A BLOCKCHAIN-BASED SMART CONTRACT MODEL FOR SECURE SUPPLY CHAIN OPTIMIZATION IN KENYA'S TEA SECTOR

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Doctor of Philosophy in Information Technology of Masinde Muliro University of Science and Technology

October, 2025

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I the undersigned, declare that this Thesis is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

To the Lord Almighty God.

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ABSTRACT

The environment of the international supply chain is continually evolving. The tea industry in Kenya plays a vital role in the country's economy, providing employment opportunities and generating substantial export revenue. However, the traditional supply chain management processes within the industry face challenges such as inefficiencies, lack of transparency, and limited trust among stakeholders. These issues result in fraud, counterfeiting, and payment delays, which diminish the efficiency and profitability of the tea supply chain. Blockchain technology, with its innovative capabilities, has shown great promise in improving supply chain networks and influencing societal practices. This study explored how blockchain-based smart contracts could address problems related to trade transparency, data management, and security in the tea supply chain industry. The study sought to design, test, and validate a blockchain-based smart contract model for Kenya's tea supply chain. Specifically, it focused on assessing the existing ICT infrastructure and process automation, examining collaboration dynamics and regulatory factors affecting transparency, developing a secure and efficient blockchain model, and validating its effectiveness in enhancing data exchange, traceability, and overall supply chain performance. The study used a pragmatist research philosophy, which worked well with the deductive approach, due to the many realities. The Research design used was cross-sectional survey design, exploratory study of tea companies in Kenya both multinational companies, KTDA owned companies, focusing on the way the organizations manage tea data, and how tea trade is done. The study employed a number of theoretical frameworks, including Principal Agency Theory, Transaction Cost Analysis Theory, Resource-Based View Theory, and Network Theory, to direct its examination of blockchain-based supply chain management. To organize the research, a cross-sectional survey method was used. The study collected and analyzed data using a mixed methods technique that included an interview guide and a standardized questionnaire. While theme analysis was used to examine the qualitative data, descriptive and inferential statistics were used to assess the quantitative data. Data was collected from a study population of 754 staff from different selected tea companies' workers from which a sample size of 156 was obtained using the formula by Kothari with a 95% confidence level. Quantitative data collected was analyzed using the frequency test and correlation coefficient analysis. The standardized path coefficients and their respective p – values, indicated a significant association between blockchain smart contracts for tea supply chain management and all the independent constructs. There is significant relationship between ICT Infrastructure and blockchain smart contracts for tea supply chain management (H1) with β = .488 and p –value = .040. Likewise, data integration and Automation and blockchain smart contracts for tea supply chain management (H2) is significant with β = .970 and p –value = .047. Collaboration equally has direct positive and meaningful effect on blockchain smart contracts for tea supply chain management (H3) with β = .843and p –value = .036. Lastly, security and privacy construct has an influence on blockchain smart contracts for tea supply chain management (H4) with β = .105and p –value =. 022.Consequently, the datasets for each factor satisfactorily fit the hypothesized model incorporating all the four independent constructs. The results of this study provided the foundation for developing the blockchain smart contract model for tea supply chain management. The model, refined through the research, effectively meets the stated objectives in Kenya. The presented model can help guide adoption of blockchain smart contract implementation in Kenya.

TABLE OF CONTENTS

APPENDICES

LISTS OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

BEV – Blockchain-enabled e-voting

BTC – Bitcoin

CS – Cabinet Secretary

EPCIS – Electronic Product Code Information Services

FSMA – Food Safety Modernization Act

GDP – Gross Domestic Product

GSMA – Group Speciale Mobile Association

HER – Electronic Health Records

IBM – International Business Machines Cooperation

ICT – Information Communication Technology

IoT – Internet of Things

KPLC – Kenya Power & Lightening Company

KTDA – Kenya Tea Development Agency

MDBM – Milk Delivery Blockchain Manager

NT – Network Theory

PLC – Public Listed Companies

RBV – Resource Based View

RFID – Radio Frequency Identification Device

SCDA – Special Crops Development Authority

SCM – Supply Chain Management

SME – Small & Medium Enterprises

TCA – Transaction Cost Analysis

USD – United States Dollar

VAT – Value Added Tax

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This chapter presents an introduction to the basic principles of managing the supply chain and explores the specific issues related to tea supply chain management that inform this study. It also presents an overview of technological advancements in supply chain management and discusses how innovations driven by blockchain technology can bring significant business benefits through enhanced supply risk reduction, chain transparency, and improved efficiency in overall supply chain management. Additionally, it proceeds to identify the research problem, articulate the research objectives, present the research questions, justify the study, highlight its significance, define the scope, as well as discuss the assumptions and limitations of the research.

1.2 Background to the study

Supply chain management (SCM) refers to the efficient management of the flow of information, services, finances, and products across multiple actors from source to customer (Mentzer et al., 2001). It integrates inter- and intra-firm capabilities to foster collaboration, competitiveness, and operational efficiency (Tyndall, 1998). Information sharing is central to SCM since it minimizes misunderstandings, improves synchronization, and enhances performance (Salcedo & Grackin, 2000). Efficient SCM also requires equitable sharing of risks and rewards to sustain cooperation, supported by practices such as commercialization, manufacturing flow management, product and customer relationship management, supplier integration, demand management, and order fulfillment (Keah, Lyman, & Wisner, 2002).

Blockchain has recently emerged as a transformative solution to address inefficiencies, fraud risks, and traceability gaps in multi-party supply chains. Its decentralized, tamper-proof ledger strengthens trust, security, and interoperability (Mire, 2020). Smart contracts—self-executing agreements embedded in blockchain—further enhance efficiency by reducing transaction costs and delays (Taherdoost, 2023).

1.2.1 Overview of Supply Chain Management in the Tea Sector in Kenya

The tea industry is a cornerstone of Kenya's economy, ranking among the largest global exporters. It encompasses a broad network of stakeholders—small-scale farmers, plantations, factories, exporters, and retailers—who collectively ensure the production and delivery of premium tea products. SCM plays a vital role in coordinating production, processing, packaging, and distribution to optimize inventory, reduce lead times, and maintain competitiveness. Beyond efficiency, SCM also addresses challenges such as quality assurance, sustainability, and global market volatility.

1.2.2 Current Supply Chain Management Practices in the Tea Sector

Kenya's tea sector employs a range of supply chain management (SCM) practices aimed at ensuring efficiency and competitiveness. Demand forecasting plays a critical role, with processors and exporters relying on historical data, market research, and collaboration with distributors to anticipate demand and align production (Zhao, 2019). Accurate forecasting helps prevent both overproduction and shortages, thereby optimizing resource utilization. Inventory management is another important practice, where techniques such as ABC analysis enable factories to optimize stock levels, reduce wastage, and ensure product freshness. Equally important is quality control, where stringent measures are enforced to uphold international standards and maintain consumer trust. These measures include certifications, residue testing, and traceability systems that enhance the reliability of Kenyan tea in global markets.

In addition, logistics and transportation are managed through collaborations between tea factories and logistics providers to guarantee timely deliveries. Efforts such as route optimization and load planning are employed to minimize costs while ensuring punctuality. Collaboration among stakeholders is also emphasized, with farmers, processors, exporters, and retailers engaging in information sharing and joint decision-making to align production and distribution activities. The sector has also embraced technology, with the adoption of digital platforms, automated forecasting systems, mobile applications, and traceability tools that enhance visibility, transparency, and real-time monitoring across the supply chain.

1.2.3 Pitfall in the current supply chain in the tea sector

Despite these advancements, Kenya's tea sector continues to grapple with persistent challenges that undermine efficiency and competitiveness. Limited information sharing remains a major concern as fragmented systems and communication gaps hinder effective collaboration, leading to delays in decision-making (Tse & Zhang, 2017). Traceability gaps further complicate supply chain operations, as the involvement of multiple intermediaries often obscures the origins of tea batches, hampering quality monitoring and accountability (Tian, 2017). Inconsistent quality control also persists, with adulteration, mislabeling, and blending eroding consumer trust and affecting the country's global reputation (Torresan, 2020).

Logistical inefficiencies compound these issues, as poor infrastructure, inadequate road networks, and long distances between plantations and processing centers increase costs and cause delays (Chege, 2017; ETTA, 2020). The sector is further exposed to market volatility, with global price fluctuations, climate conditions, and shifting consumer preferences destabilizing supply chain planning and inventory management (KTDA, 2017; Charles, 2022). Moreover, existing traceability and data management systems are weak, lacking transparency, scalability, and security, which makes them prone to tampering, counterfeiting, and fraud (Mangla et al., 2022; Snell, 2018). These pitfalls highlight the urgent need for innovative solutions that can strengthen transparency, reliability, and real-time monitoring in the tea supply chain.

1.2.4 Technological advancements in Supply Chain Management.

Technological advancements are transforming supply chain management (SCM) in the tea sector by improving collaboration, transparency, efficiency, and traceability. Emerging technologies such as blockchain, the Internet of Things (IoT), data analytics, mobile platforms, artificial intelligence (AI), and cloud-based systems are redefining traditional practices and enabling greater competitiveness.

Blockchain offers a decentralized and transparent system for secure and immutable data sharing across the tea supply chain (Deloitte, 2019). By enabling end-to-end traceability, blockchain helps stakeholders track the origin and movement of tea batches while addressing issues of adulteration, counterfeiting, and quality assurance. The integration of smart contracts further enhances trust by automating compliance and ensuring transparent verification processes among small-scale growers, processors, exporters, and retailers (Deloitte, 2019).

IoT devices, such as sensors and RFID tags, enable real-time monitoring of environmental conditions like temperature and humidity during production, storage, and transportation. These tools minimize losses, preserve tea quality, and optimize storage and logistics. Furthermore, IoT enhances visibility by providing stakeholders with reliable data on inventory flows, demand trends, and logistics operations, leading to more informed decision-making (Mire, 2020).

Advanced data analytics and predictive models play a crucial role in improving demand forecasting, inventory optimization, and supply chain planning. By analyzing historical data, consumer behavior, and market trends, tea processors and retailers can generate accurate forecasts, optimize production schedules, reduce stockouts, and enhance operational efficiency (Mangla et al., 2022).

The rapid growth of mobile and e-commerce technologies has reshaped tea marketing, distribution, and sales. Mobile applications enable real-time monitoring of shipments, inventory updates, and stakeholder collaboration. Meanwhile, e-commerce platforms provide direct access to global consumers, expand market reach, and offer insights into customer preferences (Taherdoost, 2023).

AI-driven algorithms and ML applications hold significant potential for automating and optimizing tea supply chains. These technologies facilitate pattern recognition, route optimization, and streamlined inventory management. Additionally, ML algorithms improve quality assurance by detecting anomalies, predicting defects, and automating inspection processes, thereby enhancing consistency and reducing human error (Pandey, Pant, & Snasel, 2022).

Cloud solutions promote effective collaboration by enabling real-time information sharing across different supply chain actors. Integrated digital systems link functions such as demand planning, inventory management, and logistics, fostering seamless coordination and improved visibility across the tea value chain (Xu, 2022).

