A STUDY ON

BLOCKCHAIN TECHNOLOGY FOR THE ADVANCEMENT OF SUPPLY CHAIN AND LOGISTICS

A Project Report

Submitted by

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(Registration No: 2105305013)

In partial fulfillment of the award of the degree of

MASTER OF BUSINESS ADMINISTRATION

SCHOOL OF MARITIME MANAGEMENT

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KOCHI CAMPUS

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DECLARATION

I hereby declare that the presented project titled

"BLOCKCHAIN TECHNOLOGY FOR ADVANCEMENT OF SUPPLY CHAIN AND LOGISTICS"

is my own work to the best of my knowledge and belief, is carried out under the direction of **Dr. Jayan P.A** in partial fulfillment of the requirements for the award of the degree of **Master of Business Administration in International Transportation and Logistics Management** to be submitted to the **School of Maritime Management, Indian Maritime University, Kochi Campus.**

I also confirm that the project is only prepared for my academic requirement, not for any other purpose. It might not be used with the interest of the opposite party of the corporation.

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INDIAN MARITIME UNIVERSITY

(A Central University under Ministry of Port, Shipping and Waterways)

SCHOOL OF MARITIME MANAGEMENT

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CERTIFICATE

This is to certify that the project report titled "**BLOCKCHAIN TECHNOLOGY FOR ADVANCEMENT OF SUPPLY CHAIN AND LOGISTICS**" submitted by **Ayisha Saniyath register number 2105305013** student of **MBA (ITLM)** is a bonafide record of her project report and submitted to the School of Maritime Management, Indian Maritime University, Kochi campus, under the supervision of **Dr. Jayan P.A**, Faculty IMU, Kochi campus. It is also certifying that the above work has not previously formed or submitted for the award of any degree, diploma, associateship, fellowship or other similar titles, and it is an independent work done by the candidate.

Dr. Jayan P.A

(Internship Guide)

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I am pleased to acknowledge the contributions of several individuals who have been instrumental in the successful completion of my Master's project on the topic of **"Blockchain Technology for the Advancement of Supply Chain and Logistics"** Firstly, I want to express my gratitude to God for his presence during the project's development.

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AYISHA SANIYATH

EXECUTIVE SUMMARY

This Master's project explores the potential of blockchain technology for the advancement of supply chain and logistics. The project was inspired by previous research on the use of blockchain for the distribution of COVID-19 vaccines and suggested a model for the enhancement of the coconut industry of Kozhikode by introducing blockchain technology in the for-supply chain process. Through these case studies, it became apparent that blockchain technology has the potential to revolutionize supply chain management by providing a secure, transparent, and decentralized platform for tracking and tracing products and ensuring their authenticity.

The objective of this research project is to gain insights into the ways in which blockchain technology can improve the management of supply chain systems. The project aims to identify the unique advantages that blockchain can offer to supply chain management and explore its potential as a solution to existing challenges in the field.

The specific objectives of this project are as follows:

1. To review the literature on blockchain technology and its potential applications in supply chain and logistics.
2. Analyzing a real-world example of blockchain technology's application in the distribution of COVID-19 vaccines.
3. To analyze the challenges faced by traditional supply chains, with a focus on the coconut industry in Kozhikode.
4. To identify key areas for improvement and develop a blockchain model that can overcome these challenges and enhance the efficiency of the supply chain of the coconut industry in Kozhikode.
5. To explore the benefits and challenges of using blockchain technology in supply chain and logistics.
6. To evaluate the effectiveness of blockchain technology in improving supply chain efficiency, transparency, and security.
7. To identify the key factors that influence the adoption and implementation of blockchain technology in supply chain and logistics.

The project involved a comprehensive literature review, a qualitative analysis of case studies, and the development of a conceptual framework. The results of the project suggest that blockchain technology has significant potential for improving supply chain management by enhancing transparency, reducing fraud, improving traceability, and increasing efficiency.

The project also identified several challenges to the adoption and implementation of blockchain technology in supply chain and logistics, including technological limitations, interoperability issues, regulatory challenges, and the need for standardization. Overall, this project provides valuable insights into the potential of blockchain technology for the advancement of supply chain and logistics.

GLOSSARY

1. Blockchain: A digital record-keeping system that is decentralized, meaning there is no central authority controlling the information, and transactions are verified through cryptography to ensure security and transparency.

2. Supply Chain Management: The process of managing the movement of goods and services from the point of origin to the point of consumption, including the storage and transportation of raw materials, work-in-progress, and finished products.

3. Digital Ledger: A digital database that securely records and shares information using digital technology.

4. Cryptocurrency: A type of digital or virtual currency that uses cryptography for security and operates independently of a central bank.

5. Smart Contracts: Self-executing contracts that are recorded on a blockchain and automatically execute the terms of the agreement when the conditions specified in the code are met.

6. Decentralization: The distribution of power and control away from a central authority through the use of technology like blockchain.

7. Node: A device or computer that participates in the verification and maintenance of a blockchain network.

8. Mining: The process of adding new blocks to a blockchain network by solving complex mathematical problems.

9. Consensus: The process of verifying transactions on a blockchain network through agreement among network participants.

10. Hashing: The process of converting data of any size into a fixed-size output, which is a unique representation of the original data.

11. Immutable: Refers to data recorded on a blockchain that cannot be changed or altered.

12. Supply Chain: The network of individuals, organizations, activities, information, and resources involved in the creation and delivery of a product or service to customers, including all steps from raw materials to final delivery.

13. Internet of Things (IoT): A system of interconnected devices and sensors that can collect and exchange data over the internet to create more reliable and traceable supply chain systems.

14. E-business: The use of electronic technologies to conduct business transactions.

15. Data Management: The process of collecting, storing, and analyzing data related to the supply chain to maintain visibility and transparency.

16. Traceability: The ability to track and verify the history, location, and status of a product or asset throughout its lifecycle.

17. Transparency: The quality or state of being open and easily accessible, often used to describe openness in decision-making, communication, or operations.

18. Private Blockchain: A blockchain network that is restricted to a specific group of users or organizations.

19. Public Blockchain: A blockchain network that is open to anyone to participate in and access.

20. Permissioned Blockchain: A blockchain network that requires permission to join and participate in the network.

21. Permissionless Blockchain: A blockchain network that is open and does not require permission to join or participate in the network.

22. Distributed Ledger Technology (DLT) is a term that refers to technologies which allow for the secure and transparent recording and sharing of data across a network. Examples of DLT include blockchain and other similar technologies.

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INTRODUCTION

1.1 INTRODUCTION

Emerging technologies in the fourth industrial revolution era are having an impact on various domains of the industry. Every aspect of the industry is digitalized or under digitalization. The supply chain process is one of the most crucial elements that is undergoing digitalization. The idea behind digital supply chain is to provide a platform that will help businesses to monitor the delivery of their goods or supplies.

There are still several problems with the digital supply chain, including a lack of provenance, a lack of transparency, and a trust problem and fraud. One of the developing technologies, blockchain technology, can be incorporated into the supply chain to address current problems and enhance performance.

A blockchain is a distributed ledger database which records transaction data permanently and verifiably. In the initial stage, Blockchain was used widely in the financial sector but currently various studies are conducted to utilize the properties of blockchain in other sectors. Due to its potential to guarantee data immutability and public accessibility of data streams, blockchain can highly be used in supply chain. Blockchains decentralized infrastructure can eliminate the problems of the present centralized approaches of supply chain which includes problems like fraud, corruption, tampering and falsify information.

A supply chain can be defined as a set of operations that include manufacturing of product, it's transit, storage, or distribution which is either handled by an individual company, a multiple companies, or various stakeholders. Supply networks play a significant role in the world economy and it requires huge transactions. The International Trade Administration represented that more than 76% of world trade accounts for supply chain transactions. The main objective of supply chain is to reduce the production cost. As a result, many firms outsource assembly lines to low-cost regions to cut production expenses. More affiliates are introduced in the growing stages of supply chain, which have been further fragmented and lead to supply chain standing still complicated and interdepended.

Supply chains have evolved over the centuries, becoming increasingly interconnected, complicated, and global. For smooth functioning of supply chain, it is necessary to have excellent flow of information and immediate synchronization between various parties involved in supply chain.

In a conventional supply chain ecosystem, a central database stores all data pertaining to all of the supply chain processes. This central database is maintained by a single administrator. In this centralized form of data exchange there exist various drawbacks which includes:

1. Entire system will be unavailable if the central database server goes down because this relies on a centralized server.

2. An administrator who is dishonest can modify the data on this server without the stakeholders' awareness. These alterations cannot be traced. Thus, this centralized strategy also lacks transparency and traceability.

Thus, we can conclude by saying that the major issue in conventional supply chain method is lack traceability of the products, transparency for the stakeholders, trust in the collaborative system, and security from unauthorized modification of data.

The best example to understand the problems caused due to lack of traceability in supply chain is food fraud. The main reason for food fraud is food inflation which challenge the food industry by creating a hostile climate that makes it harder to maintain product quality, safety, and transparency. Label of manufacturing date being replaced and contaminated substance being used are some problems. Since ecology of the supply chain includes a variety of stakeholders, including farmers, wholesalers, and retailers. This makes it a complicated network especially because this various stakeholder can exist in multiples and in various places. Consequently, it is exceedingly challenging to track things back if there is a food-related contamination event. Traceability in supply chain will help to reduce any kind of fraud by helping to identify the origin of a fraud during a outbreak by recalling all the executions and information.

Apart from the food industry there are similar issues in all the industry with relation to the supply chain. This project is focused on identifying the various problems in supply chain due to its centralized form which cause high risk of alteration of existing data, not being able to trace the product history and issues due lack of traceability. This project explains how blockchain can be used to decentralize the supply chain process my taking into consideration the coconut production of Kozhikode. By using blockchain and smart contract we can develop and efficient and effective supply system for coconut production to provide a system that save cost, provide fast delivery, better inventory management and less manufacturing time consumption.

1.2 OBJECTIVE OF STUDY

- To review the literature on blockchain technology and its potential applications in supply chain and logistics.
- Analyzing a real-world example of blockchain technology's application in the distribution of COVID-19 vaccines.
- To analyze the challenges faced by traditional supply chains, with a focus on the coconut industry in Kozhikode.
- To identify key areas for improvement and develop a blockchain model that can overcome these challenges and enhance the efficiency of the supply chain of coconut industry in Kozhikode.
- To explore the benefits and challenges of using blockchain technology in supply chain and logistics.
- To evaluate the effectiveness of blockchain technology in improving supply chain efficiency, transparency, and security.

- To identify the key factors that influence the adoption and implementation of blockchain technology in supply chain and logistics.
- To create a SWOT analysis for the application of blockchain technology in supply chain and logistics.

1.3 SCOPE OF STUDY

The scope for the study of blockchain in supply chain is wide and includes various aspects such as:

1. Transparency: Blockchain technology can bring transparency to the supply chain by providing a tamper-proof and immutable record of all transactions. This can improve accountability and traceability, leading to better quality control and risk management.
2. Efficiency: Blockchain technology can also improve efficiency in the supply chain by automating processes such as inventory management, shipping, and payment. This can help reduce costs and eliminate inefficiencies such as errors and delays.
3. Security: Blockchain technology provides a high level of security to the supply chain by using cryptographic algorithms and decentralized networks. This can help prevent fraud, counterfeiting, and cyber-attacks.
4. Sustainability: Blockchain technology can also support sustainability efforts in the supply chain by providing a transparent and accountable record of environmental and social practices. This can help improve compliance and reduce waste and emissions.
5. Interoperability: Blockchain technology can enable interoperability among different supply chain systems and stakeholders, including suppliers, manufacturers, distributors, and customers. This can help improve collaboration and communication, leading to better decision-making and coordination.
6. Regulation: Blockchain technology can also support regulatory compliance by providing a verifiable and auditable record of transactions and activities. This can help ensure compliance with regulations such as food safety, product traceability, and labor practices.
7. Innovation: Finally, the study of blockchain in the supply chain can also explore the potential for innovation and new business models enabled by the technology. This can include exploring new revenue streams, such as sharing economy models or decentralized marketplaces, and new supply chain configurations such as smart contracts and tokenization.

Overall, the scope for the study of blockchain in the supply chain is vast and can have significant implications for the future of global trade and commerce.

1.4 RESEARCH METHODOLOGY

To comprehend the potential benefits of adopting blockchain technology in logistics and supply chain management, it is crucial to first grasp the fundamental concepts of blockchain and thoroughly examine its key features that can be effectively leveraged to enhance these industries. To achieve this, a case study of the coconut industry in Kozhikode has been conducted, which

includes an analysis of the industry's production, exportation, and customer expectations, with the goal of identifying the current flaws in the Kozhikode coconut industry.

Based on this understanding, a blockchain model has been developed to address these challenges and enhance the efficiency of the supply chain. By leveraging the unique properties of blockchain technology, this model aims to overcome the identified shortcomings of the traditional supply chain system and improve the overall performance of the logistics and supply chain management in the Kozhikode coconut industry.

Another critical aspect of this project is to investigate whether the integration of blockchain technology into the supply chain and logistics industry can effectively address the various challenges faced by these industries and improve their overall efficiency. To accomplish this, a comprehensive study has been conducted, which includes an analysis of the distribution of COVID-19 vaccines and a comparison with the distribution of TB vaccines to identify the effectiveness of blockchain technology in the former.

Furthermore, a SWOT analysis has been conducted to evaluate the strengths, weaknesses, opportunities, and threats of blockchain technology in the context of the supply chain and logistics industry. This analysis has helped to identify the potential benefits and limitations of integrating blockchain technology into the supply chain and logistics system, which can provide valuable insights for businesses looking to adopt this technology.

Through this project, the goal is to establish a deeper understanding of the potential of blockchain technology in enhancing the supply chain and logistics industry and to provide valuable insights for businesses looking to leverage this technology for their operations. By conducting a thorough analysis of the current state of the supply chain and logistics industry, this project aims to identify the potential of blockchain technology to revolutionize these industries and pave the way for a more efficient and secure supply chain system.

1.5 DATA COLLECTION

The data required for analyzing the productivity, yield, and cultivation area of coconut in Kozhikode is obtained from the Coconut Development Board of India, which is a secondary source. The collected data is processed and transformed into the necessary formats to be studied in Excel.

