for personal gain because there's no third party engaged and encrypted transaction logs are exchanged among participants.

#### iii. Security

Furthermore, because each record on the blockchain is linked to the preceding and subsequent records, changing a single record would necessitate changing the entire chain..

## 6.HOW DOES BLOCKCHAIN OVERCOME SUPPLY CHAIN ISSUES?

In any industry, improving operations and supply chain functions has become a critical component of business operations and strategy. The modern supply chain is complicated, with geographically dispersed companies, multi-echelon structures, and so on. Globalization, in this case, comprises regulatory regulations, human behavior,

and a diverse culture in the supply chain, all of which make it impossible to locate and handle information in the network [25]. The healthcare and pharmaceutical industries have a variety of unique characteristics that make them appealing to blockchain applications. The use of blockchain technology in the pharmaceutical industry allows for the tracking of all stages of medicine production as well as their quality. The benefit of blockchain in the healthcare and pharmaceutical industries is also due to the industry's enormous scale and severe resource waste. For example, the global drugs industry was valued at US\$1.27 trillion in 2020 [22].

Pharmaceutical research and development is a multi-year process that includes drug discovery, drug development, and regulatory approval in the pharmaceutical supply chain. However, due to drug counterfeiting, such as hidden, unregulated, and obsolete information from drug regulatory authorities and manufacturers about drug supply, counterfeit pharmaceuticals are produced, marketed, and consumed. In these cases, where data security and privacy are paramount, blockchain is the most suitable technology. It ensures the safety of pharmaceuticals on the market with a high level of trust, as well as the quality of health care for the general public and recipes, by utilizing modern authentic digital mechanisms [23].

These challenges in the pharmaceutical industry can be solved by employing the six primary components of blockchain technology: decentralized, transparent, open-source, autonomy, immutability, and anonymity [24].

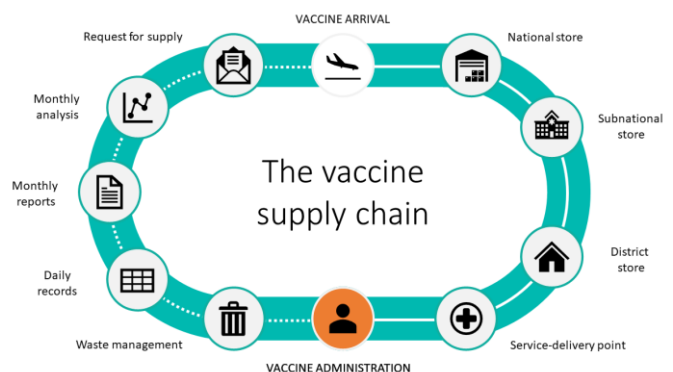


Fig -3: Vaccine Supply Chain (Source : [25])

## 7.IMPLEMENTATION

Vaccine Tracker is a Blockchain-based decentralized logistics application that tracks the vaccines whereabouts at every freight hub. Consumers can simply scan the QR code of the vaccine to acquire detailed information on the provenance of that vaccine, empowering them to only buy genuine and high-quality vaccines.



As the vaccine moves through a lot of places throughout its journey from the manufacturer to the hospital, the basic idea is to record every step of the vaccine's journey in a blockchain. Hospitals/Governments can use the blockchain database to see where items are in production and shipment to better build a delivery timeline for their country.

The Vaccine Tracker allows users (such as vaccine makers, warehouse owners, airport officials, hospitals and consumers) to add new vaccine batches, modify the status of the vaccine being scanned and view the journey of the vaccine, electronically at each step of the supply chain. All users' locations, dates, times, and operating temperatures are collected for each step. A QR (Quick Response) code must also be created, printed, and applied to the vaccines.

The users utilize the web application for registration, QR code generation, QR code scanning, and tracking of vaccines. The screenshots of the application can be seen in Figures 4, 5, 6 and 8.

Vaccine Tracker employs QR codes to store the states of vaccines upon generation, transport, delivery, and administration. Inputs to Vaccine Tracker are provided by respective stakeholders and each step.