Beyond technological innovations, regulatory reforms such as the Tea Act in Kenya play a significant role in shaping supply chain efficiency. The Act revitalizes institutions like the Tea Board of Kenya and the Tea Research Foundation, enhances research oversight, and streamlines licensing for brokers. It mandates timely payments to farmers—requiring factories to remit half of the sales receipts immediately and the balance within the financial year—thereby improving farmer welfare and reducing dependence on intermediaries (Mbabazi, 2020). Furthermore, the Act empowers the Agriculture Cabinet Secretary to regulate the tea auction, ensure transparency through electronic monitoring platforms, and strengthen oversight of the Kenya Tea Development Agency (KTDA) (Mbabazi, 2020).

The adoption of advanced technologies and supportive regulatory frameworks can significantly improve supply chain efficiency, traceability, and competitiveness in Kenya's tea sector. However, successful implementation requires investments in digital infrastructure, skills development, and collaboration among stakeholders to fully harness the potential of these innovations (Khan, 2023).

1.3 Statement of the Problem

The Kenyan tea sector, though a key contributor to the economy, faces persistent challenges of record mismatches, information gaps, and inefficiencies due to reliance on slow, manual, and fragmented systems. These outdated processes hinder traceability, increase errors and fraud risks, and weaken transparency and trust among stakeholders. The absence of a unified, real-time data-sharing mechanism further limits collaboration, raises costs, and complicates compliance with market standards. While blockchain offers potential for transparency, traceability, and data integrity, its application in the Kenyan tea supply chain remains unexplored. Existing efforts in agriculture are fragmented and fail to provide an integrated end-to-end solution. This creates a critical research gap, highlighting the need for a blockchain-based model tailored to the complexities of Kenya's tea supply chain to enhance competitiveness, sustainability, and stakeholder confidence.

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this study is to design, develop, and validate a blockchain-based smart contract model to enhance efficiency, transparency, and trust in Kenya's tea supply chain through secure data sharing, transaction processing, and traceability.

1.4.2 Specific Objective

a) To assess the current ICT infrastructure, data integration challenges, and extent of process automation within the Kenyan tea supply chain.

b) To analyze collaboration dynamics, legal frameworks, and policy constraints affecting transparency and accountability in the tea sector.

c) To develop a blockchain-based smart contract model that incorporates ICT infrastructure, data automation, security and privacy considerations for enhancing supply chain operations.

d) To test and validate the proposed blockchain-based smart contract model for improving real-time data exchange, traceability, and transparency in the Kenyan tea supply chain.

1.5 Research Questions

i. What is the state of ICT infrastructure in the Kenyan tea supply chain, and how ready is it for blockchain integration in terms of data integration and process automation?

ii. How do collaboration dynamics, legal frameworks, and policy constraints influence transparency and accountability in the Kenyan tea sector?

iii. How can a blockchain-based smart contract model that incorporates data automation, security and privacy considerations be developed to address inefficiencies in the tea supply chain?

iv. To what extent can the proposed blockchain-based smart contract model be tested and validated to enhance real-time data exchange, traceability, and transparency in the Kenyan tea supply chain?

1.6 Hypothesis

a) **H1:** ***ICT infrastructure readiness, data integration, and process automation*** have a positive and significant influence on the adoption of blockchain-based smart contracts in the Kenyan tea supply chain.

b) **H2:** ***Collaboration among stakeholders, as well as supportive legal and policy frameworks***, positively affect transparency and accountability in the adoption of blockchain-based smart contracts in the tea supply chain.

c) **H3:** ***Security and privacy*** considerations significantly influence stakeholders' willingness to adopt a blockchain-based smart contract model in the Kenyan tea sector.

d) **H4:** ***A blockchain-based smart contract model*** significantly improves real-time data exchange, traceability, and transparency within the Kenyan tea supply chain.

1.7 Justification of the Study

Blockchain technology eliminates the need for middlemen like banks by enabling transparent peer-to-peer transactions in the agricultural industry. Instead of depending on a centralized authority, peer-to-peer architecture and cryptography are used. It reduces transaction costs and builds trust between producers and consumers. A key benefit of blockchain in the tea supply chain is its ability to enhance transparency. With its decentralized and immutable nature, implementing a blockchain-based smart contract model allows for transparent and traceable records of transactions throughout the supply chain. This transparency promotes the identification of inefficiencies, reduces the occurrence of fraud, and fosters trust among stakeholders.

Improved traceability is a significant advantage of implementing a blockchain-based smart contract model in the tea supply chain. This technology enables the tracking of tea from its origin to the final consumer, ensuring stakeholders can verify its authenticity, quality, and sustainability. This level of traceability also facilitates the swift identification and resolution of potential issues or recalls, thereby safeguarding consumer safety.

Another benefit is the enhanced accountability provided by blockchain technology. Through decentralized and distributed ledger systems, each transaction is recorded and validated by multiple participants, ensuring transparency and accuracy. By recording transactions and commitments in a tamper-proof manner, the risk of disputes or unethical practices is reduced.

By adopting a blockchain-based smart contract model, tea supply chains can experience streamlined processes and improved efficiency. Traditional manual paperwork, middlemen, and information delays can be eliminated as smart contracts automate tasks such as payment settlements, quality checks, and shipment notifications based on predefined conditions. This automation reduces human errors, manual interventions, and delays, resulting in enhanced operational efficiency and cost savings for all stakeholders.

Moreover, blockchain technology promotes collaboration and trust among tea supply chain participants. With its decentralized nature, the technology enables direct and secure interactions between stakeholders, eliminating the need for a centralized authority. Smart contracts provide a reliable framework for executing agreements and transactions, reducing the reliance on intermediaries and facilitating direct peer-to-peer interactions. This foster improved relationships, better coordination, and increased trust among tea supply chain stakeholders.

The implementation and seamless integration of a blockchain-based smart contract model have the capacity to bring about a transformative impact on the tea supply chain. With its ability to solve important problems like accountability, transparency, traceability, and efficiency, this technology might completely transform the sector. Blockchain technology can help tea supply chains become more resilient, sustainable, and trustworthy, which will benefit all parties involved—producers, manufacturers, distributors, retailers, auctioneers, and consumers.

1.8 Significance of the Study

The results obtained from this study have significant implications across various domains. By identifying and addressing the factors affecting small-scale tea production in Kenya, the study contributes to the improvement of the tea subsector in the country. It sheds light on critical aspects such as production, financing, resource factors, and marketing that contribute to the decline in tea production among small-scale farmers.

Furthermore, the study is of great interest to researchers and scholars as it enriches theories of international business by incorporating factors such as marketing strategy, firm size, liberalization, and technology.

The findings of this study also hold relevance for government policymakers as they inform policy formulation in the tea sector, enabling Kenya to enhance its competitive position in the global arena. This, in turn, contributes to Kenya's vision of becoming a globally competitive, prosperous, and middle-income economy, with the international trade sector identified as a key driver of Vision 2030.

Policy makers can utilize the study findings to determine the pace and direction for further liberalization in the agriculture sector and other strategically important sectors. This will help bridge any weaknesses and mitigate any negative impacts that may arise, maximizing the positive impact for the benefit of tea farmers.

Based on the research results, planners and marketers can gain from implementing a blockchain-based strategy. The implementation of blockchain technology can add value and improve market competitiveness because many products, including tea, are mainly marketed in raw or semi-processed form, fetching lower prices in the international market compared to high value finished products imported into the country.

Finally, the study findings promote close collaboration with key stakeholders, fostering synergy to support the growth of the Kenyan economy. This collaboration involves consolidating, diversifying, and expanding target markets for Kenya's tea exports.

1.9 Scope of the Study

The scope of this study focuses on the integration and adoption of blockchain technology in Kenya's small-scale tea sector, particularly within the framework managed by the Kenya Tea Development Agency (KTDA) Ltd and private multinational companies. KTDA oversees 65 factories and represents over 619,637 small-scale tea farmers, the majority of whom cultivate tea on approximately 0.5 acres of land. These factories are organized into 12 tea zones, with each zone represented by a board member on the KTDA Board, which is the primary decision-making body for Kenya's small-scale tea industry. The 12 tea zones are further divided into seven regions at the management level, each overseen by a regional manager and supported by a regional operations manager.

This study examines how the blockchain technology can be used to improve the transparency, accountability, and efficiency of the tea supply chain. In particular, the paper will observe how blockchain will potentially solve the major problems in the industry such as the traceability, fraud, and inefficiency, and emphasize the primary stakeholders in the tea supply chain.

This research will be descriptive in nature as both qualitative and quantitative approaches will be used to present a complete analysis of the uptake of blockchain technology in the Kenyan tea industry. The research design will allow gathering not only subjective data but also objective material, which will allow obtaining a deeper insight into the modern practice of the tea supply chain and the opportunities of blockchain technology.

The study employed a purposive sampling method to collect data, a representative sample of tea factories was selected by the study that are operated by KTDA and private multinational companies. The number of tea factories sampled was decided on a sample between the size, geographical location, and the participation in the small-scale tea industry. The top management personnel of these factories were the respondents of interest to this research since they are instrumental in the operations of the supply chain and are the decision-makers in these factories. The stakeholders identified were chosen to give useful insights on how the blockchain technology can be successfully incorporated into the tea supply chain. The main ones were small-scale farmers (outgrowers), factory unit managers (FUMs), auction-related managers or sales representatives, field services coordinators (FSCs), and ICT officers.

To study the data, the study employed a mixed method of data collection using quantitative and qualitative methods. The questionnaires were filled in by the main stakeholders and were given structured questionnaires to gather quantitative information on their attitudes towards blockchain technology and how it would influence the tea supply chain. Also, semi-structured interviews with the chosen participants were carried out in-depth in order to acquire the qualitative data about the challenges, opportunities, and practical considerations of adopting blockchain. A review of the relevant documents such as reports on KTDA, industry publications, and past studies on blockchain in supply chain management was also used to gather secondary data.

Both the quantitative and qualitative analysis were used in analyzing the data collected. The descriptive statistics was used to analyze the quantitative data and determine the patterns and correlations of the perceptions of the stakeholders regarding the adoption of blockchain. Thematic analysis of qualitative data obtained in the interviews was performed, and similar themes and insights regarding the use of blockchain to enhance the tea supply chain were identified. This combination of research approaches will help the study to have a comprehensive insight into how the blockchain technology can be applied to the Kenyan tea supply chain by taking into consideration the views of the main stakeholders and empirical data of the potential advantages of the technology.

1.10 Assumptions of the study

It was assumed that there is an adequate internet infrastructure in place in Kenya to support the implementation of the blockchain-based smart contract transactions. This includes reliable internet connectivity and access to the necessary hardware and software resources.

It was assumed key stakeholders in the tea supply chain, including tea farmers, processors, distributors, retailers, and consumers, are open to adopting blockchain technology and embracing the proposed blockchain smart contract based model. It assumes that they recognize the potential benefits and are willing to participate in the implementation process.

The assumptions in this study is that there is a supportive regulatory and legal framework in place in Kenya for the implementation of blockchain technology in the tea supply chain. It assumes that there are no significant legal barriers or restrictions that would hinder the adoption of smart contracts or the use of blockchain technology.