To elaborate, the data collected from the Coconut Development Board of India provides crucial information related to the coconut industry in Kozhikode, such as the total yield, productivity, and cultivation area of coconut. These data are essential to evaluate the current state of the industry and identify the areas that need improvement.

However, since the data is obtained from a secondary source, there may be limitations or inconsistencies that could impact the accuracy of the analysis. Therefore, the collected data is

thoroughly examined and verified to ensure its reliability before being processed and transformed into the required formats. Once the data is converted into the necessary formats, it is analyzed and interpreted in Excel to extract meaningful insights that can be used to enhance the coconut industry in Kozhikode.

In addition, relevant data for studying the distribution of the COVID-19 vaccine and comparing it to that of other vaccines was obtained from the official website of the World Health Organization (WHO). The data was collected from various reports and publications related to the vaccine distribution process, which included information on the number of doses distributed, the number of people vaccinated, and the geographical distribution of the vaccine. The data was carefully analyzed and processed to identify any trends or patterns in the distribution process. The use of data from a reputable source such as the WHO website ensures the reliability and accuracy of the findings obtained from this study.

1.6 LIMITATIONS OF STUDY

- This research solely focuses on analyzing the coconut industry in Kozhikode and may not be generalized to other industries.
- The potential drawbacks or negative impacts of integrating blockchain technology into the supply chain have not been investigated.
- This study heavily relies on secondary data sources such as reports, articles, and publications, which may not provide a comprehensive understanding of the subject matter.
- Due to the novelty of blockchain technology in the supply chain field, there may be a limited number of relevant resources and research studies available for analysis.
- The study does not address the practical feasibility or cost-effectiveness of implementing blockchain technology in the supply chain.
- The study may have limitations in terms of the scope and depth of the analysis, as well as the accuracy of the data sources used.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE REVIEW

2.1.1 LITERATURE REVIEW ON BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN

Blockchain technology has emerged as a promising solution for supply chain management due to its ability to provide an immutable and decentralized record of transactions, enhanced security, and transparency. This literature review examines the current research on the applications of blockchain technology in supply chain management.

One of the earliest works on this topic is by Swan (2015), who discusses the potential benefits of blockchain technology in supply chain management, including increased efficiency, reduced fraud, and improved transparency. Since then, many studies have been conducted to explore the use of blockchain in various aspects of supply chain management, including procurement, inventory management, transportation, and traceability.

In procurement, blockchain technology can enable a more efficient and transparent bidding process. For example, Yu et al. (2019) proposed a blockchain-based system that allows suppliers to bid on procurement contracts in a secure and transparent manner. In inventory management, blockchain can help to reduce the risk of counterfeit products and improve supply chain visibility. Wang et al. (2020) developed a blockchain-based system for managing pharmaceutical supply chains that enables secure tracking of drugs from the manufacturer to the end consumer.

In transportation, blockchain technology can provide real-time tracking and monitoring of goods, which can help to reduce the risk of theft and improve delivery times. For example, Zheng et al. (2019) developed a blockchain-based platform that enables real-time tracking and monitoring of goods during transportation. Finally, in traceability, blockchain technology can enable secure and transparent tracking of products throughout the supply chain. For example, Li et al. (2019) proposed a blockchain-based system for tracking the origin and quality of agricultural products.

Overall, the literature suggests that blockchain technology has the potential to revolutionize supply chain management by improving efficiency, transparency, and security. However, there are still several challenges that need to be addressed, such as interoperability, scalability, and regulatory issues. Further research is needed to develop blockchain-based solutions that can address these challenges and provide a practical and effective solution for supply chain management.

2.1.2 LITERATURE REVIEW ON SUPPLY CHAIN TRACEABILITY AND EFFICIENCY

Supply chain traceability and efficiency have been long-standing concerns for companies across various industries. Traceability refers to the ability to track products and their components throughout the supply chain, while efficiency involves optimizing supply chain processes to reduce costs and improve overall performance. This literature review examines the current research on the relationship between supply chain traceability and efficiency.

One of the key benefits of traceability is its ability to improve supply chain efficiency by reducing waste and optimizing inventory management. For example, Oyerinde et al. (2020) found that traceability can improve inventory management by providing real-time visibility of products and enabling better demand forecasting. Similarly, Shang and Yang (2017) found that traceability can reduce product waste and improve quality control by enabling the identification and removal of defective products.

Furthermore, traceability can also improve supply chain efficiency by reducing the time required for product recalls. For example, Govindan et al. (2017) found that traceability can enable faster and more targeted recalls, which can reduce the impact of a recall on a company's reputation and bottom line.

In addition to its impact on efficiency, traceability can also provide other benefits such as enhanced supply chain transparency and improved customer satisfaction. For example, Wang et al. (2019) found that traceability can improve transparency by enabling customers to track the origin and journey of a product. This can lead to increased customer trust and loyalty.

Despite the benefits of traceability, there are also challenges that need to be addressed, such as data management, standardization, and interoperability. For example, Liu et al. (2020) found that the lack of standardization in traceability systems can limit their effectiveness and hinder their adoption.

Overall, the literature suggests that supply chain traceability can have a positive impact on supply chain efficiency by reducing waste, improving inventory management, and enabling faster recalls. Further research is needed to develop practical and effective solutions that can address the challenges associated with traceability and improve its overall impact on supply chain management.

2.1.3 LITERATURE REVIEW ON SUPPLY CHAIN TAMPERING

Supply chain tampering refers to the unauthorized alteration or manipulation of products or components during their journey through the supply chain. Tampering can have serious consequences for companies, including financial losses, legal liabilities, and damage to reputation. This literature review examines the current research on the impact of tampering in supply chain management.

One of the primary concerns with tampering is the potential impact on product safety and quality. For example, Liu et al. (2018) found that food fraud and tampering in the food supply chain can lead to serious health risks for consumers, and can have significant financial consequences for companies. Similarly, Wang et al. (2021) found that tampering in the pharmaceutical supply chain can result in the distribution of counterfeit drugs, which can have serious health consequences for patients.

In addition to the impact on product safety and quality, tampering can also have significant financial consequences for companies. For example, Lee and Tang (2019) found that tampering can lead to significant losses in revenue and profits, as well as damage to brand reputation.

Furthermore, tampering can also lead to legal liabilities for companies, particularly in cases where the tampering results in harm to consumers.

To address the issue of tampering, various technologies and strategies have been proposed, such as blockchain, RFID, and tamper-evident packaging. For example, Liu et al. (2020) proposed a blockchain-based system for food traceability that can detect and prevent tampering. Similarly, Chen et al. (2018) developed a tamper-evident packaging system that can detect and alert companies to potential tampering in the supply chain.

Overall, the literature suggests that tampering can have serious consequences for companies, including financial losses, legal liabilities, and damage to reputation. To address this issue, companies should implement robust tampering prevention strategies, such as the use of technology-based solutions and tamper-evident packaging. Further research is needed to develop practical and effective solutions that can address the challenges associated with tampering in supply chain management.

2.2 BASICS OF BLOCKCHAIN TECHNOLOGY

Blockchain technology can be considered as the most important and complicated level of industry 4.0.

Blockchain technology is a decentralized, distributed ledger system that allows for secure and transparent recording of transactions. It was first introduced in 2008 as the underlying technology behind Bitcoin, a digital cryptocurrency.

A blockchain is essentially a database that consists of a chain of blocks, where each block contains a set of transactions that have been verified and added to the chain. Each block is linked to the previous block in the chain, creating a permanent and immutable record of all transactions that have occurred on the network.

The decentralized nature of blockchain technology means that it is not controlled by any single entity or organization. Instead, transactions are validated and verified by a network of users who work together to maintain the integrity of the network.

One of the key features of blockchain technology is its security. Because each transaction is verified by multiple users and recorded on the blockchain, it is very difficult to tamper with or manipulate the data. This makes it ideal for use in applications where security and transparency are critical, such as financial transactions, supply chain management, and voting systems.

Another advantage of blockchain technology is that it can be used to create decentralized applications, or dApps, that run on top of the blockchain. These applications can be used for a wide range of purposes, from decentralized finance (DeFi) to online gaming.

Overall, blockchain technology has the potential to revolutionize the way we conduct transactions and interact with one another online. Its decentralized, secure, and transparent nature make it a powerful tool for creating new applications and improving existing ones.

2.2.1 DEVELOPMENT OF BLOCKCHAIN TECHNOLOGY

Blockchain technology was developed in 2008 by an anonymous individual or group of individuals using the pseudonym "Satoshi Nakamoto". The first blockchain was created as the underlying technology behind Bitcoin, a digital cryptocurrency.

The original purpose of blockchain technology was to provide a secure and decentralized way to record transactions and prevent double-spending in the Bitcoin network. To achieve this, the blockchain consists of a chain of blocks, each containing a set of verified transactions.

Each block in the chain is linked to the previous block, creating an unbreakable chain of blocks that cannot be altered or tampered with. This is achieved through a cryptographic hashing function that generates a unique hash for each block, based on the data contained within it.

The hash of each block is included in the next block in the chain, along with the hash of the previous block. This creates a chain of hashes that links all of the blocks together, making it impossible to alter any previous transactions without invalidating the entire chain.

The decentralized nature of the blockchain means that it is maintained and validated by a network of users who work together to ensure the integrity of the network. This makes it resistant to attacks and provides a high level of security for transactions recorded on the blockchain.

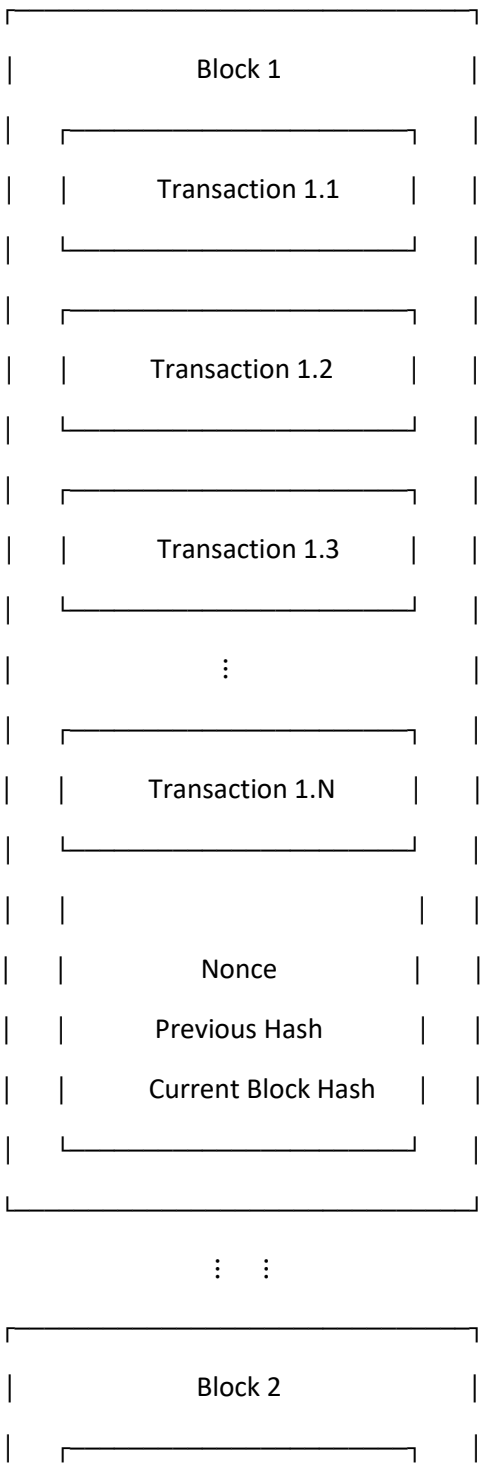
Since its development, blockchain technology has been adopted for a wide range of applications beyond cryptocurrency, including supply chain management, identity verification, voting systems, and more.

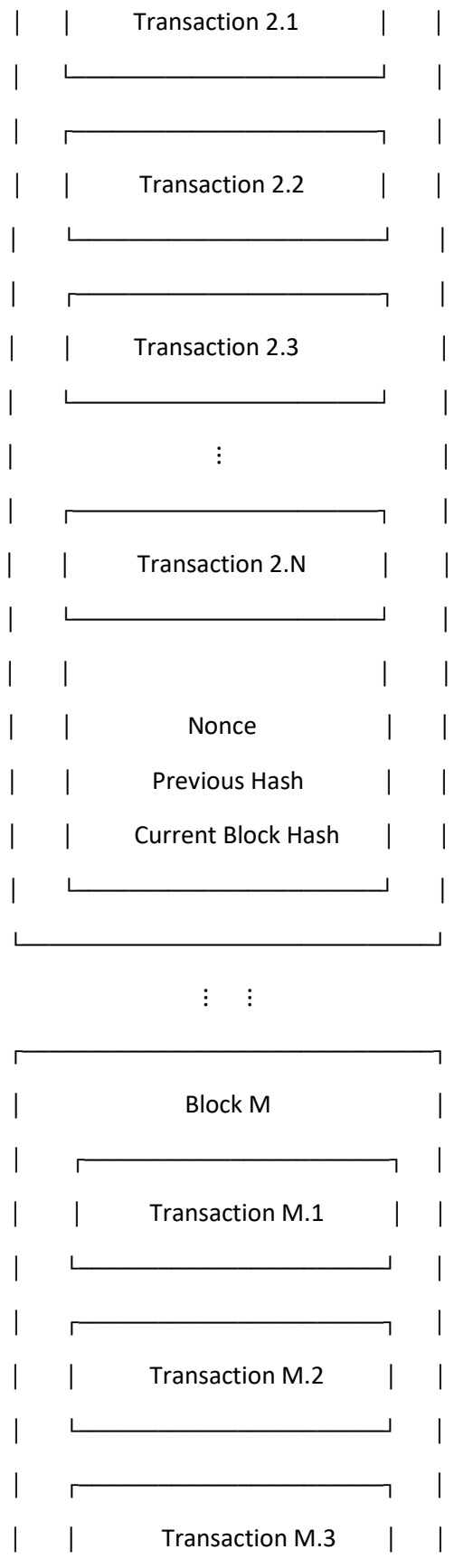
2.2.2 WORKING PRINCIPLE OF BLOCKCHAIN TECHNOLOGY

The diagram below shows a high-level working model of a blockchain. A blockchain is essentially a decentralized database that is maintained by a network of computers, or nodes. Each node has a copy of the entire database, and every time a new transaction is made, a block containing that transaction is added to the database. Each block contains a set of transactions, a nonce (a random number), the hash of the previous block in the chain, and the current block's own hash.