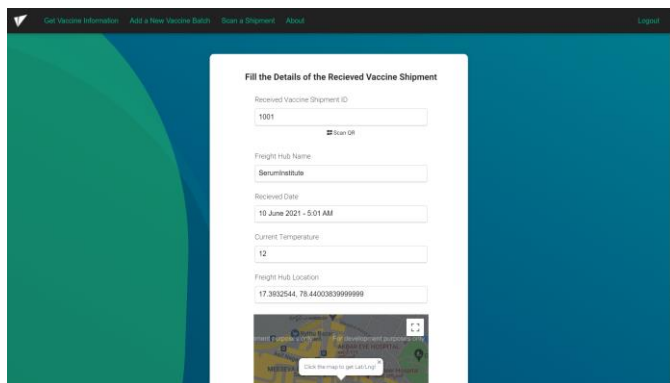


Fig -4: Vaccine Tracker for Scanning Vaccine Shipments

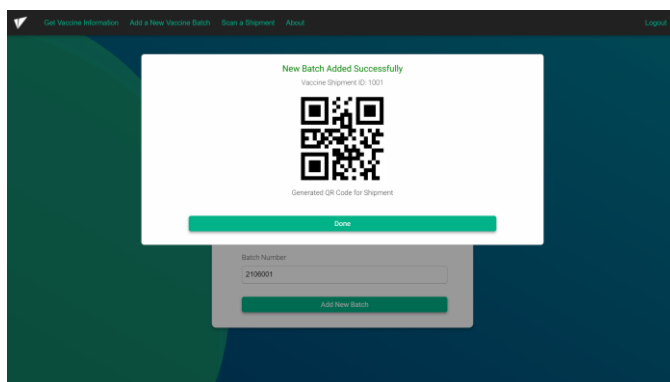


Fig -5: QR Code generated after adding a new vaccine batch

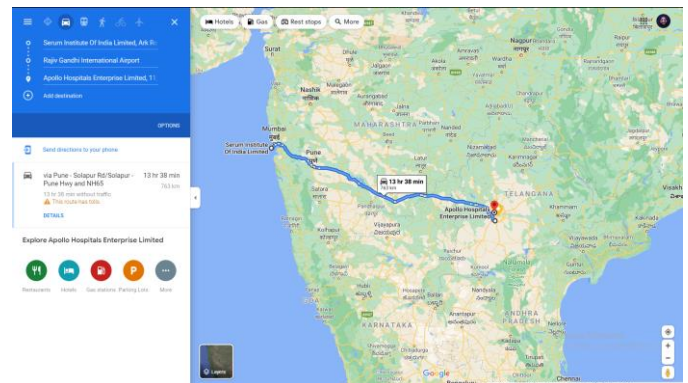


Fig -6: Map View of Vaccine Journey

The manufacturer is responsible for adding new vaccine batches into the supply chain, by entering details such as (i) Manufacturer's Information, (ii) Vaccine's Name, (iii) Date and Time of Manufacture, (iv) Expiry Date of the Vaccine and (v) Batch Number. A QR code and corresponding shipment ID is then generated for every batch.

When the vaccine shipment reaches a touch point, the respective stakeholder needs to scan the QR Code of the shipment received and enter (i) Stakeholder's Information, (ii) Date and Time of receiving the shipment, (iii) Current Temperature of the Vaccine and (iv) The Current Location.

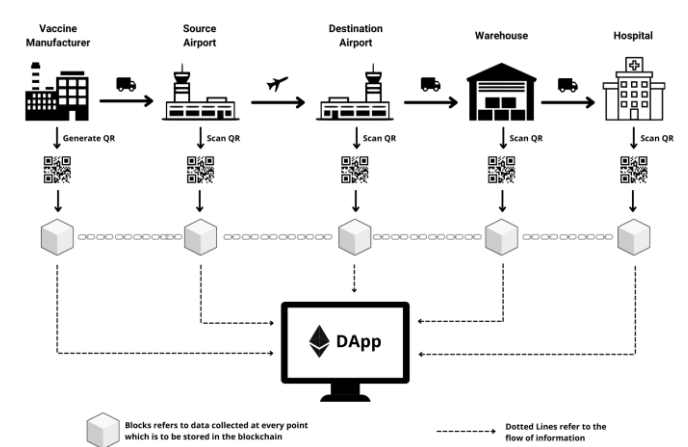
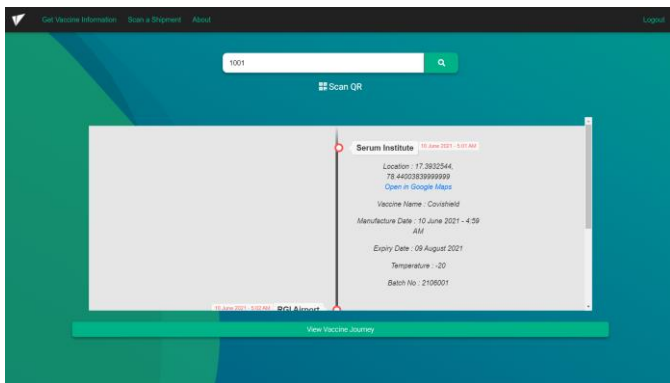


Fig -7: Collection of Data from Various Touch Points

The end users/consumers need to login and scan the vaccine's QR code for detailed information of its journey from the manufacturer to the hospital, all relevant touch points for one vaccine, including all stakeholders and steps performed for that specific vaccine will be shown on the map view.



**Fig -8: Timeline of Vaccine from Manufacturer to Consumer**

## 8. CONCLUSION

In recent years, blockchain has emerged as the most significant technical advancement. It's a ground-breaking notion that can effectively be implemented to provide consumers with transparency, security, and flexibility. Transparency is critical in the healthcare and pharmaceutical industries due to the high value of data and strict restrictions. As a result, blockchain is well-suited to these sectors. Established companies such as IBM, as well as startups such as Chronicled have developed innovative blockchain-based solutions to address diverse challenges facing this industry. Many startups, as well as established organizations like IBM, have developed creative blockchain-based solutions to meet the industry's various difficulties. In the healthcare and pharmaceutical industries, blockchain solutions have substantially improved efficiency, security, and traceability. The scanning feature of Vaccine Tracker, for example, makes it easy to check the vaccine's legitimacy. This is a regular procedure, although it is complex and time-consuming. By addressing the possible causes of mistakes and inconsistencies, blockchain solutions can help reduce chargeback rates. When it comes to the transportation of medications, blockchain, especially when combined with other technologies like the Internet of Things, can improve verifiability, safety, and efficiency. Companies in these areas may also use blockchain to comply with different regulatory standards and boost customer confidence.

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