The study assumed that there is a pool of technical expertise available in Kenya to handle the implementation and maintenance of the blockchain-based smart contract model. This includes individuals with knowledge of blockchain technology, smart contract development, and system integration.

The study assumed that the cost of implementing and maintaining the blockchain-based smart contract model is feasible and within the budgetary constraints of the tea industry stakeholders. It assumes that the long-term benefits and potential cost savings outweigh the initial investment required for the implementation.

1.11 Validation of Study Assumptions

Internet Infrastructure

Assumption: Kenya has adequate internet infrastructure to support blockchain-based smart contracts.

Validation: Kenya has made significant progress in ICT infrastructure, with high mobile phone penetration and widespread 4G coverage, and ongoing expansion of fiber-optic connectivity. However, connectivity in rural tea-growing regions remains inconsistent. Thus, while the assumption holds in urban and semi-urban areas, it is partially valid in remote tea-producing zones.

Stakeholder Willingness

Assumption: Key stakeholders (farmers, processors, distributors, retailers, and consumers) are open to blockchain adoption.

Validation: Interviews and secondary studies show growing awareness of digital solutions in agriculture. Farmers and processors are receptive when benefits such as faster payments and transparency are clear. Still, adoption may face resistance due to low digital literacy, cost concerns, and cultural inertia. Hence, the assumption is conditionally valid depending on awareness and training.

Regulatory and Legal Framework

Assumption: Kenya has a supportive regulatory framework for blockchain and smart contracts.

Validation: The Capital Markets Authority (CMA) and the Central Bank of Kenya (CBK) have shown interest in blockchain applications, particularly in fintech. However, there is no comprehensive legal framework for blockchain or smart contracts in Kenya's agriculture sector yet. Therefore, this assumption is not fully valid and highlights a policy gap.

Technical Expertise

Assumption: Kenya has a sufficient pool of blockchain technical expertise.

Validation: Kenya has a vibrant ICT ecosystem ("Silicon Savannah"), with expertise in software development, fintech, and mobile money innovations (e.g., M-Pesa). However, blockchain-specific skills (smart contract programming, system integration) remain limited and concentrated in fintech startups, making this assumption partially valid.

Cost Feasibility

Assumption: The costs of implementing blockchain smart contracts are feasible for stakeholders.

Validation: Initial costs (hardware, software, training, and integration) are relatively high for smallholder farmers and cooperatives. Yet, the long-term benefits—such as reduced fraud, faster payments, and efficiency gains—can outweigh costs if implementation is supported through cooperatives, public-private partnerships, or donor programs. Thus, this assumption is conditionally valid.

1.12 Limitations of the study

The first challenge the researcher faced during the study was choosing the right theories to address the research question. The researcher researched widely about the study topic and the theories that backed it in order to address the issue. Additionally, the researcher tackled the issue by soliciting advice from specialists in 20 different fields during seminars. Selecting the appropriate approach posed a challenge for the researcher, as they needed to determine the best course of action for carrying out the investigation. Before beginning the actual investigation, the researcher conducted a pilot study to test the solution and conferred with other researchers. The final challenge involved handling the gathered data, specifically figuring out how to make sense of it all. The researcher used tools for analysis and conducted a thorough literature review to address the issue.

It was difficult to get complete disclosure of information from different tea factory companies. Sensitive information includes details about procurement processes, production efficiency, and profitability. This will however be addressed by assuring the firms that the final report will not disclose the names of the respondents and also the report will be handed to them to better the tea sector.

An additional constraint encountered throughout the research was the mindset of the subjects. Certain participants expressed reluctance to divulge information about their familiarity with the tea trade. The researcher had to ensure the informants that the information they were providing would be kept confidential and used solely for the research in order to get around this restriction.

1.13 Operational Definition of Terms

A Smart Contract according to the provisions of a contract or agreement, a smart contract is a digital protocol designed to automatically carry out legal and signinicant events that hleps manage various acts in a company or organization.

Access Control refers to the mechanisms and protocols that regulate and restrict the entry or use of resources, data, and functionalities within the blockchain network.

Autonomous Execution refers to the ability of smart contracts or decentralized applications (DApps) to self-execute predefined instructions without the need for centralized control. Autonomous execution is a fundamental characteristic of blockchain systems that leverage smart contracts.

Blockchain technology is an online registry that encompasses numerous linked blocks, each block has particular data or information. The data that is held in a block also differs with the nature of blockchain that is being utilized. An example is that, in a bitcoin blockchain, a block can hold information on who is sending, receiving and the number of bitcoins being sent.

Consensus mechanism is the protocol or set of guidelines that nodes adhere to in order to agree on the blockchain's current state. Consensus methods make guarantee that everyone on the network comes to the same conclusion about the legitimacy of transactions and the distributed ledger's present state.

Data Encryption refers to the process of securing information by converting it into a form that can only be deciphered or accessed by authorized parties.

Data Manipulation refers to the unauthorized or improper alteration of information within the blockchain system.

Data Ownership refers to the concept that individuals or entities have control and authority over the data they generate or contribute to the blockchain.

Data Sharing/Access refers to the process of exchanging or disseminating information among participants within the blockchain network. Blockchain enables secure, transparent, and decentralized data sharing.

Immutable data refers to information that is unalterable once it has been added to the blockchain. The immutability of data is a fundamental characteristic of blockchain that ensures the integrity and permanence of recorded information.

Immutable ledgers refers to a decentralized and tamper-resistant record of transactions or data that, once added, cannot be altered or deleted.

Information Authencity refers to the assurance that data or content within the blockchain is genuine, unaltered, and originated from a legitimate source.

Information Exchange refers to the process of sharing data, transactions, or other relevant information among participants in the blockchain network.

Interoperability refers to the ability of different blockchain networks, protocols, or systems to seamlessly exchange and use information or assets, promoting a cohesive and integrated ecosystem.

Network Connection refers to the establishment and maintenance of communication links between nodes within the blockchain network.

Privacy refers to the protection and control of personal or sensitive information of participants within the blockchain network.

Security is the processes and procedures put in place to safeguard the availability, confidentiality, and integrity of data and network operations within the blockchain.

Supply chain management refers to the systematic management of the production process for goods and services, with the goal of optimizing quality, profitability, customer experience, and timely delivery to the end customer.

Technology Scalability describes a blockchain network's capacity to accommodate a growing number of users, transactions, or data without sacrificing decentralization, efficiency, or performance. Scalability is a crucial factor in ensuring that blockchain systems can accommodate growth while maintaining or improving their capabilities.

Traceability describes the capacity to follow and confirm the source, path, and modifications of information or assets that are stored on the blockchain. Participants can track the history of transactions or information thanks to blockchain's public and auditable trail.

Transaction Execution refers to the process by which a transaction is validated, confirmed, and added to the blockchain. It involves the execution of smart contracts or traditional transactions, depending on the nature of the blockchain.

Transparency refers to the degree to which information about the state of the blockchain, its transactions, and the overall system is easily accessible and visible to relevant parties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature on the application of blockchain-based smart contracts in the supply chain for the agriculture industry is presented in this chapter. It covers a wide range of topics, including an overview of supply chain management, the principles of blockchain technology, its developments and uses, how blockchain is being applied in the agriculture industry, and the current models of smart contracts on blockchain technology. The identification of prospective domains for the application of blockchain technology's smart contract models is the chapter's conclusion.

2.2 Supply Chain Management

2.2.1 Overview of Supply Chain Management

The term "supply chain" refers to the entire process, which includes the actual and associated data movement of money, goods, information, and raw materials. It impacts the performance of businesses and plays a special and crucial function (Maouchi, Ersoy, & Zekeriya, 2018). Supply chain or Store network oversees or is engaged with sourcing, acquisition, assembling, circulation, and coordination, and, subsequently, influences speed-to-advertise, the expense of an item, administration discernment, and capital necessities in organizations (Maouchi, Ersoy, & Zekeriya, 2018). Store network incorporates a bunch of divided and regularly geologically discrete cycles into a durable framework to convey worth to the client. The center capacities and tasks of a common inventory network is represented in Figure 2.1.

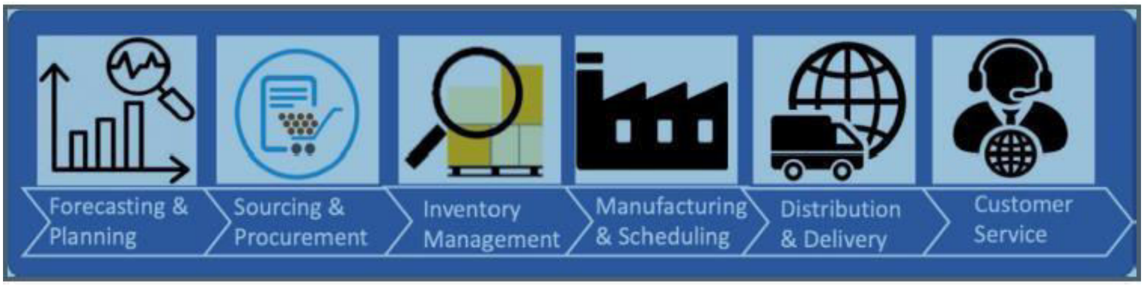


Figure 0.1: Supply Chain and Operation

Source: (Maouchi, Ersoy, & Zekeriya, 2018)

2.2.2 Key Short Comings of supply chain

The current supply chain landscape is characterized by evolving customer requirements, competitive challenges, geographical dispersion, and the emergence of various models of business like e-commerce. The widespread adoption of e-commerce and handheld digital devices has revolutionized consumer behavior, particularly in the realm of shopping (White, Afolayan, & Plant, 2014). Customers now have a growing demand for personalized products, transparency and streamlined shopping experiences regarding the value and origins of products (White, Afolayan, & Plant, 2014). While these changing customer needs create opportunities for businesses, they also present serious difficulties for the current supply chains. Outdated supply chains find it difficult to trace goods from raw materials to final consumers, manage demand, and offer end-to-end data visibility. This complex process is further compounded by the limitations of current technologies, which hinder adequate, cost reduction and the management of risk, and furthermore the ability to adapt to rapidly changing market trends.

Lack of traceability: The benefits of traceability in the process supply chain over the last decade has seen improvements, particularly in areas such as customer service and business operations forecasting and planning (Maouchi, Ersoy, & Zekeriya, 2018). However, implementing a centralized system in an interconnected network is challenging due to limited trust among participants. Each party in the supply chain maintains discrete systems with their own databases for product tracking throughout the entire process, further complicating traceability efforts (Maouchi, Ersoy, & Zekeriya, 2018).

Stakeholder distrust: The lack of trust among stakeholders poses a significant challenge in supply chain management (Tyndall, 1998). Trust forms the fundamental basis for a strong and effective supply chain network (Poirier, 1999). When participants lack trust in one another, it becomes a major setback for the entire supply chain network and hinders efforts to improve its functioning. As a result, stakeholders often rely on intermediaries, such as agents, to facilitate transactions and mitigate trust-related issues. However, this reliance on intermediaries increases operational costs and reduces overall network efficiency.