The blocks are linked together in a chain, which means that once a block is added to the chain, it cannot be modified or deleted without invalidating the entire chain. This makes the blockchain very secure, as any attempt to tamper with a block would require changing every subsequent block in the chain, which would be extremely difficult and would require control of a majority of the nodes on the network.

In the diagram, each block is labeled with a number (1, 2, 3, etc.) and contains a set of transactions (Transaction 1.1, Transaction 1.2, etc.). The blocks are linked together by including the hash of the previous block in each block, and the entire chain is secured by cryptographic hashes that ensure that any modification to any block would be immediately detected.

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Transaction M.1
Transaction M.2
Transaction M.3

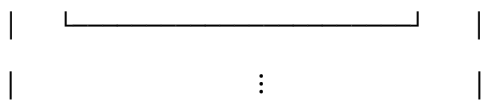


Fig.1. Working model of Blockchain

The flowchart for a blockchain involve the flowing steps:

1. A transaction is initiated by a user:

   In a blockchain, a transaction refers to any transfer of digital assets, such as cryptocurrencies or other types of tokens. The user who initiates a transaction is essentially sending a message to the network requesting to transfer some amount of digital assets from their account to another account.

2. The transaction is verified by the network of nodes to ensure that the user has sufficient funds to complete the transaction:

   Once a user initiates a transaction, the network of nodes verifies that the user has enough digital assets in their account to complete the transfer. This is typically done by checking the user's account balance and ensuring that it is sufficient to cover the requested transaction.

3. Once the transaction is verified, it is added to a block:

   Once a transaction is verified, it is added to a new block that is created by the network. This block contains a set of verified transactions along with other metadata, such as a timestamp and a reference to the previous block in the chain.

4. The block is broadcast to the network, and each node on the network verifies the block's contents and hashes before adding it to their copy of the blockchain:

   After a new block is created, it is broadcast to the network of nodes. Each node on the network receives the block and verifies its contents to ensure that the transactions within it are valid. Once the block is verified, each node adds it to their copy of the blockchain.

5. Once the block is added to the blockchain, it is considered immutable and cannot be altered or deleted:

   Once a block is added to the blockchain, it is considered part of the permanent, immutable record of transactions. The hash of each block in the chain is dependent on the contents of the block as well as the hash of the previous block, which ensures that any attempts to modify a block in the chain will be immediately detected.

6. The transaction is considered complete, and the user's account balance is updated to reflect the transaction:

Once a block is added to the blockchain and the transactions within it are confirmed, the transaction is considered complete. The user's account balance is updated to reflect the transfer of digital assets from their account to the recipient's account.

These steps ensure that transactions on a blockchain are secure, transparent, and tamper-proof. By using a distributed network of nodes to verify and confirm transactions, blockchain technology eliminates the need for a centralized authority or intermediary, which can reduce the risk of fraud and errors in the transaction process.

The security of Blockchain lies in the fact that it is a shared database that is accessible to everyone. However, this could potentially compromise the security and privacy of the stored information. Despite this, people trust Blockchain with large amounts of money because of the use of encryption and the consensus protocol, which is called Proof-of-Work in Bitcoin's implementation.

Proof-of-Work is a solution to the problem of the Byzantine fault, which models situations where a decision must be made from contradictory sources of information. In a Proof-of-Work designed Blockchain, it is necessary for 51% of the nodes in the network to be honest to ensure a reliable system. However, this protocol requires an enormous demand for electrical energy from the validating nodes or miners, who are responsible for validating the information of a block. Due to this high electrical consumption, China is considering restricting or banning mining activities in the country.

Without Proof-of-Work, any node could publish false information in the Blockchain, creating chaos. Other examples of consensus protocols include Proof-of-Stake used in Ethereum and Consensus in Ripple.

2.3 ELEMENTS OF BLOCKCHAIN TECHNOLOGY

The blockchain system comprises several components that collaborate to execute business transactions. Each of these elements has a distinct function, which are outlined below.

1. **NODE**: In the context of blockchain, a node is a computer or device that is part of the network and is capable of initiating, receiving, or verifying transactions. Nodes rely on software applications that provide various functionalities related to the business case. Two types of nodes are commonly found in a blockchain: validator nodes and member nodes. Validator nodes have more capabilities than member nodes, as they are capable of initiating, receiving, and validating transactions, while member nodes can only initiate and receive transactions.

2. **TRANSACTION:** In a blockchain, a transaction is a group of data items that contain information about the transfer of something of value, such as a product, service, entity, event, or any other valuable item. For instance, a transaction can involve the transfer of ownership or issuance of a certificate.

3. **BLOCK:** A Block is a component in a blockchain system that stores a group of transactions. Once a block is successfully verified, it is shared with all the nodes in the

blockchain network. Each block is identified by a unique block number in a chain of blocks. Nonce is a random number used to create a hash code through complex mathematical computation. The previous block's hash code is represented by "Previous" and the hash code of the current block is represented by "Hash".

Fig.2. Example of block

Block	#1				
Nonce	36584				
Transaction	Rs 65	from	Ravi	to	Mohit
	Rs 30	from	Pankaj	to	Vishal
	Rs 45	from	Ravi	to	Mohit
	Rs 50	from	Rohit	to	Sonu
	Rs 30	from	Mohit	to	Kunal
Previous	00000000000000000000000				
Hash	0000ab2des234f453f4r5tfe34				

Block	#2				
Nonce	82549				
Transaction	Rs 25	from	Mohit	to	Priya
	Rs 30	from	Sonu	to	Reena
	Rs 15	from	Kunal	to	Ravi
	Rs 25	from	Ravi	to	Sonu
	Rs 30	from	Pankaj	to	Kunal
Previous	0000ab2des234f453f4r5tfe34				
Hash	0000rgtf3r4r45t6y6hfrett56y5				

4. **CHAIN:** To put it differently, a Blockchain's Chain refers to a sequence of blocks that are linked together chronologically. The most recent block is located at the end of the chain, with each block having a reference to the previous block in order to trace the entire blockchain.

5. **MINERS:** In a blockchain, there are two types of nodes: Miner nodes (also known as Network nodes) and User Nodes. Miner nodes are responsible for maintaining a copy of the blockchain and also participate in the verification process of blocks. On the other hand, User nodes can only start a transaction.

6. **CONSENSUS:** In a blockchain system, consensus algorithms are employed to ensure that all distributed machines or network nodes in the network are in agreement on the same state. The consensus is achieved by verifying the hash codes of all copies of the blockchain. This verification process involves complex mathematical computations that require significant computing power. To incentivize individuals to contribute resources to maintain the network, rewards are offered.

CHAPTER 3

BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN

3.1 SUPPLY CHAIN

A supply chain refers to the network of organizations, individuals, activities, information, and resources involved in the creation and delivery of a product or service to customers. It encompasses all the steps involved in the production, transportation, storage, and distribution of goods and services, from raw materials to the final product reaching the end consumer. The supply chain includes suppliers, manufacturers, distributors, retailers, logistics providers, and other intermediaries that are involved in the process of getting a product from its point of origin to the end customer. Effective supply chain management is essential to ensure the timely delivery of products and services, reduce costs, and improve overall customer satisfaction.

The concept of Supply Chain involves the flow of information across different stages of the production process, starting from customers' demands to the selection of raw materials, and ending with the delivery of the final product to the customer. With the advancements in technology, Industry 4.0 emphasizes the use of smarter networks, enabling machines, processes, and products to exchange information, which has a direct impact on the Supply Chain models used in the current industrial scenario.

The Supply Chain model is often simplified as a horizontal flow of information and products between a few members, but in reality, it involves complex relationships among multiple companies. This complexity makes it difficult for consumers to validate the processes behind a product or service, resulting in a lack of transparency and inflated prices. Additionally, the identification and punishment of illicit activities within the chain are challenging, leading to scandals and negative consequences for all involved parties. The emergence of blockchain technology can address these issues by providing a transparent and reliable ledger of transactions, allowing for easy validation of processes and reducing the likelihood of fraudulent activities.

The smooth functioning of a supply chain depends on the uninterrupted flow of information, which must be collected and presented to stakeholders on a continuous basis. To achieve this, the system must be highly reliable, transparent, and provide an immutable record of all operations. The use of technologies such as Blockchain and Internet of Things (IoT) can provide more reliable, transparent, and traceable systems. By reducing the number of intermediaries in the information distribution process, these technologies can increase efficiency and lower costs. With its transparent and immutable record-keeping features, Blockchain can significantly improve information exchange and tracking protocols, thereby enhancing asset tracking in the supply chain.

The objective of supply chain management is to bring together all the operations involved in the movement and storage of raw materials, work-in-progress inventory, and finished goods from the starting point to the end consumer. The major challenge lies in finding the optimal configuration of the supply chain that enables efficient and responsive operations.

The complexity of supply chain systems is due to the involvement of various stakeholders and the increasing complexity of operations over time. There are several contributing factors to this complexity, including:

- The development of new products and services and the continuous improvement of existing ones contribute to the complexity of supply chain systems
- Regular change in regulatory and compliance requirements
- Continuous expansion and geographically spread supplier and customer networks.
- Process outsourcing, risk management practices, and security considerations.
- Rise of e-business and technological transformations to increase the speed of change in supplier networks and customer expectations.
- Expected increase in the number of participants within the supply chains

With the growing complexity of supply chains, companies are dealing with a larger volume of data. This creates data management challenges, as it is important to maintain the visibility and transparency of data for all operations in the supply chain. There is also a risk of reduced data accuracy due to the involvement of multiple sources. To overcome these challenges, it is essential to have a system in place that can handle such data and provide an uninterrupted flow of goods and services to all stakeholders.

3.2 BLOCKCHAIN-BASED SUPPLY CHAIN

The unique features of Blockchain make it well-suited for nearly all applications that involve the exchange of anything that holds value. In the past ten years, there has been a significant increase in its use, and there are now many providers offering Blockchain solutions, which are detailed in below:

1. IBM - provides blockchain services for various industries such as finance, healthcare, and supply chain management.
2. Microsoft - offers Azure Blockchain Services and has collaborated with various companies to provide blockchain solutions for supply chain and digital identity management.
3. Amazon Web Services (AWS) - provides blockchain solutions for developers, including a managed blockchain service.
4. Deloitte - offers blockchain solutions for supply chain management, digital identity, and financial services.
5. Accenture - provides blockchain solutions for supply chain, identity management, and insurance.
6. Ernst & Young (EY) - offers blockchain solutions for supply chain management and digital identity verification.
7. Oracle - provides blockchain solutions for supply chain management, financial services, and identity management.
8. Chain - provides blockchain solutions for financial services and supply chain management.
9. Baidu - offers blockchain solutions for supply chain management and copyright protection.

10. Bitfury - provides blockchain solutions for various industries, including supply chain management, healthcare, and financial services.

The integration of blockchain technology is not restricted to a specific industry, and it has attracted substantial investments in various sectors. The table below provides examples of current projects that use blockchain in the supply chain and logistics industries, highlighting their compelling business cases.

Sector	Name	Year	Description
Supply Chain, Logistics	DHL	2016	A digital ledger is used to maintain the accuracy and reliability of transactions related to the transportation of goods. This ledger ensures that all information regarding the shipment of products is recorded and easily accessible, making the process more efficient and secure.
	BLOCK ARRAY	2017	Block Array is a blockchain-based platform that specifically caters to logistics operations and provides various features such as secure payment methods, efficient monitoring, and detailed tracking to help businesses transport goods safely from their starting point to their destination.
	SHIPCHAIN	2017	ShipChain is a blockchain platform that aims to handle all aspects and transactions related to the shipping process.
	MAERSK	2018	IBM and Maersk are collaborating to enhance their understanding of the supply chain and to enable digital real-time tracking of goods across global borders.

Table.1. Current project of Blockchain in Supply Chain and Logistics

The adoption of blockchain technology is rapidly increasing as various industries are constantly evolving. Many startups are implementing blockchain use cases and there is a significant increase in investments in blockchain projects, particularly in sectors like supply chain and finance. Blockchain technology can be applied to various use cases, making processes more efficient and effective. In the era of digitization and process automation, organizations need to keep up with technological advancements to maintain a competitive edge, reduce turnaround time, and adapt to rapidly changing business environments.

The implementation of blockchain technology in the supply chain has the potential to revolutionize the entire process of supply and establish a more robust network. It is crucial to have a

comprehensive understanding of how blockchain is utilized in supply chain management. In the following section, we will delve into this aspect and analyze the significance of blockchain technology in supply chain management.

3.3. CONCEPT SMART CONTRACT

Smart contracts can be utilized to automate transaction processing related to business rules in supply chain management. They can be programmed to handle a range of criteria and logics that dictate how transactions are processed. For instance, a smart contract can execute a fund transfer when a specific event occurs, such as the payment of a security amount in an escrow system. Smart contracts can be applied in numerous applications, including financial processes like sub-currencies, financial derivatives, savings wallets, and wills. Additionally, they can be used for self-enforcing or self-directed governance applications, such as outsourced computation.

A smart contract is identified by its unique address on the blockchain, and its underlying source code is permanently stored on the blockchain. When a user wants to interact with a smart contract, they send a transaction to the contract address, which triggers the execution of the contract code.

Whenever a new transaction is posted to a smart contract address, all the nodes participating in the blockchain network validate and execute the code with the current state of the blockchain and the input parameters of the transaction. This process is commonly referred to as "mining" or "validation."

The code execution results in updating the state of the smart contract and the blockchain network. The updated state is then stored on the blockchain, and every node in the network updates its copy of the blockchain. This ensures that every participant on the network has an identical and consistent copy of the blockchain and the smart contract.

Smart contracts can be invoked automatically or manually, depending on the design of the contract and the nature of the transactions that trigger them. They can execute automatically when specific conditions are met, or they can be invoked by specific users or applications that require their services. Overall, smart contracts enable the automation of complex business logic, increasing transparency, security, and trust in digital transactions.