Limited transparency: In the context of this study refers to the degree to which various stakeholders have access to reliable and sufficient data about various items (Deimel, Frentrup, & Theuvsen, 2008; Pant, Prakash, & Farooquie, 2015). Transparency is crucial for building trust among stakeholders and ensuring data integrity and product quality. However, the current supply chain network lacks transparency, as valuable information is often lost during transfer between stakeholders. This is compounded by the use of paper-based documentation, leading to inconsistencies and inadequate interoperability. Despite significant research investments, these critical challenges persist. The Chipotle Mexican Grill case serves as a notable example of the inefficiency and potential inability of the current supply chain system to provide reliability in the production cycle of an item (Kshetri, 2018).

Old approaches to data sharing: In today's supply chain network, information is exchanged among many businesses through paper-based documentation (Chang & Iakovou, 2019). All associated products must come with bills of lading, letters of credit, invoices, insurance policies, and a plethora of certificates. To finish a single shipment of frozen items from Mombasa to Europe in 2014, Maersk, a significant logistics and transportation business, had to handle about 200 talks (Allison, 2016). These communications resulted in a stack of paperwork around 25 centimeters high. However, this archaic and inefficient information sharing approach frequently causes delays in ports when the paperwork does not coincide with the real delivered cargo.

Compliance challenges: Companies must adhere to stricter regulations to ensure product safety. Recent laws from the FDA and FTC aim to enhance food safety and transparency across the supply chain. However, current procedures complicate gathering data from various stakeholders and building compliant databases.

2.3 Technological Advancements of Supply Chain Management System

Blockchain technology underpins smart contracts, which use it to verify and enforce agreements among multiple parties. These contracts allow transactions between anonymous users without needing a central authority or external enforcement. Transactions are visible, traceable, and irreversible on the blockchain, which is secure and immutable. All information is encrypted and recorded in a tamper-proof ledger (Meijer, 2020).

Financial services, in particular, have rapidly embraced blockchain technology, largely influenced by the earlier success of Bitcoin as a blockchain implementation. In 2015, Nasdaq Private, Nasdaq, and OMX Group Inc. partnered with blockchain startup Chain to test blockchain technology for share trading (Laura, 2015). Additionally, major organizations such as RBS, Visa Europe, the Commonwealth Bank of Australia, and various UK high street banks announced they are developing blockchain proof-of-concepts (Rizzo, 2015; Caffyn, 2015; Cuthbertson, 2015).

Mobile technology, in combination with blockchain technology and smart tagging, has been implemented to track fish caught in fishing areas while verifying sustainability claims. The primary objective was to establish verifiable proof of compliance with standards at the origin and throughout the supply chain, aiming to prevent the duplication of certificates. Furthermore, the objective was to investigate the potential of these developing technologies in establishing a transparent and open food and other physical items traceability system (Mohd et al., 2021). Throughout the export chain, the experimental project effectively tracked fish that was responsibly caught and significant social claims. The use of provenance information aimed to address the need for data interchange and interoperability in tracking various items from end to end, without relying on a centralized data management system. The research findings revealed that blockchain technology met these requirements and presented an exciting paradigm for achieving traceability (Mohd et al., 2021).

Blockchain technology is used to track and verify the flow of physical goods and their confirmed qualities from the point of sale (POS) to their origin via mobile and smart tags. The first known use of blockchain technology was in the well-known peer-to-peer (p2p) Bitcoin payment system. On May 22nd, 2010, Laszlo Hanyecz conducted a transaction with another Bitcoin user, exchanging 10,000 BTC for two Papa John's pizzas. This transaction occurred online without the involvement of traditional financial institutions like Visa or PayPal (Lazlo, 2010).

As blockchain technology continues to gain attention, numerous companies and startups are exploring its applications beyond the financial services sector. Many organizations are conducting experiments and pilot projects to leverage blockchain technology for various purposes (Chege et al., 2017). For example, Provenance, a business that focuses on supply chain transparency, just finished a successful six-month pilot program to use blockchain technology to track ethical tuna sourcing in Indonesia. Furthermore, a 2014 startup called Monograph uses blockchain technology to enable income sharing between media artists, publishers, and distributors while securing usage and sharing rights for digital media property like video clips and brand-sponsored content (KTDA, 2022).

With a reported 444 million mobile subscribers in sub-Saharan Africa, as stated by the Groupe Speciale Mobile Association (GSMA) in 2017, the potential for both large-scale and small-scale farmers to adopt blockchain technology is within reach. (GSMA, 2022). However, for farmer transactions to be recorded on the blockchain ledger, internet connectivity is necessary. In 2017, only 38% of internet users in the region had access to mobile broadband (GSMA, 2022). While infrastructure limitations exist, there is optimistic progress towards improvement. By 2025, it is estimated that more than two-thirds (87%) of mobile users in sub-Saharan Africa will have internet connectivity (GSMA, 2022).

2.4 Blockchain Technology

Blockchain technology is a cutting-edge approach that boosts operational effectiveness, improves end-to-end value, and improves customer service, claim Ahmed Gad et al. (2022). In the end, it decreases costs by streamlining transactions, improving transparency, cutting waste, and enhancing transparency. Because of this powerful technology, new internet and business models have been created. Blockchain has the potential to become the main engine for safe and effective social and financial systems (Ahmed et al., 2022).

The blockchain technology was initially introduced as a platform for the digital currency Bitcoin, which remains the largest and oldest blockchain network globally. However, blockchain technology has evolved beyond cryptocurrencies and now offers various applications and advantages (Mearian, 2017). Blockchain technology is built on its distributed ledger, a database that is publicly updated by all participants or nodes in the network (Feign, 2022). This open, collaborative update process is a core feature of blockchain. Transparency is ensured by the distributed structure of the database since each computer node independently creates and maintains files instead of a central authority transferring them to other nodes. Furthermore, because the data on the blocks are connected to one other and cannot be changed once a transaction is approved for inclusion in the chain, blockchain provides security by employing public-private key cryptography to verify transactions.

Blockchain technology has been a major factor in many corporate and social activities because of its transparency, security, and performance improvements (Frizzo-Barker et al., 2020).

A blockchain is an appropriated, advanced ledger (Lee, 2018). The ledger records exchanges in a progression of squares. It exists in numerous duplicates spread over different PCs, which are additionally called 'hubs'. The ledger is secure on the grounds that each new square of exchanges is connected back to past blocks such that makes altering essentially impossible (TransVoyant, 2018). Being decentralized, blockchain does not rely on a single organization for storage, like a bank. Instead, as new transactions occur, the ledger is updated and distributed to all nodes in the network. The truth about each transaction is reflected in the multiple copies of the ledger. In order to attempt a ledger fraud, one would need to perfectly time the falsification of the copies. There is very little probability that this can be accomplished on blockchain networks of any practical magnitude (TransVoyant, 2018).

A hash encryption algorithm is used in a blockchain framework to uniquely identify each data block, which is then connected to other blocks to construct a data blockchain (Bahga & Madisetti, 2016). Blockchain technology also lessens the need for middlemen, which can result in fraud, hacking, and disruption. The network and its operations are made more trustworthy by using blockchain technology (Wang & Singgih, 2019). With the help of this technology, digital assets may be created and transferred with great confidence. The smart contract module, which maintains transaction terms and validates the results based to the agreed-upon terms, is another noteworthy feature. As a result, there are fewer middlemen involved and more transparency in exchanges and interactions (Saberi, Cruz, Sarkis, & Nagurney, 2018). These blockchain capabilities are also applicable in supply chain management.

The utilization of blockchain technology enables secure tracing of transactions among anonymous participants, leading to quick detection of fraud and malfunctions. Furthermore, the use of smart contracts makes it possible to report problems in real time, which helps with the difficulty of tracking products in the intricate agri-food supply chain (Haveson, S., Lau, A., and Wong, V, n.d.). This technology provides answers to issues related to food safety and quality, which are priorities for both consumers and government agencies. Blockchain makes it possible to record a product's entire value chain, from production to end-of-life, by offering transparency and dependable data collection. Access to trustworthy farming process data is crucial for the development of data-driven facilities and insurance solutions, which in turn makes farming smarter and more resilient.

Blockchain technology offers effective solutions for various aspects of these problems. Firstly, it ensures information security through private key encryption, providing robust authentication requirements and immutable linking of data related to agricultural production processes (Xu et al., 2016). Secondly, in supply chain management, blockchain technology enables more efficient monitoring and lowers signaling costs for each entity involved, including producers, shipping companies, warehouses, and final delivery (Chod et. al, 2019). The blockchain's visibility, validation, automation, and resilience provide advantages in tracking and managing each link of the supply chain (Babich, V., and Hilary, G, 2018). Thirdly, blockchain offers digital payment solutions with low or zero transaction fees, reducing costs and facilitating secure transactions in the agricultural industry. Additionally, the decentralized nature of blockchain ensures transparency and immutability of information, boosting consumer confidence in e-commerce by mitigating issues related to counterfeit products (Karame, 2016). Finally, blockchain technology can significantly reduce transaction costs for small-scale farmers, enabling their participation in the market that traditional e-commerce often excludes.

Blockchain technology offers additional benefits to the supply chain. First off, it improves a company's reputation by lowering marketing risks related to supply chain carelessness, improving data accuracy and public trust, and offering openness about the materials used in products (Iansiti & Lakhani, 2017). Second, supply chain end-to-end tracking is made easier and more precise by blockchain technology. By digitizing physical assets and creating a decentralized, permanent record, organizations can track assets from manufacturing to delivery or end-user use, enhancing supply chain transparency (Sachin et al., 2022). Additionally, blockchain technology improves control over outsourced contract production by providing all parties in a supply chain with access to the same information, reducing misunderstandings and data discrepancies.

This allows for less time spent on data validation and more focus on delivering goods and services, leading to improvements in quality, cost reduction, or both (Sachin Chauhan; Rohit Bansal; Ram Singh, June 2022). Furthermore, blockchain can improve regulatory processes and lower costs by allowing for efficient audits of supply chain data. Manual checks for compliance or credit purposes, which may now take weeks, can be expedited using a distributed ledger including all essential information (Sachin Chauhan; Rohit Bansal; Ram Singh, June 2022).

2.4.1 Permissioned verses Permissionless blockchain

Following the launch and subsequent surge in popularity of Bitcoin, other blockchain systems have been classified as permissioned or permissionless blockchains. A permissionless blockchain network, often called a public blockchain, allows anybody to join and engage anonymously (Zhang, Jian, 2019). Trust among users in this form of network is minimal or non-existent, hence miners are used to validate transactions.

A permissioned blockchain, on the other hand, is a network for a group of identifiable users that operates under a consensus governance model in order to improve transactional trust. Joining this network requires authorization from the majority of private blockchain users on the network (Zhang, Jian, 2019). These networks do away with the need for pricey miners while fostering user confidence. More effective consensus techniques, such the Byzantine fault-tolerant protocol, validate data faster and with less latency in transactions.

2.4.2 Features of Blockchain Technology

Blockchain innovation has numerous interesting highlights that take into account the making of a certain, protected, straightforward, and permanent dispersed record, the center qualities of which are summed up as follows (Zhang, Jian, 2019).

i. Versatile value exchange: Blockchain gives a safe and productive stage for recording the exchanges of licensed innovation rights, the provenance of administrations and merchandise, resource possession, cryptographic money trade, and that's just the beginning.

ii. Distributed governance: A blockchain network isn't constrained by any assigned position, association, or individual, and the requirement for believed go-betweens to check exchanges is disposed of. It is a conveyed information base that gives secure and approved information to all members in the organization at the same time. Hence, there is full straightforwardness along the whole stream of exchanges, and resources and information can be moved between a few associations in a brisk and effective manner.

iii. Decentralized architecture: The ledger is decentralized and put away taking all things together hubs (i.e., singular partner data sets) of the organization, and disappointment of it at a focal infrastructural point is preposterous. Thus, it cultivates a hearty organization that improves the quality, dependability, and accessibility of administrations and data.

iv. Logically centralized: With just a single exchange record imparted to and settled upon by all members, a blockchain network acts like a consistently incorporated framework.

v. Data transparency: Blockchain innovation considers a profoundly straightforward organization that is noticeable to every partner consistently. This drastically lessens the odds of illicit exchanges.

vi. Immutable data: Once a block including several transactions has been added to the chain and confirmed by the consensus, the data that is contained within cannot be altered.

vii. Enhanced data security: Asymmetric cryptography and digital signature techniques are used by blockchain technology to safeguard information and verify identity.

2.4.3 Available Blockchain Platforms

Numerous blockchain platforms exist, with varying consensus techniques, programming languages, and development tools. Body & Adrien, 2020). We'll examine a few important blockchain applications and platforms here.

2.4.3.1 Bitcoin

The most well-known and first blockchain network that facilitates bitcoin transactions. Since its introduction in 2009, it has developed swiftly to become a significant online and offline monetary system. An increasing number of companies have begun to accept Bitcoin as payment since the mid-2010s. As of this writing (Kartsev, 2020), the market worth of Bitcoin was approximately $68 billion. The creation of a new block takes about ten minutes.

2.4.3.2 Ethereum

Ethereum is an open-source blockchain technology that was introduced by Buterin in 2015 and is well-known for its intricate smart contracts for decentralized applications (Dapps). Although Ethereum's main network functions as a public blockchain, its technology also permits the development of private blockchain networks (Buterin, 2015). Majority (*Ethereum Governance | Ethereum.org*, 2021) is one such model and conveys the Ethereum organization to make an undertaking prepared dispersed record and savvy contract stage, the two of which add to quicker handling. In Ethereum's fundamental organization where a greater part of exchanges happens, it requires around 10–15 seconds to make another square (Johnston & Guide, 2018). Nonetheless, the quantity of exchanges prepared each moment is still just about as restricted as Bitcoin.

2.4.3.3 Hyperledger fabric

Hyperledger Fabric is an open-source, private blockchain network designed for enterprise applications. Founded by the Linux Foundation, it is maintained by various organizations (hype, 2020). It utilizes a configurable design that gives different highlights, for example, appropriated record systems, shrewd agreement motors, pluggable agreement conventions, UIs, and that's only the tip of the iceberg. These flexible qualities take into consideration a wide scope of business applications, including money, protection, store network, medical services, and human assets.

2.4.3.4 Skuchain

Skuchain is a blockchain network designed for enterprise supply chains in global trade (Skuchain, 2020). It provides a zero-knowledge collaboration platform for global supply chains, enabling precise inventory control across all partners and reducing friction and costs.

2.4.3.5 Sweetbridge

Sweetbridge is a blockchain-based application that ensures reliable real-time financial transactions between parties. It integrates trusted identification, smart legal contracts, smart accounting, and payment rails into a single, observable transaction for all participants.

2.4.3.6 Zerv network

A decentralized exchange stage dependent on blockchain innovation. It intends to give frictionless exchanges among all members inside the protection business (Danecek & Bonfield, 2021).

2.5 Potential Merits and Demerits of Blockchain Technology Adoption in SCM

2.5.1 Merits of blockchain Technology adoption in Supply Chain Management

Evidence from case studies, interpreted through the theoretical framework, indicates that blockchain technology is likely to provide significant advantages to supply chain management (SCM). With its sophisticated features, blockchain has established itself as a secure, decentralized, and intricate system, enabling data storage with traits such as transparency, anonymity, auditability, immutability, and timestamping. All of these particular characteristics have contributed vital advantages to a sustainable SC. Figure 2.2 shows many of these advantageous features. The blockchain-based solution enhances information sharing across the supply chain, enabling faster and more accurate tracking of products and assets, which improves traceability, trust, and transparency. It maintains a complete audit trail of product movements and financial transactions, reducing fraud and minimizing manual errors. This leads to cost savings, increased efficiency, and greater transparency. According to enterprise management, blockchain can boost business performance, profitability, customer service, and operational integration, while offering a competitive edge. As blockchain technology matures, it is expected to drive further advancements, including process automation, potentially leading to a fully automated, human-free system in the future.

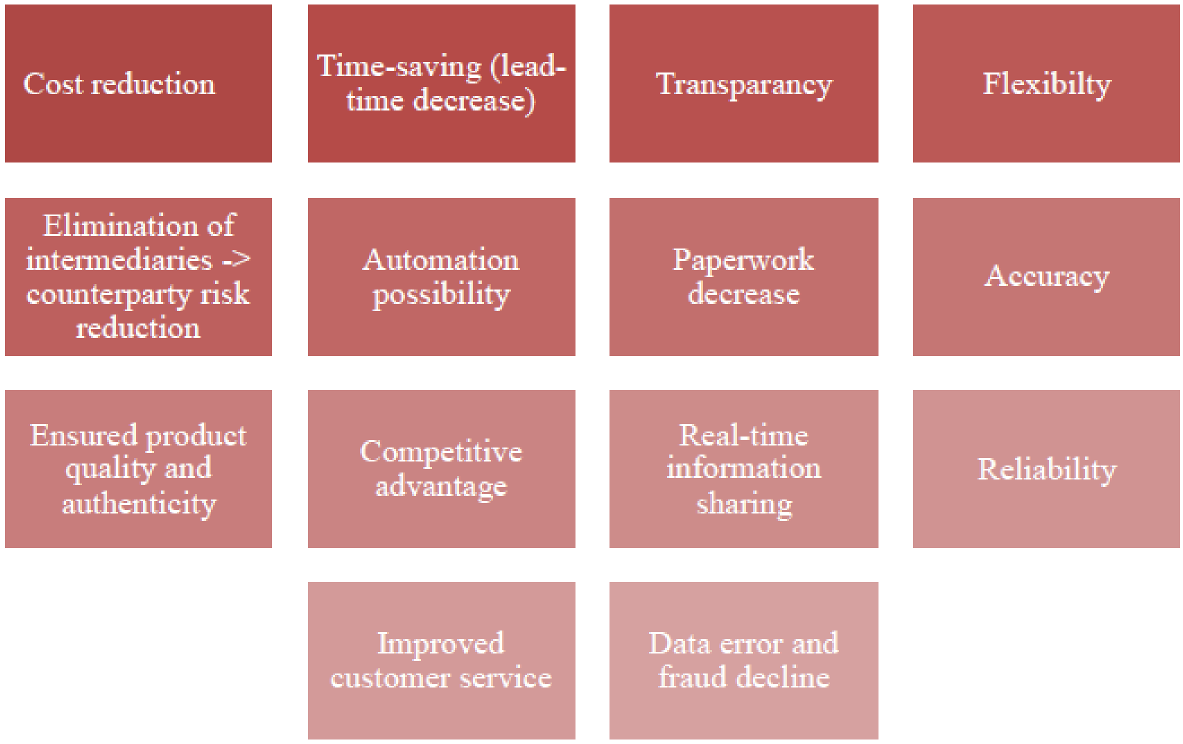


Figure 0.2: Summary on block chain's benefits in SCM: Source: Lee, P. (2018).

Figure 2.2, which summarizes the literature, will provide simple information about the benefits of blockchain adoption in SCM as well as the advantages of blockchain itself.

a) Enhancing Traceability

Lee (2018). The U.S. Medication Supply Chain Security Act of 2013 requires drug organizations to distinguish and follow doctor prescribed medications to shield customers from fake, taken, or hurtful items. Driven by that command, an enormous drug organization in our examination is teaming up with its inventory network accomplices to utilize blockchain for this reason. Medication is tagged with GS1-standard electronic item numbers (Lee, 2018). As each stock unit transitions between enterprises, its tag is logged on the blockchain, creating a comprehensive record of its journey through the network, from origin to final buyerEarly success in the United States has led the organization to expand its pilots and aim for broader implementation in Europe. Meanwhile, IBM is advancing food supply chain security through its IBM Food Trust initiative and has partnered with Walmart to track fresh produce and other food items using blockchain (HBR, 2020).

The benefits are clear. Blockchain allows a company to trace a faulty item through its supply chain, identify all involved suppliers, and evaluate the affected production and shipment batches. For perishable items, blockchain can track quality by recording temperature changes from IoT-enabled devices (HBR, 2020). Furthermore, if there are concerns regarding the legitimacy of an item that a shop returns, the blockchain can allay such fears, as phony items would fail a blockchain check. Companies across industries are considering the use of blockchain, prompted either by regulations requiring them to demonstrate the origin of their products or by downstream clients seeking the ability to track part inventory (HBR, 2020).

b) Increasing efficiency and speed and reducing disruptions.

Emerson, a global assembly and design company, has an unexpected store network. It contains a large number of segments spanning several providers, clients, and geographies. Emerson's chief, Michael Train, told us that such 41 stockpile fasteners usually face long, erratic lead times and a lack of perceivability. As a result, a minor delay or interruption in any portion of the shop network might cause excess stock and stock-outs in different areas. He acknowledges that blockchain technology could help overcome these difficulties (HBR, 2020).

Here's a summary of the issue and how blockchain can help: Item A uses parts C1 and C2, while item B uses C1 and C3. If production of item B is delayed due to a disruption in C3, C1 stock should temporarily be redirected to item A until the issue is resolved. However, if different companies manufacture the items and parts with limited visibility into each other's inventory, excess C1 may accumulate with the maker of item B, even if the maker of item A is out of stock. Blockchain can improve visibility and coordination to prevent such mismatches.

One arrangement is for the organizations being referred to consent to concentrate their information on creation and stock allotment choices in a typical storehouse. In any instance, consider the level of coordination that would require: All sophisticated businesses, whether partners or competitors, must trust one another with their information and acknowledge focused decisions (Zhang, Jian, 2019).

A practical approach involves organizations sharing their inventory data on a blockchain, allowing each to make decisions based on standardized information. They would use a Kanban system for ordering and production management, with Kanban cards linked to digital tokens stored on the blockchain. Emerson is not the only one who thinks blockchain technology might improve supply chain effectiveness. This is also the opinion of international pool equipment maker Hayward. Don Smith, Senior VP of Operations at Hayward, claims that blockchain technology may make it possible to consider raw materials, work-in-progress, capacity, and completed goods as digital assets. This strategy would make it possible to precisely track inventory and machine time, avoiding the double-spend problem where resources can be inadvertently assigned to several orders (HBR, 2020). Walmart Canada has implemented blockchain with its shipping partners to synchronize data, track shipments, and automate payments, requiring minimal changes to the firms' existing systems. Blockchain's appeal for enhancing supply chain efficiency lies in its ability to improve visibility while sharing only essential data, making it effective across large organizations with different ERP systems.

c) Enhancing international interactions, contracting, and finance.