Smart contracts were first proposed by Nick Szabo in [35] and gained popularity with the development of blockchain technology, referred to as "Blockchain 2.0" in [34]. These contracts are often used to establish fairness among multiple parties without the need for a trusted third party. A comparison is made between smart contracts and traditional judicial system contracts, where in the latter scenario, two or more parties agree to the terms of a written contract and rely on the judicial system to resolve any disputes that arise. In contrast, in a smart contract scenario, the owner creates the contract and publishes it on the blockchain. The parties that agree to the contract conditions then interact with it. It is important to note that the conditions outlined in a smart contract cannot be modified even by the owner once published on the blockchain. Additionally, the conditions are enforced by the underlying blockchain system's consensus mechanism, ensuring fairness without the need for a trusted third party.

After the smart contract is invoked, the network reaches an agreement on the output and the subsequent state of the contract through a consensus protocol. Ethereum is a widely used blockchain platform that comes with a complete Turing programming language. It enables developers to create "contracts" that can represent any state transition functions using just a few lines of code, thereby allowing them to build a variety of systems, including the ones discussed above. However, since every use case is different, it is crucial to customize the blockchain system to suit the specific needs of a business. This requires extensive research to understand the business requirements of a use case, along with cost-benefit analysis to build a genuine business case. As such, blockchain technology offers ample opportunities for exploration, given its features and ability to strengthen supply chain processes.

To truly grasp the benefits of blockchain technology, it is useful to consider real-world use cases, such as the distribution of vaccines during the COVID-19 pandemic. The next chapter will delve into the analysis of how blockchain was utilized during the distribution of COVID-19 vaccines and examine its effectiveness and efficiency in ensuring a productive outcome. By exploring this case study, we can gain a deeper understanding of how blockchain can be leveraged to address complex challenges in a supply chain context and how it can be customized to meet the specific needs of a use case. Overall, the COVID-19 vaccine distribution provides an excellent example of the potential of blockchain technology to revolutionize supply chain management and promote transparency, trust, and efficiency among stakeholders.

In addition to examining the use of blockchain in vaccine distribution during the COVID-19 pandemic, we will also investigate the supply chain of coconuts originating from Kozhikode, a district located in Kerala. Through this analysis, we aim to develop a blockchain framework that can enhance the effectiveness and profitability of the coconut market in Kozhikode. This framework will explore the various stages of the supply chain, including cultivation, harvesting, transportation, and distribution, and evaluate the challenges faced in each stage. By leveraging the unique features of blockchain, such as immutability, auditability, and real-time verification, we can potentially improve transparency, traceability, and trust in the coconut market, ultimately leading to better stakeholder management and higher profitability. The development of this blockchain framework requires a thorough understanding of the business requirements and cost-benefit analysis to ensure a genuine business case. We believe that this study can contribute to the evolving technology of blockchain and its application in enhancing supply chain processes in the agricultural industry.

CHAPTER 4

BLOCKCHAIN TECHNOLOGYFOR VACCINE SUPPLY CHAIN

4.1 COVID-19 VACCINE SUPPLY CHAIN

In late 2019, a new strain of coronavirus was discovered in Wuhan, China, capable of infecting humans. The virus spread quickly and caused severe respiratory illness in those infected, leading countries to impose strict quarantine measures. As a result, many small and medium-sized businesses have been forced to shut down, causing a rise in unemployment worldwide. The urgent need to develop a vaccine to combat this virus has become crucial in preventing further fatalities and restoring the global economy.

The discovery of a vaccine for COVID-19 has been a significant scientific breakthrough. Several pharmaceutical companies and research organizations worldwide have been working tirelessly to develop a vaccine that can provide immunity against the virus.

Several COVID-19 vaccines have been developed and approved for use in various countries worldwide. These vaccines have been shown to be highly effective in preventing severe illness and death caused by the virus. Vaccines have played a crucial role in controlling the spread of the virus and reducing the number of cases and fatalities globally.

There are currently several COVID-19 vaccines that have been developed and authorized for use by regulatory authorities in various countries. Some of the most important COVID-19 vaccines are:

1. Pfizer-BioNTech COVID-19 Vaccine: This vaccine is a messenger RNA (mRNA) vaccine that has been shown to be highly effective in preventing COVID-19 infections. The vaccine requires two doses administered three weeks apart and has been authorized for use in several countries worldwide.
2. Moderna COVID-19 Vaccine: This is another mRNA vaccine that has shown to be highly effective in preventing COVID-19 infections. The vaccine requires two doses administered four weeks apart and has also been authorized for use in several countries worldwide.
3. Johnson & Johnson COVID-19 Vaccine: This is a viral vector vaccine that has shown to be highly effective in preventing severe COVID-19 infections. The vaccine requires a single dose and has been authorized for use in several countries worldwide.
4. Oxford-AstraZeneca COVID-19 Vaccine: This is another viral vector vaccine that has shown to be highly effective in preventing COVID-19 infections. The vaccine requires two doses administered four to twelve weeks apart and has been authorized for use in several countries worldwide.
5. Sinovac COVID-19 Vaccine: This is an inactivated virus vaccine that has shown to be highly effective in preventing severe COVID-19 infections. The vaccine requires two doses administered two to four weeks apart and has been authorized for use in several countries worldwide.

These vaccines work by teaching the immune system to recognize and attack the COVID-19 virus without causing disease. They have been shown to be highly effective in preventing severe illness and death caused by the virus and have played a critical role in controlling the spread of the pandemic.

A supply chain encompasses all the processes involved in creating a product from its raw materials and delivering it to the customer. This includes transforming raw materials into the final product, as well as transportation and distribution to the end customer. For vaccines, this supply chain is known as the cold chain, as vaccines require specific temperatures during transportation to maintain their effectiveness. Maintaining the cold chain involves specialized transportation and storage facilities, training of personnel, and efficient management procedures. This is essential for ensuring the vaccines are delivered in optimal condition, which is crucial for their efficacy in preventing diseases. The cold chain is a critical component of the vaccine supply chain and requires careful planning, monitoring, and management at every stage to ensure the vaccines reach their destination in good condition.

4.1.1 DISTRIBUTION ISSUE OF COVID-19 VACCINE

The discovery of a COVID-19 vaccine is crucial, but ensuring its distribution on a global scale is equally important. Achieving this goal will require the creation of a manufacturing and supply chain capacity that is larger and more efficient than ever before. To achieve this, it will be necessary to leverage new tools and capabilities, such as blockchain technology, in ways that have never been seen before in the fight against pandemics.

The challenges associated with the present vaccine distribution process can be classified into four main categories. These categories are:

i) Physical limitations, which may include a shortage of manufacturers and manufacturing capacity, insufficient supplies of raw materials, and a lack of nurses and facilities.

ii) Communication issues, which may arise from inaccurate vaccine distribution planning and inadequate communication among stakeholders.

iii) Security concerns, such as cyberattacks, misinformation of the public, and counterfeit vaccines and records.

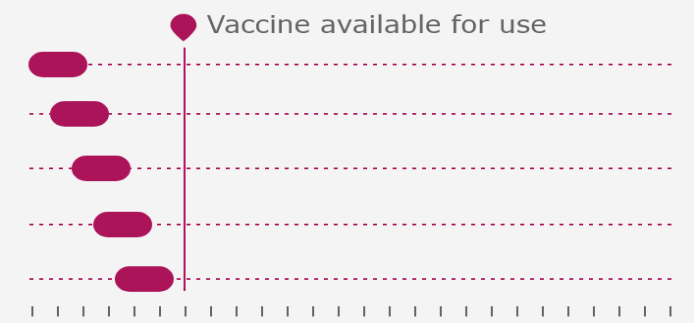
iv) Efficiency difficulties, such as mishandling of vaccines, lack of digitization, and the absence of a unified database.

4.2 DATA ANALYSIS OF VARIOUS VACCINE DISTRIBUTION

This section aims to compare the speed of development, distribution, and immunization of the COVID-19 vaccine with other vaccines such as the TB vaccine. The purpose is to highlight how advanced the COVID-19 vaccine process is in comparison to the TB vaccine, especially due to the technological innovation, government support and introduction of blockchain technology.

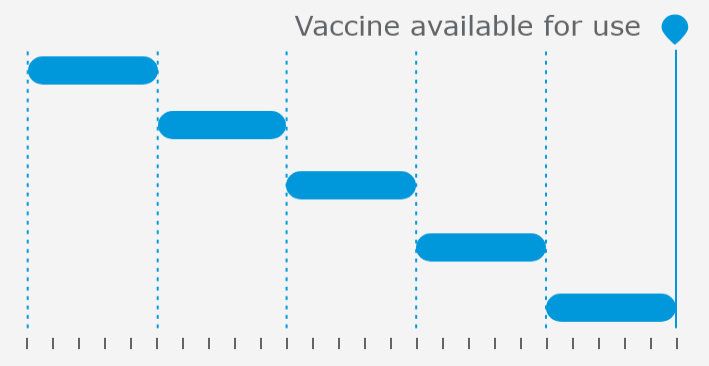
4.2.1 COMPARISON BETWEEN BCG AND COVID 19 VACCINE DEVELOPMENT RATE

The development of the COVID-19 vaccine has been much faster compared to the development of the TB. The first COVID-19 vaccine was developed in less than a year after the virus was identified, which is a record-breaking achievement in the history of vaccine development. This was made possible by the use of novel vaccine technologies, such as mRNA vaccines, and the significant investment made by governments and private companies in vaccine research and development.



Graph.1. COVID 19 vaccine development rate

In contrast, the development of the TB vaccine took more than a century. The Bacille Calmette-Guérin (BCG) vaccine, which is the only approved TB vaccine, was first developed in the early 1900s and has undergone several modifications since then. It was not until the 1920s that the vaccine was first tested in humans, and it was not widely used until the 1950s.

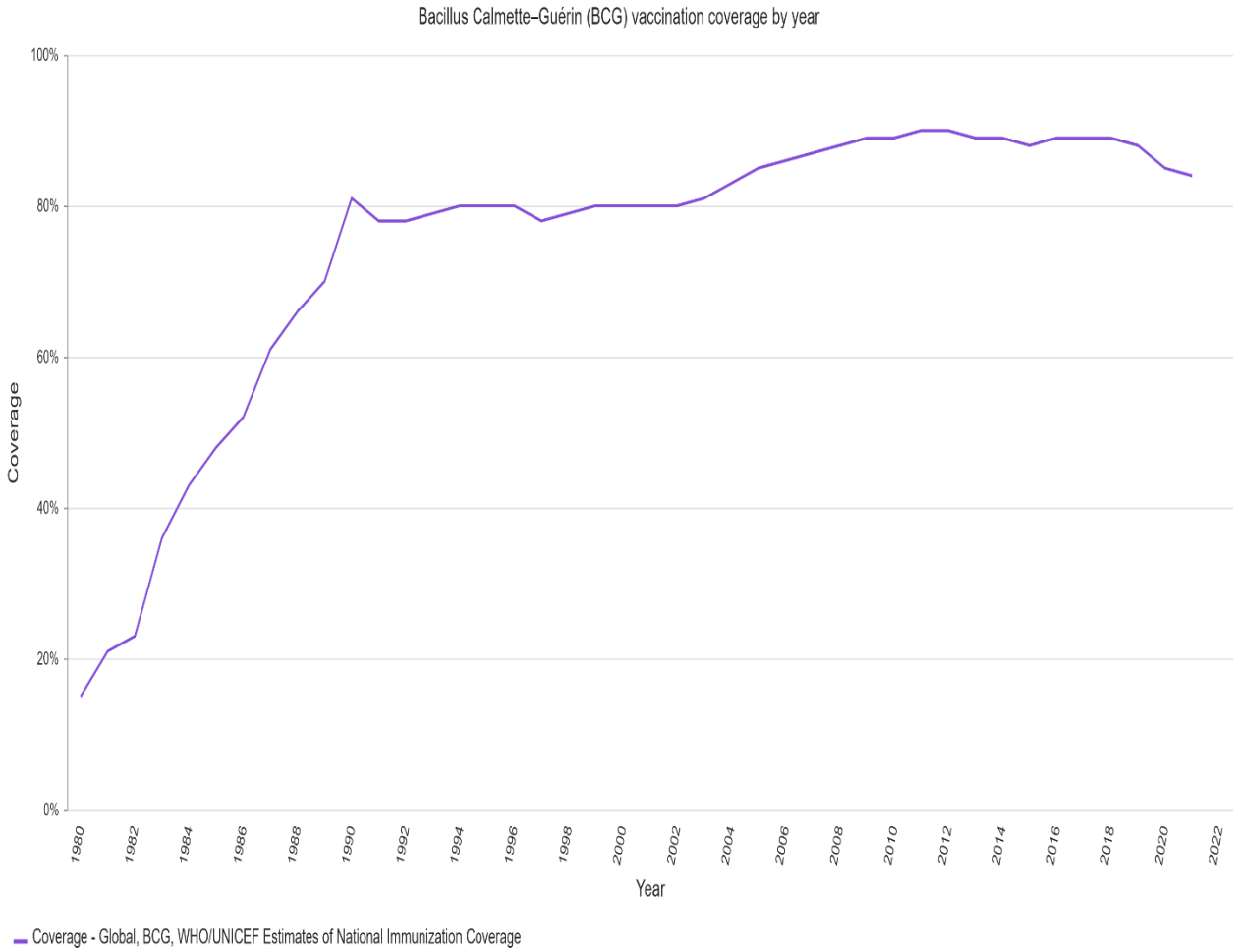


Graph.2. BCG vaccine development rate

To summarize, the development of the COVID-19 vaccine was significantly faster than that of the BCG vaccine. While the COVID-19 vaccine was developed and authorized for emergency use within a year, the development of the BCG vaccine took several decades.

4.2.2 COMPARISON BETWEEN BCG AND COVID 19 VACCINE COVERAGE RATE

Based on decades of experience running immunization programs, UNICEF and the Gavi Alliance have found that it takes several years to establish a stable vaccine supply chain and delivery system, depending on the location. For example, it took over a decade to immunize all children under the age of five in India against polio through the Pulse Polio program, which was launched in 1995 and had its last reported case in 2011. Similarly, BCG vaccine coverage rate has started increasing globally only recently. According to the World Health Organization (WHO), the global BCG coverage rate was 81% in 2000, which increased to 88% in 2020. However, due to the COVID-19 pandemic, there has been a decline in routine immunization coverage rates, including BCG vaccination, in some countries.