Businesses can achieve significant benefits in supply chain financing, contracting, and international commerce when they share inventory, information, and financial flows via blockchain (HBR, 2020). Consider the financial challenge where banks providing working capital and trade credit face information asymmetry about borrowers' businesses, assets, and liabilities. For instance, a company might secure loans from multiple banks using the same asset or use funds for unintended purposes. Banks design their processes to mitigate these risks, which increases transaction costs, limits capital access, and reduces available funding for small firms, ultimately harming both banks and businesses seeking affordable working capital (HBR, 2020).

d) Tracing counterfeits using the blockchain trail.

Cross-border transactions, involving physical papers, many intermediaries, manual processes, and frequent inspections and verifications at entrance and exit ports, constitute a third area of risk. These transactions are expensive and have little visibility into the status of shipments. Retail and financial services companies are exploring blockchain pilots or platforms to address these issues. Blockchain can streamline order processing, invoicing, and payments by integrating inventory, data, and financial flows, and making them accessible to all parties. When a supplier receives an order, a blockchain-enabled account can quickly provide operating cash, and payments can be made to the bank immediately upon delivery. The availability of an audit trail and automated settlements through smart contracts reduce disputes between banks and purchasing firms (Dutta, Choi, Somani, & Butala, 2020).

e) Creating a Workable Technology

The firms we examined found that applying blockchain to inventory networks requires new concepts, as supply chain needs differ from those of digital currency networks. The Bitcoin blockchain provides a robust, permanent record of transactions, prevents double-spending, and proves ownership without central authority, while allowing participants to remain anonymous and join or leave freely. However, this system sacrifices speed, consumes substantial energy for mining, and is vulnerable to hacking (HBR, 2020).

f) Known participants.

Private blockchains between known parties are what supply chains require instead of public blockchains with anonymous users. At every level, every inventory unit needs to be firmly connected to its owner, allowing only those who are permitted to participate. This setup requires selective permission for joining the blockchain to protect data privacy (Zhang, Jian, 2019). Public blockchains expose all transaction data to every participant, which could lead to misuse of sensitive information. Thus, participants must be verified and authorized (Dutta, Choi, Somani, & Butala, 2020).

Building trust among partners for blockchain information sharing involves several challenges. Key issues include establishing governance rules for network access, data sharing, encryption, dispute resolution, and the integration of IoT and smart contracts. Another challenge is assessing how blockchain transparency might affect pricing and inventory decisions, as the impact on costs and benefits is uncertain.

Consequently, organizations are focusing on specific applications like tracking medications and managing accounts payable, which have well-defined use cases and regulatory requirements. By limiting the data recorded on the blockchain, firms aim to enhance data security and ensure easier acceptance among supply chain partners (Bertrand et al., May 2020).

g) Simpler consensus protocols.

Blockchain requires a consensus protocol to maintain a unified transaction history. In cryptocurrency networks, this is achieved through proof of work, which ensures network-wide approval of transactions but slows down the creation of new blocks. This approach is inadequate for the high transaction volume in supply chains (Zhang, Jian, 2019).

For example, the U.S. pharmaceutical industry processes 4 billion marketable units annually, while Bitcoin handles only about 360,000 transactions per day (Gaur & Gaiha, 2020). In contrast, private, permissioned blockchains do not need proof of work. Instead, simpler consensus methods, such as rotational protocols among known participants, can be used. This approach reduces the risk of malicious activities and facilitates easier resolution of disputes by validating previous blocks (Gaur & Gaiha, 2020).

h) Security of Physical Assets

Even with secure blockchain records, there is still a risk of tainted or counterfeit products entering the supply chain due to errors or malicious actions, as well as inaccuracies from scanning and data entry mistakes. To address these issues, organizations are implementing three strategies: First, rigorous physical inspections ensure shipments match blockchain data. Second, decentralized applications (dApps) track items, verify accuracy, and prevent errors. If issues arise, blockchain traceability identifies the source. Third, IoT devices and sensors automatically update the blockchain, minimizing human error (Gaur & Gaiha, 2020). Tokenization enhances trust and security in trading digital assets such as e-books and music. By linking ownership to a blockchain, counterfeiting can be eliminated. For instance, integrating digital reading materials into a blockchain with smart contracts could significantly improve efficiency, allowing for easier access, ownership verification, and payment processing.

2.5.2 Pitfalls and Challenges of Blockchain Adoption in SCM

As stated in the literature, figure 2.3 depicts the key disadvantages of blockchain and the problems of implementing blockchain in SCM. According to the literature examined, the challenges of applying blockchain technology in SCM may be divided into three kinds of challenges: technology, government and company. Figure 2.3 shows the list of challenges. First, the limitations of blockchain technology may stem from its limited maturity, scalability, and complexity.

Second, in terms of company obstacles, the high cost of adoption appears to be the most significant challenge, whilst enterprises cannot be guaranteed a solid return on investment due to a lack of successful instances. Furthermore, inter-organizational barriers resulting from collaborative efforts, reluctance to change management systems, and a lack of skilled workforces all have a detrimental impact on blockchain technology adoption.

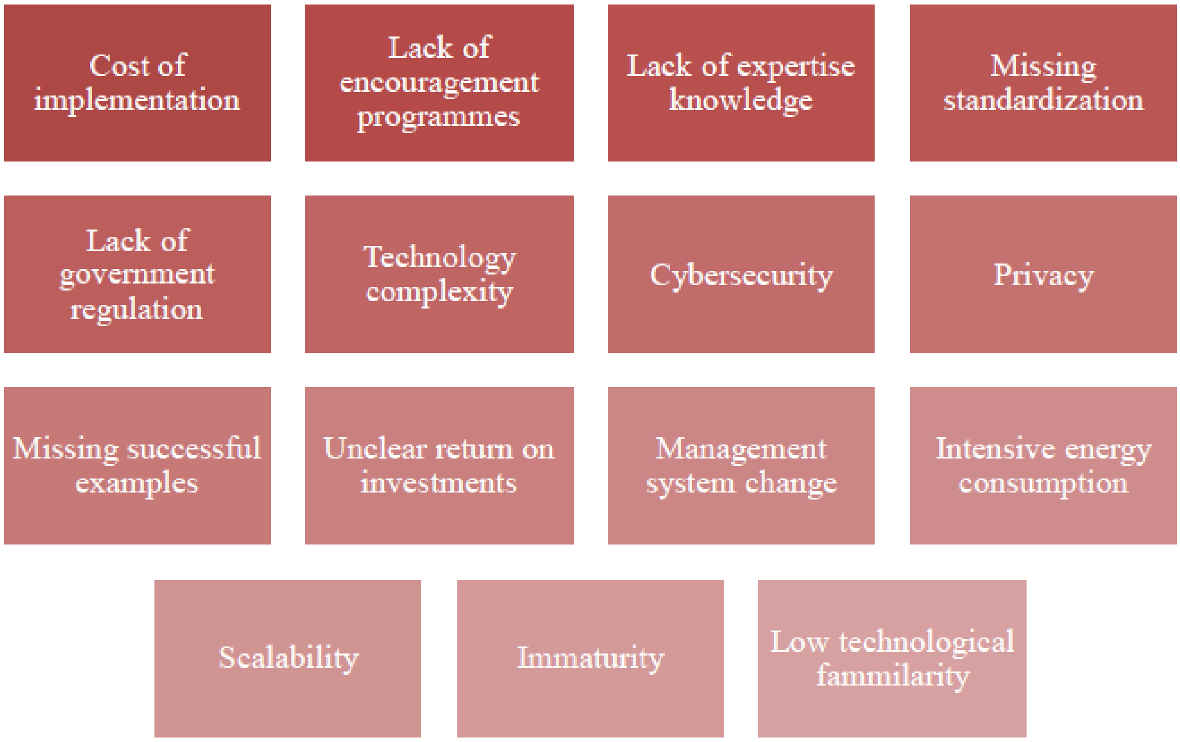


Figure 0.3: Summary on block chain's pitfalls and challenges of its adoption in SCM: Source Yiannas, 2018

Blockchain appears to be a promising technology that has the potential to alter the food supply chain by increasing efficiency and eliminating risks. More pilot tests were conducted and got excellent feedback (Yiannas, 2018; CBH Group, 2017). However, it is evident that blockchain is still in its infancy and has a long way to go before becoming extensively used. Based on our review, several academics have identified a few issues that must be solved. Some of these are explored briefly in the paragraphs that follow.

Companies lack a deep understanding and knowledge of blockchain technology.

The first challenge is introducing blockchain to the public. Many professionals in supply chain management still struggle to fully grasp its potential (Zhao & Liu, 2019; Hackius & Petersen, 2017; Kamilaris & Boldú, 2018). Understanding technology significantly affects participants' attitudes, with those more knowledgeable being more positive about blockchain adoption (Hackius & Petersen, 2017).

Recent pilot projects reveal a persistent lack of understanding of blockchain's capabilities. For instance, Verhoeven et al. (Verhoeven & Sinn, 2018) found that some companies adopted blockchain without first diagnosing their issues. In Walmart's mango tracing pilot, the speed improvement was due to the removal of manual validation, not blockchain itself, and the study overlooked the importance of immutable records for ensuring food quality. Leong et al. (Gong & Brown, 2023) noted that technology needs can vary by supply chain stage, highlighting the importance of evaluating both costs and benefits to find the most effective solution, as other technologies might be better suited (Verhoeven & Sinn, 2018; Gong & Brown, 2023).

2.5.3 Technology Scalability Issue

The second difficulty is blockchain scalability, often known as the "scalability trilemma" by Ethereum's founder, Vitali Buterin (Perboli and Musso, 2018). He argues that it's challenging to achieve decentralization, scalability, and security simultaneously; typically, only two of these three can be realized at once (Perboli & Musso, 2018; Ometoruwa, 2020). For instance, Bitcoin was designed to be decentralized and secure but sacrificed scalability.

Scalability refers to the network's ability to handle increasing capacities. Currently, Ethereum, a smart contract platform, processes 15 transactions per second, whereas Visa can handle 45,000 transactions per second (Hillman & McKie, 2019). Blockchain achieves high decentralization and security through complex mining processes that validate transactions and store copies on each node. However, this approach can slow down validation, particularly during high transaction volumes. Thus, while enhanced scalability might raise security risks, limited scalability can lead to transaction congestion and reduced network efficiency.

The global food supply chain is vast, handling up to petabytes of data annually (Pearson & May, 2019). As a result, developers are focused on improving blockchain scalability without compromising security and decentralization. Pearson and May predict that blockchain will be more effectively implemented in niche areas of the food supply chain, like organic products, where its benefits are most needed due to scalability issues.

2.5.4 Raw Data Manipulation before Uploading to Blockchain

There is a risk of intentionally destroying products without informing blockchain users (Kshetri, 2018). To ensure data integrity, third parties such as governments and certification bodies can join the blockchain network for regular audits (Tian, 2017; Gong & Brown, 2023). Additionally, immutable records can encourage suppliers to provide accurate data and be accountable for their products.

2.5.5 Challenge of Stakeholders Involvement for Blockchain Adoption in the Food Supply Chain

Blockchain requires all supply chain stakeholders, from raw material suppliers to customers, to participate by registering as authorized users. This allows them to upload data, check transactions, and access historical records, improving transparency and efficiency. However, varying levels of awareness and infrastructure can pose challenges, especially for SMEs and developing countries, where implementation costs may be prohibitive (Kamilaris & Boldú, 2018; Gong & Brown, 2023; Perboli & Musso, 2018; Pearson & May, 2019). Kamilaris and Boldú (2018) note that most blockchain projects are in developed countries. Therefore, making blockchain accessible for SMEs—with low costs and ease of implementation—is crucial. Perboli and Musso

(2018) proposed a Hyperledger Fabric-based model, suggesting that partial blockchain adoption could be more cost-effective than a full system replacement.

2.5.6 Regulations/Laws Need to Be Updated

Blockchain's open database nature requires policies to protect users' rights and confidential information. Tse et al. (2017) applied PEST analysis to explore the political, economic, social, and technological factors affecting blockchain adoption. Their study highlights that blockchain could enhance governmental access to supply chain data and mitigate food safety risks. Some countries and organizations, such as China with its Blockchain White Book, are actively supporting blockchain initiatives. ISO Blockchain (TC307) is also working on establishing global standards (Pearson & May, 2019). However, comprehensive regulations for blockchain in the food supply chain are still lacking. Leong et al. (2023) and Pearson et al. (2019) advocate for the development of regulations to manage data handling and ownership. Kamilaris et al. argue that the absence of such policies may hinder widespread blockchain adoption, emphasizing the need for clear standards before broad implementation can occur.

2.6 Pilot Initiatives of Blockchain Technology

Walmart and IBM have been testing a blockchain-based system to track fruit in the United States and pork in China since late 2016. This system records each product’s origin, storage temperature, and serial number, significantly speeding up the identification and recall of contaminated items. Walmart reported that blockchain enabled them to trace Chinese pork and U.S. mangoes in just 2.2 seconds, compared to weeks with traditional methods (Hype, 2020; Zhang, 2020).

Intel also explored blockchain for seafood traceability, aiming to track conditions like temperature from the ocean to the consumer. Public documents on the Traceability Blockchain website outline how blockchain can collect and manage seafood data, enhancing transparency and safety across the supply chain (Zhang, Jian, 2019).

In 2018, Maouchi introduced TRADE, a blockchain-based traceability system that supports product tracking across the supply chain and allows users to verify product data. Testing showed that TRADE can handle approximately 351 transactions per second, with 437 validations per second (Maouchi et al., 2018).

Since August 2018, IBM and Maersk (the world's biggest transportation organization) have collaborated to make TradeLens, a blockchain-based framework for the worldwide inventory network. TradeLens plans to make a stage for various exchange gatherings to safely share data sets containing monstrous measures of value-based data, and to construct a more community climate for worldwide exchange. This framework is an integral asset for setting up a solitary and reliable shared status of each transaction (IBM, 2017).

In close to continuous while keeping up partner classification. Reports show that Trade Lens altogether diminished deferrals brought about by documentation blunders and decreased the travel time related with transportation bundling raw blocks to produces in the United States up to 70% (Zhang, Jian, 2019).

2.7 Blockchain Based Smart Contracts

Smart contracts are automated programs that use software and blockchain technology to enforce and execute contract terms. Introduced by Mentzer et al.(2020) and initially applied in banking, these contracts operate as decentralized applications on the blockchain. They are immutable and cryptographically secure, allowing for peer-to-peer execution without central authority. Unlike traditional paper contracts, smart contracts self-execute based on predefined conditions, leveraging blockchain's features for various applications.

2.7.1 Elimination of Trusted Third Party

Blockchain enables smart contracts to run autonomously through decentralized nodes, removing the need for a central authority. This decentralization mitigates single points of failure and reduces data consumption and latency compared to centralized systems. It also enhances transparency by eliminating centralized "Black Box" operations and ensuring accountability among all participants (Hewa, Ylianttila, & Liyanage, 2021).

2.7.2 Forge Resistance

Blockchain's integrity is maintained through cryptographic validation of each transaction and block. This resistance to tampering is a crucial feature of blockchain technology, ensuring that transaction records and execution logic remain immutable and trustworthy (Hussain, Adedoyin, & Al-Turjman, 2021).

2.7.3 Transparency

The major benefit of smart contracts based on blockchain is transaction transparency. The smart contract logic, as well as blockchain ledger, are accessible to everyone in the blockchain ecosystem. This is one of the differences between blockchain and centralized databases, which is caused by this transparency (Kanchan et al., 2019).

2.7.4 Autonomous Execution

The execution state and chain of events are activated when the blockchain system is in the particular state. This activation state is characterized by the smart contract when all parties in the blockchain network fulfilled it. It is likely to be any situation such as a decline in assets, when a hub reaches a certain geological zone or framework receives an installment. The massive element is that the performance is programmed and activated on a condition of the friend without mediating a integrated outsider. The assistance availability is guaranteed because the practice does not require a focused outsider (Belonick, 2019).

2.7.5 Accuracy

The modified conditions in the keen agreements are permanent and confirmed before the arrangement in hubs in the blockchain network. The execution is programmed once the condition is met. The exactness is ensured with no human or some other mistake on the execution. The self- sufficient exact execution wipes out the one-sided activity and improves the trust through straightforward precise execution (Copigneaux, Vlasov, & Bani, 2020)

2.8 Blockchain technology in Practice

Supply chain management innovations powered by blockchain can dramatically increase business value by lowering risk, boosting transparency, and improving management efficiency (HBR, 2020). Despite only being around for ten years, blockchain's distinctive qualities—like decentralization—have allowed it to grow beyond Bitcoin and become a game-changing technology with a wide range of uses. Blockchains are very useful for a variety of non-financial industries since they are excellent at documenting ownership histories.

2.8.1 Blockchain Technology in Financial Services

Bitcoin, the first blockchain implementation, led to significant experimentation, especially in finance. In 2015, Nasdaq and OMX Group partnered with Chain to explore blockchain for share trading. Visa Europe, Commonwealth Bank of Australia, and several UK banks have also developed blockchain proof-of-concepts (Laaper et al., 2019).

As blockchain's popularity grows, its applications extend beyond finance. Provenance tracked responsible tuna sourcing in Indonesia with blockchain, while Monegraph uses blockchain to manage digital content rights and revenue sharing. Skuchain offers blockchain-based B2B trade and supply chain finance products (Laaper et al., 2019).

In finance, blockchain addresses transparency, security, and efficiency issues. For cross-border payments, Ripple facilitates faster and cost-effective transactions with its protocol (Ripple, n.d.), and Stellar offers low-cost remittances through its platform (Stellar, n.d.). In asset management, blockchain enables fractional ownership and automated compliance through platforms like Polymath and Harbor (Polymath, n.d.; Harbor, n.d.). These examples highlight solving kchain's potential to revolutionize financial processes and solve longstanding challenges.

2.8.2 Blockchain Technology in Healthcare

In healthcare, blockchain offers solutions for interoperability, data security, and patient consent management. Medical Record Sharing: Blockchain can enable secure and efficient medical record sharing, allowing providers seamless access to patient data while maintaining privacy. For example, MedRec uses blockchain's immutability to create a tamper-resistant ledger for medical records, giving patients control over their data and access permissions (Azaria et al., 2016).

Secure Health Data Management: Blockchain can also enhance health data security by providing a transparent, tamper-proof system for data storage and management. Coral Health leverages blockchain to ensure secure storage, sharing, and access control, in compliance with privacy regulations like HIPAA (Coral Health, n.d.) These examples show blockchain's potential to improve data interoperability, security, and patient consent management in healthcare.

2.8.3 Supply Chain Management and the Blockchain Technology

In supply chain management, blockchain technology has attracted significant attention for its potential to enhance transparency, traceability, and trust among participants. This section provides additional details and examples of blockchain applications in supply chain management. Product Authenticity and Traceability: Blockchain allows for the construction of a transparent and immutable record of a product's path within supply chain, ensuring traceability and authenticity. IBM's Food Trust is a platform designed to improve traceability and transparency in the blockchain component throughout the food supply chain (IBM, n.d.). It allows participants to track and trace food goods from farm to shop, protecting the supply chain and enhancing food safety. Everledger is another blockchain network that tracks and authenticates diamonds, confirming their provenance and lowering the risk of fraud in the diamond supply chain.

Supply Chain Efficiency and Transparency: This can provide end-to-end visibility of products, enabling stakeholders to track and monitor goods at every stage of the supply chain. This enhanced transparency helps identify inefficiencies, reduce delays, and optimize inventory management. VeChain, a blockchain platform, offers supply chain solutions that allow businesses to track products, verify authenticity, and ensure quality control (VeChain, n.d.). It uses blockchain technology to provide a secure and transparent system for supply chain management.

These examples highlight how blockchain technology is being used in supply chain management to improve transparency, traceability, and efficiency. By leveraging blockchain's capabilities, these platforms aim to build trust among supply chain participants and ensure the authenticity and integrity of products throughout the supply chain.

2.8.4 Blockchain Technology in the Agricultural Sector

Agricultural sector in Africa has effectively seen the beginning of blockchain based arrangements being presented on the lookout. Existing tech players and arising new companies have created blockchain arrangements, like eMarket places, horticultural credit/financing stages, and harvest protection administrations (EOS, 2020). Organizations, internationally just as inside Africa, are tackling uses of blockchain to create imaginative arrangements focused at key partners across the food esteem chain.

In 2017, Bext360, in collaboration with Coda Coffee and Great Lakes Coffee, launched a trial to track espresso beans from East Uganda. They developed a machine that assesses the beans and sends data via a blockchain-based SaaS platform. This system enables customers to trace the beans' journey and facilitates payments to farmers through tokens based on their output (Vu & Kim, 2018).

In 2017, Moyee Coffee, based in Amsterdam, partnered with blockchain firm KrypC to create coffee traceable through blockchain. Beans are sourced from Ethiopian farmers, roasted locally, and then exported to the Netherlands. This transparency helps trace any foodborne illnesses and allows consumers to know the origins of their food ingredients (EOS, 2020).

This element of blockchain likewise empowers formation of a straightforward climate where organizations can follow the creation and excursion of farming items across their production network. Straightforwardness across the production network makes trust among ranchers and purchasers, and the improved perceivability of costs further down the worth chain likewise empowers ranchers to improve an incentive for their produce.