Graph.3. Coverage rate of BCG vaccine from 1980 to 2022 (Source: WHO website)

In terms of regional coverage rates, the Western Pacific region has the highest coverage rate of 96%, followed by the African region with a coverage rate of 92%. The Eastern Mediterranean, European, and Southeast Asian regions have coverage rates of 89%, 86%, and 84%, respectively. The Americas region has the lowest coverage rate of 74%.

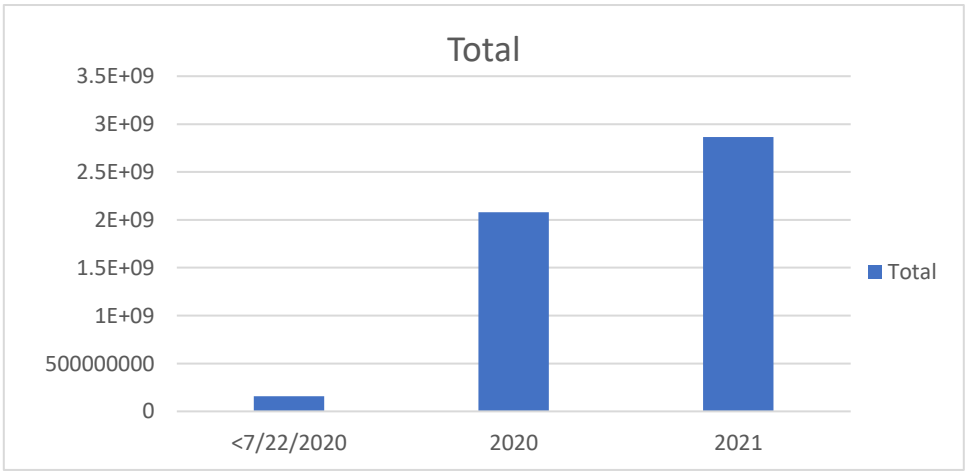
It is worth noting that BCG vaccination is primarily given to infants to protect them against severe forms of tuberculosis, and some countries also recommend it for adolescents and healthcare workers. However, the coverage rate may vary based on the country's immunization policies, vaccine availability, and access to healthcare services.

The coverage rate of BCG vaccine and COVID-19 vaccine are difficult to compare directly as they have different target populations and vaccination strategies.

BCG vaccine is primarily administered to newborns and infants in countries with a high burden of tuberculosis, whereas COVID-19 vaccine is being administered to adults and elderly individuals globally in response to a pandemic.

In terms of coverage rate, the BCG vaccine has been administered for many years, with coverage rates varying depending on the country and region. According to the World Health Organization (WHO), the global coverage rate for BCG vaccine among one-year-olds was 85% in 2020. However, the coverage rate in some low-income countries was lower, with some countries reporting coverage rates below 50%.

On the other hand, the COVID-19 vaccine has only been available since December 2020, so the coverage rate is still increasing. As of April 2023, over 9.4 billion doses of COVID-19 vaccine have been administered globally, covering approximately 38.8% of the world's population. However, the coverage rate varies widely among countries and regions, with some countries achieving high coverage rates while others lag behind due to various factors such as vaccine supply, distribution challenges, and vaccine hesitancy.



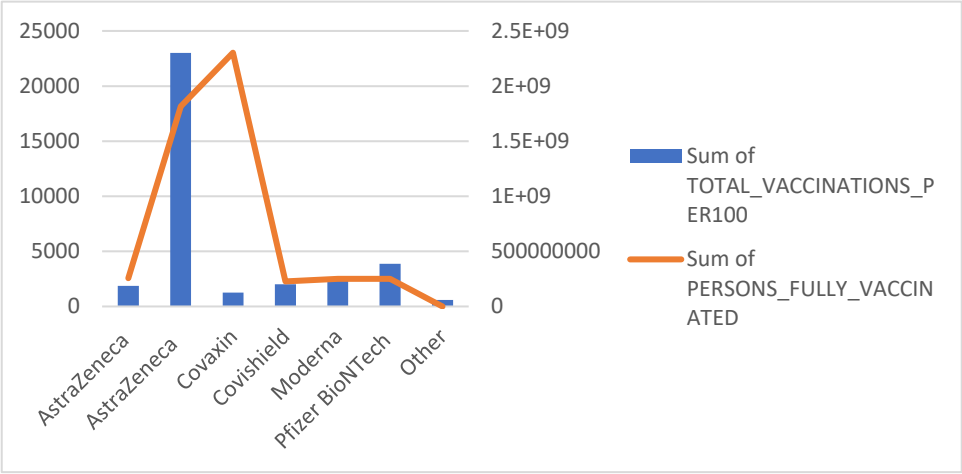
Graph.4. Coverage rate of covid 19 vaccine

The challenge of distributing COVID-19 vaccines is unprecedented due to the scale of the effort. The vaccine must be distributed to every country, continent, and age group, meaning that every person must be covered. Assuming that only one dose is needed per individual, healthcare workers

will need to have access to at least 7 billion doses of the vaccine. However, assuming that up to 20-30% of the doses may be lost during transit and storage, the total number of doses required could be closer to 10 billion. If two doses are required per individual, the number of vials needed could exceed 19 billion.

As of April 2023, the World Health Organization reports that over 8.2 billion doses of COVID-19 vaccine have been administered globally. The coverage rate of COVID-19 vaccine has been steadily increasing since the rollout began, with more and more people being vaccinated every day.

As of January 2021, less than 1% of the world's population had received a COVID-19 vaccine. However, this number increased significantly by the end of 2021, with about 15% of the world's population receiving at least one dose of the vaccine. By mid-2022, around 30% of the global population had received at least one dose, and by April 2023, the coverage rate had increased to approximately 45% of the world's population receiving at least one dose of the COVID-19 vaccine.



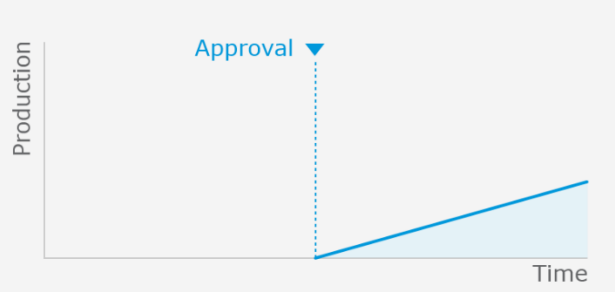
Graph.5. Coverage rate of different covid 19 vaccines

The coverage rate varies significantly between countries, with some countries having vaccinated a large proportion of their population, while others are still struggling to vaccinate even a small fraction of their citizens. The rate of vaccination is also affected by factors such as vaccine availability, infrastructure, and public trust in vaccines.

Overall, the global coverage rate of the COVID-19 vaccine has been steadily increasing, and with continued efforts to increase vaccination rates in all countries, it is expected to continue to rise in the coming months.

4.2.3 COMPARISON BETWEEN BCG AND COVID 19 VACCINE MANUFACTURING AND PRODUCTION RATE

The production of the BCG vaccine has increased significantly from 1980 to 2022. In 1980, the global production of BCG vaccine was approximately 100 million doses, while in 2022, it is estimated to reach around 200 million doses. The production rate of the BCG vaccine has increased due to various factors, including the increasing demand for the vaccine, the development of new manufacturing technologies, and the expansion of vaccine production facilities.



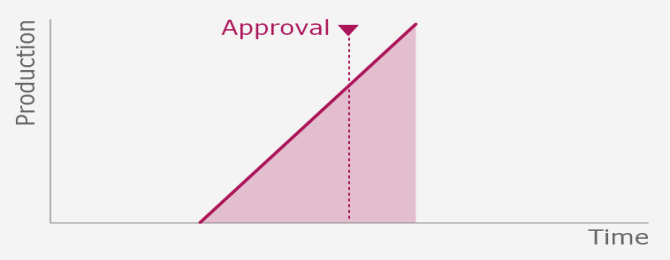
Graph.6. Production rate of BCG vaccine

In the early 2000s, the World Health Organization (WHO) initiated a plan to increase the global production of BCG vaccine to meet the rising demand. As a result, several countries increased their production capacity, and new manufacturing facilities were established. The production rate of the vaccine also increased due to the development of new production technologies, such as lyophilization, which allows for the production of stable, dried vaccine formulations.

In addition, the increasing awareness of the importance of vaccination and the increasing burden of tuberculosis in many parts of the world have also contributed to the increase in BCG vaccine production. Many countries have launched national vaccination campaigns, and the WHO has recommended the inclusion of the BCG vaccine in routine immunization programs for infants in countries with high tuberculosis burden.

The production rate of the BCG vaccine and the COVID-19 vaccine varies significantly due to differences in manufacturing processes, resources, and technology available.

As mentioned earlier, it took over a decade for BCG vaccine production to reach 200 million doses per year. In contrast, the production rate for COVID-19 vaccines has increased significantly since the beginning of the pandemic. For example, Pfizer-BioNTech was able to produce 50 million doses of their vaccine within the first few months of its development, and Moderna was able to produce 20 million doses in the same time frame. As of now, the production rate for COVID-19 vaccines has continued to increase steadily due to global efforts to vaccinate the population as quickly as possible. According to data from the Our World in Data project, as of April 15, 2023, over 12.7 billion doses of COVID-19 vaccines have been administered worldwide. This indicates a significant increase in production and distribution of COVID-19 vaccines.



Graph.7. Production rate of Covid 19 vaccine

It is important to note that the production rate of the COVID-19 vaccine varies by manufacturer and by country, with some countries having more access to vaccines than others. Additionally, the production rate of COVID-19 vaccines may also be affected by supply chain issues, distribution challenges, and other factors.

4.2.4 FINDINGS AND UNDERSTANDING

Comparing the BCG vaccine for TB and the Covid-19 vaccine, it is evident that the rate of production, coverage, and development differs significantly between the two types of vaccines. The rate of production for the BCG vaccine was slow, taking almost a decade to increase, while the rate of Covid-19 vaccine production was incredibly fast.

It has been 100 years since the Bacillus Calmette–Guérin (BCG) vaccine was created to fight against tuberculosis (TB) on July 18, 1921. The BCG vaccine is the only approved vaccine for TB and gives a moderate level of protection against severe forms of TB in infants and young children. It has been distributed widely across countries through immunization programs and has played a crucial role in saving numerous young lives and preventing severe illnesses.

By comparing the slow progress in the development and distribution of the BCG vaccine for TB to the rapid advancements in COVID-19 vaccines, we can see that with political commitment and significant investments in research, access to life-saving vaccines can be achieved much faster. The enormous funding provided by both public and private sectors for COVID-19 vaccine research, development, and manufacturing has paved the way for faster vaccine development.

Another reason is the use of blockchain technology which certainly played a role in the success of supply chain distribution for the COVID-19 vaccine. Blockchain allows for greater transparency and security in the supply chain, enabling stakeholders to more effectively track and manage the flow of vaccines from manufacturing to administration. By using blockchain, it is possible to create an immutable and transparent record of vaccine transactions, which can help to prevent fraud, counterfeit vaccines, and other supply chain issues. However, it is important to note that the success of vaccine distribution is also dependent on other factors, such as political will, funding, and logistical capacity.

To elaborate, the slow increase in production rate of BCG vaccine is attributed to the lack of transparency and information flow in the supply chain. There were various stakeholders involved

in the production and distribution of the vaccine, including manufacturers, donors, and governments. However, there was limited communication and coordination between these parties, which hindered the flow of information and slowed down the production process.

In contrast, the production rate of COVID-19 vaccines has seen a massive increase due to various factors, including significant investment in research and development, unprecedented global demand, and the use of advanced technologies such as mRNA and viral vector platforms. Additionally, governments and other stakeholders have prioritized the production and distribution of the COVID-19 vaccine, which has resulted in a faster increase in production rate compared to BCG vaccine.

The success of Covid 19 development, production and distribution proves that there is no need to wait for a century or more to access new TB vaccines, but with similar investments as in COVID-19, we can significantly reduce the suffering and deaths caused by TB, which remains one of the leading infectious killers worldwide.

4.3 APPLICATION OF BLOCKCHAIN FOR COVID 19 VACCINE DISTRIBUTION

The management of vast amounts of data has become necessary due to the COVID-19 pandemic. Such data is often sensitive and must be easily verifiable and transparently managed. However, providing central authorities with complete access to such data management platforms could raise significant privacy concerns, which could be counterproductive.

One way that blockchain technology has been utilized is to create vaccine passports, which are digital records that show a person has been vaccinated against COVID-19. These records can be stored securely on a blockchain, allowing individuals to easily prove their vaccination status without needing to carry around a physical card.

In addition, blockchain technology can also be used to track the distribution and administration of vaccines. By creating a transparent and immutable record of each vaccine dose, it can help prevent fraud, reduce errors, and ensure that vaccines are being distributed fairly and efficiently.

There are also several blockchain-based platforms that have been developed to help facilitate the distribution of COVID-19 vaccines. For example, IBM has created a blockchain-based platform called Digital Health Pass, which can be used to verify an individual's vaccination status and allow them to securely share their health data with organizations such as airlines and event venues.

The implementation of rapid testing and vaccination strategies in response to the COVID-19 pandemic may require the use of health and immunity certificates. Blockchain technology can provide a secure and decentralized environment for cross-border verification of COVID-negative or immunity status. Several studies have demonstrated the use of blockchain technology in this context. For example, Garg and colleagues developed a blockchain-based movement pass that relies on smart contracts and tokens to dispense with the need for personal particulars for verification purposes. Similarly, Xu and colleagues used a blockchain platform to desensitize a

user's identity and location information through its hash function, thereby ensuring the privacy of patients with COVID-19 and the public in a decentralized environment.

Another way blockchain technology can be used in the context of the pandemic is by storing COVID-19 vaccination details of each recipient on-chain on a publicly readable platform, and authenticating users and anonymously located vaccination records with an iris extraction technique to avoid any leakage of personal identifiable information. Eisenstadt and colleagues used a consortium, Ethereum-based blockchain architecture combined with a mobile application to achieve instant verification of tamper-proof test results, achieved through the use of public or private key pairs.

These studies show how blockchain solutions can address concerns related to scalability, latency, and storage, and provide secure and decentralized environments for data management and verification, thus helping to overcome the challenges posed by the COVID-19 pandemic.

The COVID-19 pandemic has increased the need for efficient supply chain management of essential medical supplies, including personal protective equipment, essential medications, and COVID-19 vaccines. To ensure the accuracy of distribution data, IoT, oracles, and APIs can be utilized to track each vial or package at a granular level. Antal and colleagues developed a system that combined IoT sensor devices with self-enforcing smart contracts on an Ethereum blockchain platform to achieve end-to-end tracking and visibility of COVID-19 vaccine distribution data, including on-chain recording of side-effects. Similarly, Ahmad and colleagues used blockchain technology to manage the entire forward supply chain and waste management of COVID-19-related medical equipment and supplies. Both studies used Ethereum architecture and smart contracts to provide a versatile solution for managing supply chains in the COVID-19 pandemic.

The fourth potential use of blockchain technology in response to the COVID-19 pandemic is for telemedicine initiatives, including test kit management and medical data sharing amongst trusted stakeholders. Kumar and Tripathi developed a blockchain network for the sharing of COVID-19-related reports, such as chest CT scans. The network was designed to filter out non-COVID-19-related reports by comparing the similarity of the perceptual hash of each report with existing on-chain perceptual hashes. Lee and colleagues created a global electronic medical record system for patients using Proof of Authority consensus, allowing real-time uploading from clinic electronic medical records systems via open APIs and Fast Healthcare Interoperability Resources. This system could assist authorities in adjusting health-care policies dynamically and support pandemic research by providing timely public updates on the pandemic.

While blockchain technology has been used in some instances during the distribution of COVID-19 vaccines, it is not yet widely adopted and is still a relatively new technology in this field.

CHAPTER 5

BLOCKCHAIN MODEL FOR THE COCONUT INDUSTRY OF KOZHIKODE

5.1 BLOCKCHAIN MODEL FOR DISTRIBUTION OF COCONUTS FROM KOZHIKODE

5.1.1 INTRODUCTION

In this section, we aim to present a blockchain model that can enhance the production and distribution of coconut and its by-products in Kozhikode, a district in Kerala. In order to develop this model, we need to first understand the current production rate, distribution channels, by-products, and export of coconuts from Kozhikode. We also need to examine the current profitability of the farmers and all other stakeholders involved in the coconut business from Kozhikode and explore ways in which blockchain technology can be used to increase their profits.

To elaborate further, the blockchain model we propose will leverage the inherent transparency, immutability, and security of blockchain technology to streamline the coconut supply chain in Kozhikode. We will use smart contracts to create a decentralized system that tracks the movement of coconuts from the point of harvest to the point of sale. This will help to eliminate the current inefficiencies in the supply chain, such as delays, theft, and spoilage, which often result in losses for farmers and other stakeholders.

Through the blockchain model, farmers will be able to receive fair prices for their coconuts, as the system will provide real-time market data that reflects demand and supply trends. This will enable farmers to make informed decisions about when to sell their coconuts, and at what price. The system will also create a direct link between farmers and buyers, thereby reducing the number of intermediaries involved in the supply chain and increasing the profits of farmers.

In addition, the blockchain model will enable the efficient tracking of by-products of coconuts, such as coconut oil, milk, and fiber, which are often produced by small-scale industries in Kozhikode. By tracking the production and distribution of these by-products on the blockchain, we can ensure that they are of high quality and meet the standards required for export. This will enable small-scale industries to access new markets and increase their profits.

The proposed blockchain model has the potential to transform the coconut industry in Kozhikode by increasing the profits of farmers and other stakeholders, improving the quality of products, and expanding access to new markets.

5.2 COCONUT INDUSTRY IN KOZHIKODE

Kozhikode is a coastal city located in the state of Kerala, India. It is known for its rich history, culture, and natural beauty, including its vast coconut plantations. The coconut industry is a significant part of Kozhikode's economy, with the region being one of the major coconut-producing areas in India with a vast area of coconut plantations spread throughout the district.

The coconut industry in Kozhikode comprises a vast network of small-scale farmers and producers who grow and process coconuts into various products such as coconut oil, coconut water,

desiccated coconut, and copra. The industry provides employment to a large number of people in the region and contributes significantly to the local economy.

The annual yield of coconuts in Kozhikode varies depending on the region and the type of coconut cultivated. According to the Department of Agriculture, Kerala, coconut is cultivated on around 10,000 hectares of land in the Kozhikode district, with Kuttiady being one of the major coconut-producing regions. However, in some regions, the yield can go up to 15,000 coconuts per hectare.

The major coconut-producing regions in Kozhikode include Thiruvambady, Koduvally, Thamarassery, Koyilandy, and Vadakara. These regions have a favorable climate for coconut cultivation, with ample rainfall and tropical temperatures, which are ideal for the growth of coconut trees.

Apart from coconut, the Kozhikode region is also known for the production of various coconut-based products such as coconut oil, copra, and desiccated coconut. The coconut oil industry is one of the most significant industries in the region, with several small-scale units engaged in the production of coconut oil.

The total area under coconut cultivation in Kozhikode is approximately 74,000 hectares, which accounts for more than 20% of the total area under coconut cultivation in the state of Kerala. The region has favorable climatic conditions for coconut cultivation, with ample rainfall and tropical temperatures, which are ideal for the growth of coconut trees.

The region is known for its production of high-quality coconuts, which are in high demand both in domestic and international markets.

The coconut trees in Kozhikode are predominantly of the tall variety, which is known for its high yield and quality. The coconut trees are often intercropped with other crops such as pepper, banana, and cocoa, which provides additional sources of income for the farmers.

It is estimated that around 60-70% of the coconuts produced in Kozhikode are used for the production of these coconut-based products, while the remaining 30-40% are consumed as fresh coconuts.

Kozhikode is also known for its production of value-added coconut products, such as virgin coconut oil, coconut cream, and coconut water. These products are in high demand in both domestic and international markets, particularly in the Middle East and Southeast Asia.

The export of coconut-based products from Kozhikode has been steadily increasing over the years. According to reports, around 25-30% of the coconut-based products produced in Kozhikode are exported to other countries. The major export destinations for Kozhikode's coconut-based products are the United Arab Emirates, Saudi Arabia, and the United States.

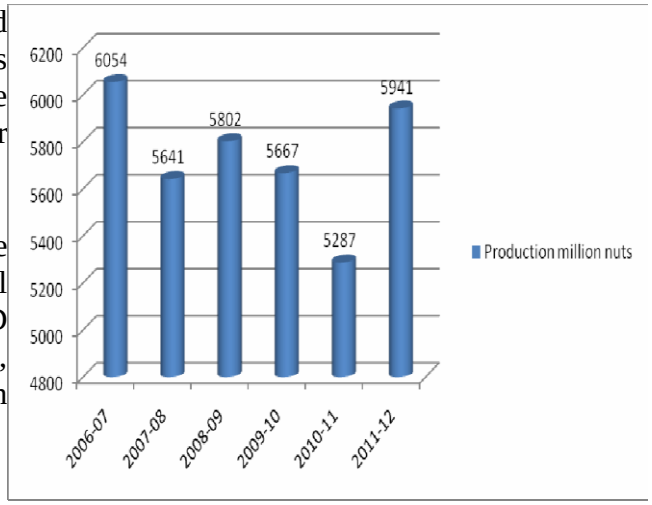
The coconut harvest season in Kozhikode is from January to June, and the peak harvest period is from March to May. During this period, the demand for coconuts is high, and farmers often face challenges such as storage, transportation, and market access.

Also, the coconut industry in Kozhikode faces challenges such as inefficient supply chains, lack of market information, and unfair pricing. This has resulted in low profits for farmers and other stakeholders. The proposed blockchain model aims to address these challenges and enhance the profitability and sustainability of the coconut industry in Kozhikode.

The following section 5.3 will examine the main obstacles encountered by the coconut industry in Kozhikode.

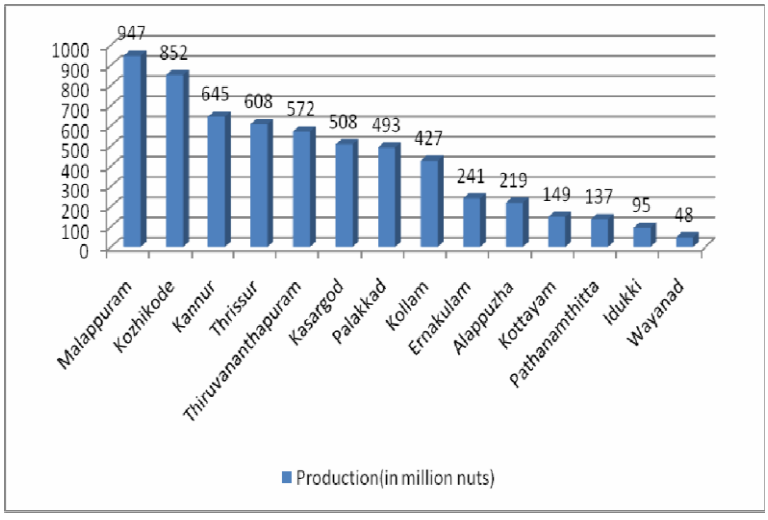
5.2.1 DATA ANALYSIS AND FINDINGS

Graph.8. Coconut Production in Kerala (Source: Coconut Development Board of India)

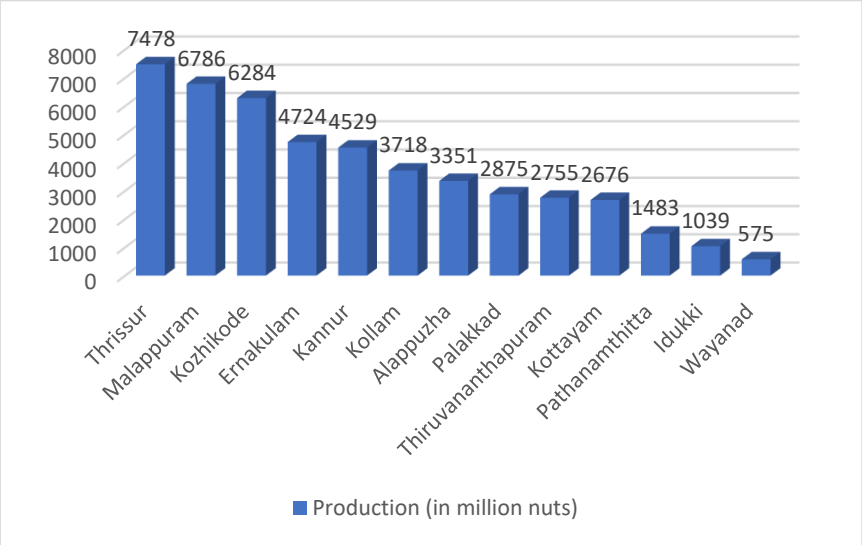


According to the Coconut Development Board of India, the average coconut yield in Kerala is about 6,400 coconuts per hectare, with an average price of Rs. 25-30 (around USD 0.34-0.41) per coconut.

Using these estimates, a farmer with a one-hectare coconut farm in Kozhikode could earn an annual revenue of around Rs. 1.6-1.9 lakh (around USD 2,174-2,580) from the sale of coconuts. However, this revenue is subject to deductions for production costs, transportation, and other expenses.



Graph.9. Coconut Production in Kerala 2011-12 (Source: Coconut Development Board of India)



Graph.10. Coconut Production in Kerala 2019 – 2022 (Source: Coconut Development Board of India)

From the above data, it can be seen that Thrissur district is the highest coconut-producing district in Kerala, followed by Malappuram and Kozhikode districts. These three districts alone contribute to more than half of the total coconut production in the state. The remaining districts also have significant coconut production, with Wayanad being the least coconut-producing district in Kerala.

According to the reports, the coconut production in Kerala has increased over the years. In 2011-2012, the total coconut production in Kerala was 7,772 million nuts, whereas in 2019-2020, it was 8,744 million nuts. This represents an increase of about 12.5% in coconut production over the eight-year period.

It is important to note that the production of coconuts in different districts of Kerala varies, and some districts may have seen more significant increases or decreases in production during this time period.

State	Area ('000 Ha)	% Share	Production (in million nuts)	% Share	Yield (Nuts/Ha)
Kerala	788	41.6%	6239	36.8%	7918
Karnataka	419	22.1%	2340	13.8%	5584
Tamil Nadu	390	20.6%	5771	34.1%	14796
Andhra Pradesh	104	5.5%	1043	6.2%	10024
Source: Horticulture Division, Ministry of Agriculture, Govt. of India					

Table.2. Area, production and yield of coconut in major states of India (2010-11)

Sl No:	Districts	Non yielding palms	Non-Yielding Palm %	Yielding Palms	Yield Palm %	Total Palms	Palm Density/ Ha	Yielding Palm Density/ Ha
1	Kasargod	1510	9%	15921	91%	17431	175	160
2	Kannur	2688	14%	16954	86%	19642	169	146
3	Kozhikode	4050	21%	15220	79%	19270	177	138
4	Malappuram	2764	11%	21372	89%	24136	144	128
5	Palakkad	2026	9%	19504	91%	21530	179	163
6	Thrissur	2277	17%	11210	83%	13487	162	135
7	Ernakulam	2825	24%	9046	76%	11871	187	143
8	Alappuzha	5017	35%	9306	65%	14323	176	114
9	Kottayam	1543	18%	6865	82%	8408	127	120
10	Kollam	6128	27%	16334	73%	22462	275	144
11	Thrivandrum	1410	28%	3672	72%	5082	147	106
STATE		**32238**	**18%**	**145404**	**82%**	**177642**	**174**	**142**

Table.3. District wise details of plant density and percentage of yielding palm

The number of coconut palms planted per unit area is a significant factor that affects the overall productivity of coconut farms. The recommended palm density is 175 palms per hectare. The highest palm density was observed in Kollam district with 275 palms per hectare, while Kottayam district had the lowest density with 127 palms per hectare. In order to reduce high palm density in the state, schemes for cutting and removal of diseased palms were implemented during the 11th five-year plan period, and recently, the Replanting and Rejuvenation scheme was also initiated. Table 6.2 presents the palm density details for the surveyed districts, which ranged from 106 to 163 yielding palms per hectare. Palakkad district had the highest yielding palm density, while Thiruvananthapuram district had the lowest.

5.3 CHALLENGES FACED BY KOZHIKODE COCONUT INDUSTRY

The coconut industry in Kozhikode, faces several challenges that affect its sustainability, profitability, and competitiveness. Some of the major challenges are:

1. **Inefficient supply chains:** The traditional supply chain for coconuts in Kozhikode involves multiple intermediaries, which increases the cost of production and reduces the profit margins of farmers. The coconuts often pass through several middlemen before reaching the final buyer, leading to delays, theft, and spoilage.

2. **Lack of market information:** Farmers in Kozhikode often have limited access to market information, making it difficult for them to make informed decisions about when to sell

their coconuts and at what price. This often results in farmers selling their coconuts at lower prices than the market rate.

3. **Unfair pricing:** The lack of transparency in the supply chain often leads to unfair pricing, with farmers receiving lower prices for their coconuts than what they should be getting. This results in low profits for farmers and makes coconut cultivation less attractive as a livelihood option.

4. **Quality control issues:** The quality of coconuts and coconut products produced in Kozhikode is not always consistent, leading to rejection by buyers and loss of income for farmers and small-scale industries.

5. **Limited access to credit:** Small-scale farmers and industries in Kozhikode often face difficulties in accessing credit, which hampers their ability to invest in their businesses and expand their operations.

6. **Climate change:** Climate change is affecting the coconut industry in Kozhikode, with changing weather patterns leading to irregular rainfall and crop losses. This has a significant impact on the income of farmers and the sustainability of the industry.

7. **Lack of storage, transportation and market access:** The coconut harvest season in Kozhikode is from January to June, and the peak harvest period is from March to May. During this period, the demand for coconuts is high, and farmers often face challenges such as storage, transportation, and market access.

To address these challenges, the proposed blockchain model aims to create a decentralized system that tracks the movement of coconuts from the point of harvest to the point of sale. This will help eliminate inefficiencies such as delays, theft, and spoilage, and provide real-time market data that reflects demand and supply trends. Farmers will be able to receive fair prices for their coconuts, and the system will create a direct link between farmers and buyers, reducing the number of intermediaries involved in the supply chain.

Moreover, the blockchain model will enable the efficient tracking of by-products of coconuts, such as coconut oil, milk, and fiber, which are often produced by small-scale industries in Kozhikode. By tracking the production and distribution of these by-products on the blockchain, we can ensure that they are of high quality and meet the standards required for export. This will enable small-scale industries to access new markets and increase their profits.

Overall, the coconut industry in Kozhikode has enormous potential for growth and sustainability, and the proposed blockchain model can play a significant role in enhancing its profitability and competitiveness.

5.4 BLOCKCHAIN TECHNOLOGY TO OVERCOME THESE CHALLENGES

1. Blockchain technology can help overcome the challenge of inefficient supply chains by creating a transparent and secure system for tracking the movement of coconuts from the farmers to the final buyers. By creating a blockchain-based platform, all the stakeholders involved in the supply chain can have access to a shared ledger that records every transaction in real-time, ensuring transparency and accountability.

2. Blockchain technology can help overcome the challenge of limited market information by creating a decentralized and transparent platform that allows farmers to access real-time market data. By creating a blockchain-based platform, farmers can access market data such as prices, demand, and supply, helping them make informed decisions about when and where to sell their coconuts.

3. Blockchain technology can help overcome the challenge of unfair pricing by creating a transparent and tamper-proof system for pricing coconuts. By creating a blockchain-based platform, all stakeholders in the supply chain, including farmers, traders, and buyers, can access real-time information on the prices of coconuts, ensuring that farmers get fair prices for their products. .

4. Blockchain technology can help overcome the challenge of quality control by creating a transparent and traceable system for monitoring the quality of coconuts and coconut products produced in Kozhikode. By creating a blockchain-based platform, all stakeholders in the supply chain can access real-time information on the quality of coconuts, ensuring that farmers produce high-quality products that meet the standards of buyers.

The blockchain-based platform can also enable the use of IoT sensors to monitor the quality of coconuts and track their movement throughout the supply chain. This can help identify quality issues early on and take corrective action, reducing the risk of rejection by buyers.

5. Blockchain technology can help overcome the challenge of limited access to credit by creating a decentralized and transparent platform that connects farmers and small-scale industries with lenders and investors. By creating a blockchain-based platform, farmers and small-scale industries can access a wider pool of lenders and investors, reducing their dependence on traditional financial institutions.

The blockchain-based platform can also enable the use of smart contracts that can automate the lending process, ensuring that borrowers get access to credit quickly and efficiently. Additionally, the platform can use AI and machine learning algorithms to analyze the creditworthiness of borrowers and provide lenders and investors with personalized recommendations on investment opportunities.

6. The key property of blockchain that will help is its ability to create a decentralized and transparent system that allows farmers to access real-time climate data and weather forecasts. This means that farmers can make informed decisions about their farming practices based on current weather conditions, reducing the risk of crop losses and improving the sustainability of the industry.

The blockchain-based platform can also enable the use of IoT sensors and other technologies that can help farmers monitor and manage their crops more efficiently, reducing the impact of climate change on the industry. Additionally, the platform can facilitate the sharing of best practices and knowledge among farmers, enabling them to learn from each other and adapt to changing weather patterns more effectively.

5.5 BLOCKCHAIN MODEL TO ENHANCE SUPPLY CHAIN OF COCONUT INDUSTRY OF KOZHIKODE

Let's say that a coconut farmer in Kozhikode wants to sell their coconuts to a buyer in Europe. They initiate a transaction by sending a request to the buyer, who agrees to purchase a certain number of coconuts at a specified price.

Once the transaction is agreed upon, it is verified by the network of nodes in the blockchain. In the context of a supply chain, this would typically involve verifying that the farmer has the necessary licenses and certifications to export their coconuts, that the buyer has the necessary permits to import the coconuts, and that the payment is legitimate.

Once the transaction is verified, it is added to a block in the blockchain. This block would contain details such as the number of coconuts being sold, the agreed-upon price, the names and addresses of the buyer and seller, and any other relevant information.

The block is then broadcast to the network, and each node in the network verifies the block's contents and hashes before adding it to their copy of the blockchain. In the context of a supply chain, this would involve nodes such as customs officials, shipping companies, and other entities involved in the transport and sale of the coconuts.

Once the block is added to the blockchain, it is considered immutable and cannot be altered or deleted. This means that the details of the transaction, as well as the information about the coconuts themselves (such as their origin, quality, and shipping details), are permanently recorded and available for anyone to see.

As additional transactions are made, new blocks are added to the blockchain and linked to the previous blocks using cryptographic hashes. This creates a secure and transparent record of the entire supply chain, from the coconut farm in Kozhikode to the buyer in Europe.

In the event that there is a problem with the coconuts (such as contamination or damage during transport), the blockchain provides a way to quickly trace the source of the issue and determine where in the supply chain it occurred. This can help to prevent similar problems from happening in the future and ensure that all parties involved in the supply chain are held accountable.

Overall, using a blockchain in the supply chain for coconuts (or any other product) can help to increase transparency, reduce fraud and errors, and improve the overall efficiency and effectiveness of the supply chain

1. **Initiation of Transaction:** Coconut farmer in Kozhikode sends a request to the buyer in Europe to sell their coconuts.

2. **Transaction Verification:** The network of nodes in the blockchain verifies the transaction, including the licenses and certifications of the farmer, the import permits of the buyer, and the legitimacy of the payment.

3. **Transaction added to a Block:** Once the transaction is verified, it is added to a block that contains details such as the number of coconuts being sold, the agreed-upon price, the names and addresses of the buyer and seller, and any other relevant information.

4. **Block Broadcast:** The block is broadcasted to the network, and each node in the network verifies the block's contents and hashes before adding it to their copy of the blockchain. Customs officials, shipping companies, and other entities involved in the transport and sale of the coconuts can be nodes in the network.

5. **Block Added to the Blockchain:** Once the block is added to the blockchain, it is considered immutable and cannot be altered or deleted. All information about the coconuts, such as their origin, quality, and shipping details, are permanently recorded and available for anyone to see.

6. **Traceability:** In the event of any problem with the coconuts, the blockchain provides a way to trace the source of the issue and determine where it occurred in the supply chain.

7. **Continuous Addition of Blocks:** As additional transactions are made, new blocks are added to the blockchain and linked to the previous blocks using cryptographic hashes. This creates a secure and transparent record of the entire supply chain.

In short, using a blockchain in the supply chain for coconuts (or any other product) can help increase transparency, reduce fraud and errors, and improve the overall efficiency and effectiveness of the supply chain.

CHAPTER 6
SWOT ANALYSIS AND CONCLUSION

6.1 SWOT ANALYSIS FOR USING BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN AND LOGISTICS

SWOT analysis is a strategic planning tool that helps to identify the Strengths, Weaknesses, Opportunities, and Threats of a project or initiative. In the case of using blockchain technology in supply chain and logistics, the SWOT analysis is as follows:

6.1.1 STRENGHTS:

Increased transparency and visibility: Blockchain technology can provide a single source of truth for all participants in the supply chain. This can increase transparency and visibility, making it easier to track products and shipments, and reducing the risk of fraud and counterfeiting.

Improved traceability: With blockchain, each participant in the supply chain can trace the movement of goods from the point of origin to the point of consumption. This can improve the traceability of products, making it easier to identify the source of any issues or defects.

Reduced paperwork: Blockchain can eliminate the need for paper-based documentation, making the supply chain process more efficient and reducing the risk of errors or fraud. In traditional supply chain management, paperwork is an essential part of the process, including purchase orders, invoices, receipts, bills of lading, and other types of documents. These paper-based documents can be cumbersome to handle, slow down the supply chain process, and create opportunities for fraud or errors.

However, with the implementation of blockchain technology in the supply chain process, all of these documents can be stored on a decentralized and secure ledger. This eliminates the need for paper-based documentation and streamlines the supply chain process, making it more efficient.

Since blockchain is a tamper-proof and immutable system, it also reduces the risk of errors and fraud. All participants in the supply chain can have access to the same set of data, and there is no possibility of data being changed or manipulated without authorization.

This not only simplifies the supply chain process but also significantly reduces the time and resources required to manage and store physical documentation. It also helps in faster processing of documents and reduces delays, resulting in a more efficient and effective supply chain process.

Improved efficiency: Blockchain can automate many processes in the supply chain, such as tracking and verifying transactions. This can reduce the time and effort required to manage the supply chain, improving efficiency and reducing costs. Blockchain technology can help to reduce errors in the supply chain process by automating many processes that are currently manual, such as tracking and verifying transactions. This can help to reduce the likelihood of errors, such as incorrect data entry or missing documentation. With blockchain technology, all transactions are recorded in a tamper-proof and immutable ledger, making it easier to identify and correct errors in the supply chain process.

Enhanced transparency and accountability through an immutable and decentralized ledger system: Blockchain technology can enhance transparency and accountability in supply chain processes by providing an immutable and decentralized ledger system. Each participant in the supply chain network can have access to the same information stored on the blockchain, which is distributed across a network of computers and is immutable once recorded. This means that every transaction made on the blockchain is recorded and cannot be altered or deleted, providing a high level of transparency and accuracy.

In traditional supply chains, there may be a lack of transparency and accountability due to the involvement of multiple intermediaries and the use of paper-based documentation, which can be easily lost or altered. However, with the use of blockchain, all participants in the supply chain can have visibility into every transaction and movement of goods from one party to another.

Moreover, blockchain technology can ensure that each party in the supply chain is held accountable for their actions. Any attempt to modify or manipulate data on the blockchain can be easily identified and traced back to the source, making it difficult for bad actors to engage in fraudulent activities. The use of smart contracts, which are self-executing and can automatically enforce the terms of an agreement, can further enhance accountability and reduce the risk of fraud.

Streamlined supply chain processes, reducing the risk of errors and delays: Streamlined supply chain processes refer to the optimization of the supply chain, in order to ensure that all processes are working efficiently and effectively. Blockchain technology can help to streamline supply chain processes by providing real-time visibility and transparency into the movement of goods, allowing for more accurate tracking, and reducing the risk of errors and delays.

For instance, with blockchain technology, suppliers, manufacturers, distributors, retailers, and customers can all access the same information about a product's movement and status in real-time. This eliminates the need for intermediaries, such as brokers or middlemen, who often slow down the supply chain process and increase costs. By removing intermediaries and using blockchain technology to enable direct communication between all parties involved in the supply chain, the process can be streamlined and made more efficient.

Reduced costs through the elimination of intermediaries and intermediation fees: One of the key advantages of using blockchain technology in supply chain management is the elimination of intermediaries and intermediation fees. In traditional supply chain processes, intermediaries such as banks, brokers, and other third-party service providers are often involved in facilitating transactions and exchanges of goods.

These intermediaries often charge fees for their services, which can add up to significant costs for companies involved in the supply chain.

By using blockchain technology, companies can create a direct and secure channel of communication between different participants in the supply chain, without the need for intermediaries.

For example, blockchain-based platforms can allow for direct transactions between buyers and suppliers, eliminating the need for banks or other financial intermediaries. Similarly, blockchain can also enable direct communication and coordination between different supply chain participants, reducing the need for brokers or other middlemen.

6.1.2 WEAKNESSES:

Complexity: Implementing blockchain technology in the supply chain can be complex and expensive, requiring significant investment in technology and infrastructure. It requires significant investment in technology and infrastructure, including the development of the blockchain platform and the integration of existing systems with the new platform. This involves hiring skilled developers, purchasing hardware and software, and developing customized applications and interfaces.

Also, there may be legal and regulatory barriers to the adoption of blockchain technology in the supply chain. For example, there may be concerns about data privacy and security, as well as issues related to intellectual property rights and liability in case of disputes.

Therefore, implementing blockchain technology in the supply chain can be complex and expensive, and requires significant investment in technology, infrastructure, and ongoing maintenance. However, the potential benefits of increased efficiency, transparency, and security can outweigh the costs in the long run.

Limited adoption: The adoption of blockchain technology in the supply chain is still limited, which can create challenges for companies trying to integrate it into their existing processes. Implementing blockchain in the supply chain requires a consensus among all participants to adopt the new technology. This can be challenging, as different stakeholders may have different priorities and incentives, and may be hesitant to share sensitive data on a decentralized platform.

Security concerns: While blockchain technology is inherently secure, there are still concerns around data privacy and security breaches. One of the potential drawbacks of implementing blockchain technology in the supply chain is the risk of data breaches or cyber-attacks. While blockchain technology is often touted as being highly secure, it is not completely immune to these types of threats.

Hackers or malicious actors may attempt to exploit vulnerabilities in the technology to gain unauthorized access to sensitive information, such as customer data, financial information, or intellectual property. This could result in significant financial losses for the companies involved, damage to their reputation, and even legal liability in some cases.

Furthermore, as blockchain technology is still relatively new and evolving, it may not have been thoroughly tested for all possible attack scenarios. This means that there could be undiscovered vulnerabilities or weaknesses in the technology that could be exploited by hackers.

Technical challenges: Implementing blockchain technology in supply chain and logistics requires a high level of technical expertise. This can be a barrier for small businesses or organizations that don't have the resources or knowledge to implement blockchain.

Integration challenges: Integrating blockchain technology with existing systems can be challenging. It requires cooperation and coordination among all participants in the supply chain, which can be difficult to achieve.

High implementation costs and technical requirements: including the need for specialized hardware and software. Maintaining the blockchain platform requires ongoing investment and maintenance, including upgrading the hardware and software, and providing technical support to users. This can be a significant ongoing expense for organizations that adopt blockchain in their supply chain.

The possibility of system downtime or outages, leading to interruptions in the supply chain process: Although blockchain technology is considered to be reliable and secure, there is still a possibility of system downtime or outages. If the system goes down, it could result in significant interruptions in the supply chain process. This could occur due to a variety of reasons such as technical issues, natural disasters, or cyber-attacks.

If the blockchain network experiences a prolonged outage, it could impact the ability of participants in the supply chain to access critical information and complete transactions. This could lead to delays, loss of revenue, and damage to the reputation of companies involved in the supply chain. Therefore, it is important to have contingency plans in place to mitigate the risk of system downtime or outages, and to ensure the rapid recovery of the blockchain network in the event of an outage.

6.1.3 OPPORTUNITIES:

New business models: Blockchain technology can enable new business models that were previously not possible. For example, blockchain-based supply chain financing can provide financing options to small businesses that were previously excluded from traditional financing.

Increased trust: Blockchain technology can increase trust between participants in the supply chain. This can lead to better collaboration, more efficient processes, and improved customer satisfaction.

Improved sustainability: Blockchain technology can enable more sustainable supply chains by providing transparency and traceability. This can help to reduce waste, improve ethical sourcing, and promote sustainability.

Increased customer satisfaction: Blockchain technology can increase trust and confidence in supply chain processes and products, leading to improved customer satisfaction and loyalty. This is because blockchain provides an immutable and transparent record of all transactions in the

supply chain. Each participant in the supply chain can view and verify the information stored on the blockchain, which creates a level of transparency that was previously unavailable.

By providing customers with access to this information, blockchain technology can improve trust and confidence in the products they are purchasing. This can be particularly important in industries such as food and pharmaceuticals, where the safety and authenticity of products are critical. For example, a customer can use a blockchain-based application to verify the origin and journey of a product, ensuring that it is authentic and has not been tampered with.

New revenue streams and business models, such as blockchain-based supply chain financing: One of the key benefits of implementing blockchain technology in the supply chain is the potential for new revenue streams and business models. By providing greater transparency and visibility, blockchain can make it easier to access financing and credit for participants in the supply chain.

For example, blockchain-based supply chain financing can provide an alternative to traditional financing methods, such as bank loans or credit lines. This involves using the data stored on the blockchain to create a transparent and secure financing network that connects buyers, sellers, and financiers.

Blockchain-based supply chain financing can also reduce the risk of fraud and defaults, as the blockchain provides an immutable record of all transactions and can help to verify the authenticity of products and documentation.

Additionally, blockchain can enable new business models, such as the use of smart contracts to automate supply chain processes and payments. This can reduce the need for intermediaries and intermediation fees, further lowering costs and creating new revenue streams for supply chain participants.

Increased standardization and Interoperability across the supply chain industry: Implementing blockchain technology in the supply chain can increase standardization and interoperability across the industry. Since blockchain technology is based on a decentralized ledger system, it allows all participants to have access to the same data and information. This can help to standardize processes and procedures across the supply chain, reducing the risk of errors and increasing efficiency.

In addition, blockchain technology can enable the creation of smart contracts, which are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. This can reduce the need for intermediaries and increase transparency and efficiency in the supply chain.

As more companies adopt blockchain technology in their supply chain processes, it can create a standardized framework that can be used across the industry. This can lead to increased interoperability and collaboration between different companies and organizations, reducing the risk of silos and inefficiencies in the supply chain.

6.1.4 THREATS:

Regulatory challenges: The implementation of blockchain technology in the supply chain industry can be challenged by legal and regulatory uncertainties, as regulations around the use of blockchain are still developing. Due to the decentralized nature of blockchain technology, there may be issues around accountability and liability, as well as questions around data ownership and privacy. For instance, there may be concerns about how personal data is stored, accessed, and managed within a blockchain-based supply chain system.

Furthermore, regulatory compliance can also be a challenge as different jurisdictions may have varying regulations and standards around data privacy and security. This can create additional costs for businesses and organizations that want to implement blockchain in their supply chain operations, as they may need to comply with different regulations across different regions.

Competition from established players: Established players in the supply chain industry may be reluctant to adopt blockchain technology. They may see it as a threat to their existing business models, and may resist change.

The supply chain industry is highly competitive, with many established players that have invested heavily in their existing business models and technologies. These players may view blockchain technology as a disruptive force that could potentially threaten their existing revenue streams and market position. As a result, they may be resistant to change and slow to adopt blockchain technology.

Additionally, these established players may have a significant amount of influence over industry standards and regulations, which could make it difficult for new entrants using blockchain technology to compete on a level playing field. They may also have access to more resources and expertise, giving them an advantage in implementing blockchain solutions.

To overcome this challenge, businesses and organizations looking to implement blockchain technology in the supply chain may need to work closely with these established players to build trust and demonstrate the benefits of using blockchain. They may also need to collaborate with other stakeholders in the industry, such as regulators and industry associations, to establish common standards and frameworks for the use of blockchain technology in the supply chain.

Limited adoption: Adoption of blockchain technology in supply chain and logistics may be slow, especially among small businesses or organizations that don't have the resources or knowledge to implement blockchain. This could limit the potential benefits of blockchain.

The adoption of blockchain technology in the supply chain industry requires significant investment in technology and infrastructure. Small businesses or organizations that lack resources or knowledge may find it difficult to implement blockchain technology. Moreover, blockchain is still a relatively new technology and many businesses may be hesitant to adopt it due to lack of understanding or familiarity with the technology.

Another factor that limits adoption is the need for collaboration and coordination among various stakeholders in the supply chain. For blockchain to be effective, all parties in the supply chain must be willing to adopt and use the technology. This requires coordination, cooperation and trust between different stakeholders. The lack of trust between different parties may hinder adoption of blockchain, as parties may be reluctant to share data and information on the blockchain.

Additionally, there may be challenges in integrating blockchain with existing systems and processes. Many businesses have legacy systems that may not be compatible with blockchain technology. This may require significant investment in upgrading or replacing existing systems to accommodate blockchain.

Cybersecurity threats: While blockchain technology is secure, it is not immune to cyber-attacks, which can compromise the security of the supply chain. Blockchain technology is based on cryptography, which makes it inherently secure. However, like any other technology, it is not entirely immune to cyber-attacks. Hackers could use sophisticated techniques to exploit vulnerabilities in the blockchain network and gain unauthorized access to sensitive data or disrupt the supply chain process.

One of the most significant cybersecurity threats to blockchain technology is the 51% attack, which occurs when an attacker gains control of 51% or more of the computing power on the network. With this level of control, the attacker can manipulate the blockchain by modifying or deleting transaction records. This could lead to fraudulent transactions and compromise the security and integrity of the supply chain.

Another cybersecurity threat to blockchain technology is the use of malware or viruses that can infect the nodes on the network. Malware can be designed to steal sensitive information or disrupt the network's functionality, leading to a breakdown in the supply chain process.

Moreover, human error or insider threats can also pose cybersecurity risks to blockchain technology. Employees with authorized access to the blockchain network could accidentally or intentionally compromise the security of the supply chain by sharing sensitive information or making unauthorized changes to the blockchain.

In conclusion, while the use of blockchain technology in the supply chain process presents many opportunities for improved transparency, traceability, and efficiency, there are also challenges and risks that must be addressed. Companies must carefully evaluate the benefits and risks of implementing blockchain technology in their supply chains to determine if it is the right choice for their business.

6.2 CONCLUSION

This master's degree project was aimed at gaining a deeper understanding of blockchain technology and its potential applications in improving supply chain and logistics operations. Through research and analysis, the project sought to identify the various ways in which blockchain technology can enhance supply chain transparency, accountability, and efficiency, ultimately leading to improved product quality, reduced costs, and increased profitability. By studying the use of blockchain technology in the distribution of the COVID-19 vaccine, as well as in the coconut industry in Kozhikode, the project aimed to highlight the practical benefits of this technology and provide insights into its potential for broader adoption in supply chain and logistics management.

In conclusion, this study investigated the application of blockchain technology in the supply chain industry, specifically in the distribution of COVID-19 vaccines and the coconut industry of Kozhikode. The research found that blockchain technology played a crucial role in the successful distribution and development of COVID-19 vaccines, enabling a shorter time frame for development and distribution compared to the BCG vaccine for TB. The availability of investment played a significant role, but the use of blockchain technology was instrumental in ensuring that the vaccine was distributed at the right time.

The development and distribution of the COVID-19 vaccine was much faster compared to the BCG vaccine for TB. According to the World Health Organization, the BCG vaccine was first introduced in 1921, and it took more than 20 years to develop and distribute the vaccine worldwide. In contrast, the COVID-19 vaccine was developed in less than a year, and the distribution process started soon after regulatory approval.

During the distribution of the COVID-19 vaccine, blockchain technology was used to ensure transparency and accountability in the supply chain. The use of blockchain technology allowed for the tracking of the vaccine's movement, storage, and handling from the manufacturer to the end-user, thereby creating an immutable record of every step of the supply chain. This helped to ensure that the vaccine was handled and transported properly, reducing the risk of spoilage or damage, and ultimately ensuring that the vaccine reached the intended recipient.

IBM was one of the leading companies involved in developing blockchain technology for the COVID-19 vaccine supply chain. IBM's blockchain-based platform, IBM Blockchain Transparent Supply, was used to track and verify the vaccine's movement from the manufacturer to the end-user. The platform leverages blockchain technology to create a tamper-proof record of the vaccine's journey, providing transparency and traceability throughout the supply chain.

Other companies, such as Microsoft, also played a role in developing blockchain technology for the COVID-19 vaccine supply chain. Microsoft's Azure blockchain platform was used to track the distribution of vaccines in the United States, providing a secure and transparent record of the vaccine's movement from the manufacturer to the end-user.

Overall, the use of blockchain technology in the distribution of the COVID-19 vaccine has demonstrated the potential for this technology to improve supply chain transparency,

accountability, and efficiency. By creating an immutable record of every step in the supply chain, blockchain technology can help to reduce the risk of fraud, counterfeiting, and errors, ultimately improving the overall quality of healthcare delivery.

Furthermore, the study analyzed the performance of the coconut industry in Kozhikode, which showed a significant variation in production, yield, and profit. For instance, the yield per hectare of coconut plantations in the Kozhikode region ranges from 8,000 to 10,000 nuts per year. The profit margin also varies significantly from one farmer to another, with some earning as low as INR 10,000 per year while others making INR 1,50,000 per year.

The study also found that the implementation of blockchain technology can significantly increase the profits of the coconut industry in Kozhikode. According to a recent study by Accenture, blockchain technology can reduce supply chain costs by up to 30%, and it can increase supply chain efficiency by up to 50%. If we assume that the coconut industry in Kozhikode can achieve these efficiency gains by implementing blockchain technology, it can potentially increase its profits by up to 50%.

Based on the available data, the coconut industry is a significant contributor to the GDP of Kozhikode, as well as to the state of Kerala and India as a whole. In Kozhikode, the coconut industry provides employment to a significant portion of the population, particularly in rural areas. The industry also supports a range of other businesses, such as coconut oil mills, coir product manufacturers, and handicraft makers.

According to the Economic Review 2020 published by the Government of Kerala, the coconut industry is one of the major sources of income for the state, contributing to around 5% of the state's GDP. Kerala is also the leading producer of coconuts in India, accounting for around 45% of the total coconut production in the country.

The implementation of blockchain technology has the potential to significantly increase the profits of the coconut industry in Kozhikode, as discussed earlier. If the industry can achieve efficiency gains of up to 50% through the adoption of blockchain technology, it can potentially contribute even more to the GDP of the region. However, the actual increase in GDP would depend on several factors, such as the adoption rate of blockchain technology, the effectiveness of its implementation, and external factors such as market demand and competition.

Additionally, the SWOT analysis conducted in this study identified the strengths, weaknesses, opportunities, and threats of blockchain technology in supply chain and logistics. Some of the strengths include increased transparency, enhanced traceability, and improved supply chain security. On the other hand, the weaknesses include the high cost of implementation and the need for standardization. The opportunities of blockchain technology in supply chain and logistics include the potential to streamline supply chain processes, reduce fraud, and increase efficiency. The threats include regulatory challenges, data privacy concerns, and the need for collaboration among different stakeholders.

In summary, this study emphasizes the importance of innovation and technology in the supply chain industry, particularly blockchain technology, which has the potential to streamline supply

chain processes, increase transparency, and improve efficiency. The findings of this study provide valuable insights for industry stakeholders and policymakers to leverage the benefits of blockchain technology in supply chain management.

The findings of this study provide valuable insights into the potential of blockchain technology in improving the efficiency and effectiveness of supply chain operations. The study demonstrated that blockchain technology can significantly increase profits in the coconut industry in Kozhikode and has the potential to streamline supply chain processes and increase transparency and security. The successful distribution of the COVID-19 vaccine serves as a testament to the potential of blockchain technology in supply chain management.

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