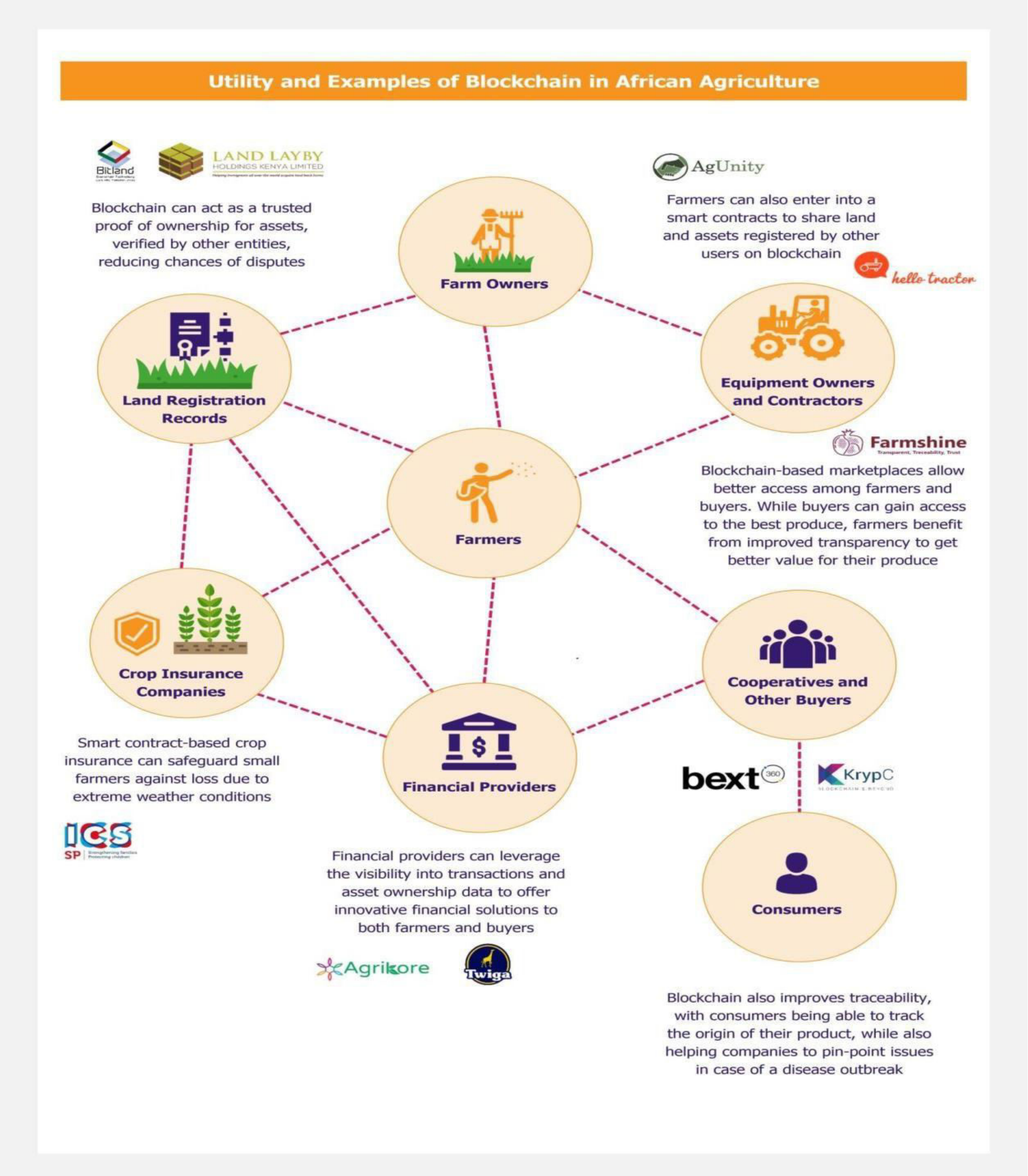


Figure 0.4: Utility and Examples of Blockchain in Africa Agriculture

Source: (Tapscott & Tapscott, 2016)

2.8.5 Blockchain-based platforms to improve farmer and buyer collaboration.

Blockchain can likewise go about as a stage to interface ranchers with sellers, food handling, and bundling organizations, giving a safe and confided in climate to the two purchasers and providers to execute without the need of a broker. This additionally brings about disposal of edges that should be paid to these go-betweens, and improves the edges for purchasers (Kumar & Singh, 2020)

Farmshine, a Kenyan startup, developed a blockchain platform to enhance trade collaboration among farmers, buyers, and service providers in Kenya. In January 2020, the company secured $250,000 from Gray Matters Capital to support its planned expansion into Malawi. These blockchain stages can likewise be utilized to associate ranchers to different ranchers, for exercises, for example, resource or land sharing, bringing about more productivity in affordable cultivating tasks. Blockchain stage can likewise empower little ranchers to rent inactive homesteads from their companions, in this manner furnishing them with admittance to extra income sources, which they would not have the option to do generally.

Hello Tractor, a Nigerian start-up, leverages International Business Machines Corporation (IBM) blockchain technology to allow small farmers in Nigeria who cannot afford their own tractors lease idle machines from owners and contractors at inexpensive pricing via a smartphone application.

2.8.5.1 Improving mobile internet access to boost blockchain implementation

While blockchain can possibly change horticulture in Africa, its execution is restricted by the absence of versatile/web access and specialized ability among little ranchers.

Starting at 2018, versatile web had infiltrated just 23% of the complete populace in Sub-Saharan Africa (Torresen, 2020).

Still, the GSM Association projects a significant improvement in portable web penetration over the next five years, reaching approximately 39% by 2025. To assist farmers, engage with blockchain solutions, additional internet providers must be admitted, which will accelerate the creation and implementation of more blockchain-based agricultural solutions (EOS, 2020).

2.8.5.2 Establishing trust

Establishing trust among all members is critical to the smooth operation of the production network. In a Blockchain, each member has a duplicate of a record and understands where everything began. Everyone approaches data based on who previously held it and when (Application, 2018). Nestle, a well-known global company, is an amazing example of Blockchain in a food inventory network. Blockchain is currently being used to track the origin of food ingredients in a variety of products. However, Blockchain allows customers to see the origin of products – from the source to the point of use, if permitted. It establishes trust between an intended interest group and a brand.

2.8.5.3 Consensus and permission

Blockchain is commonly defined as "one version of the truth" for each product. It is a record-keeping system designed to collect proof of financial transactions such as bills of lading and money transfers. The system tracks every supply chain step—serialization, shipping, reception, and installation—automatically, based on trust, transparency, and auditability. All participants access the same information

(Krishnamani, 2019). Any attempt at fraud causes a participant to be out of sync with the system and marked as a threat, serving as a strong deterrent to malicious activities.

2.8.5.4 Monitoring of product conditions

A few sorts of items, similar to food or drugs, are vulnerable and have explicit requirements. The item stockpiling conditions, like temperature, dampness, or vibration, can be recorded by sensors and put away on a Blockchain. In the event that one of the boundaries veers off from a standard, it will be promptly followed by the Blockchain members. For this situation, a brilliant agreement can consequently take care of an issue by setting off required activities.

These days, organizations effectively use Radio Frequency Identification (RFID) labels to store data about items in supply chains. Normally, they are naturally handled by IT frameworks and utilized for keen agreements in coordination's. RFID-labels for containers or beds safeguard data about the area and date of conveyance. Coordination's accomplices utilize explicit applications to look for these labels and offer for a conveyance contract. The accomplice offering ideal cost and administration acquires an arrangement. After this, a keen agreement can screen the status and last conveyance execution.

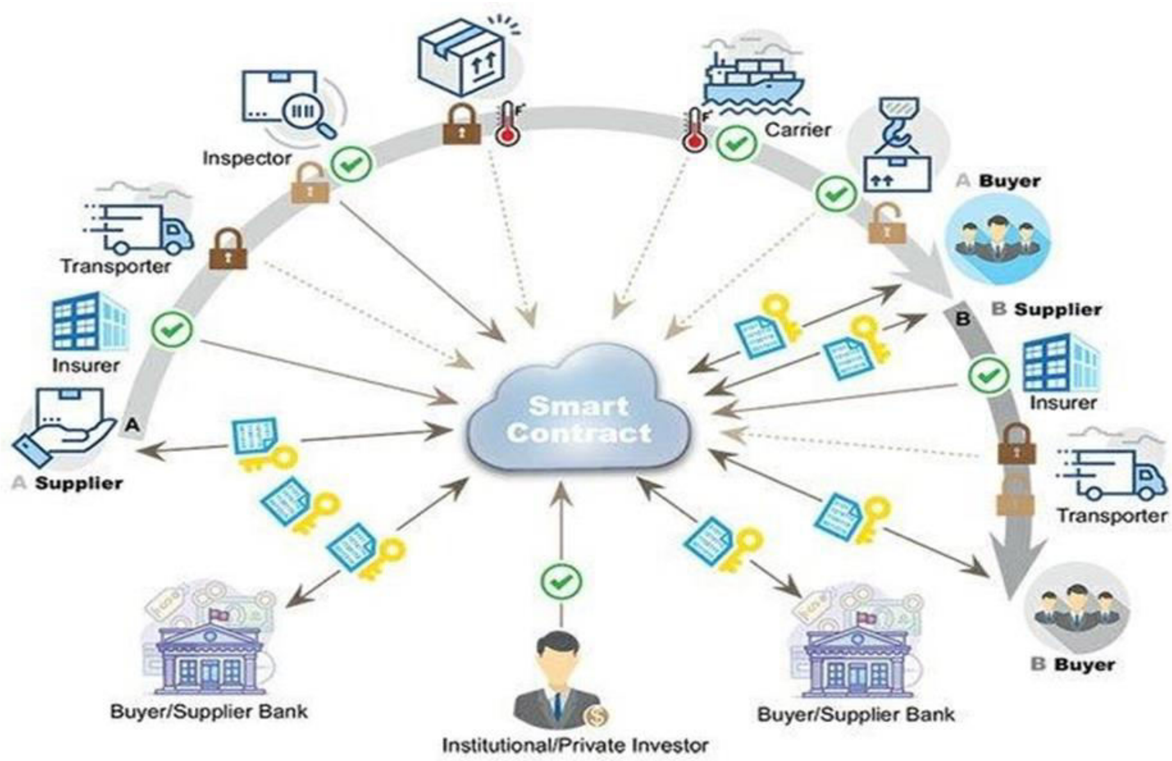


Figure 0.5: Blockchain Supply Chain Model.

Source: (Snell, 2018)

To accomplish this, extra verification (V2) is required. The combination of blockchain and a V2 smart contract provides complete traceability, transparency, and the ability to express gateway requirements across the commercial process from bush to cup. This overly simplified assertion requires more than just a gorgeous infographic to gain the support of jaded tea farmers, producers, and those farther up the chain (Snell, 2018). Blockchain is not easy to deploy or integrate into existing systems. There are numerous options available, and not all of them are the same.

At the highest level, you can choose between public, consortium, and private blockchains, which are simply defined as: everyone can see and use it (as with Bitcoin). A select set of organizations or individuals may utilize it (reflecting the realities of our trade), or only those within a corporation or single group (appropriate for a complex internal structure, such as a bank). A supply chain consortium comprised of manufacturers, exporters, importers, packers, retailers, certifiers, and banks. They were picked because they are all involved in the supply chain from "origin x" to a consuming country.

How about we expect that we are signatories to the update of comprehension (MoU) professionally wage, an activity trying to raise tea laborer income. Presently, the strategy for guaranteeing this includes numerous means and a great deal of trust. A checked expense of creation should be discovered and the extent of this, paid for work, should be affirmed. The hole between current compensation rates and the living pay should then be determined and the distinction applied to a recipe to characterize a base value, ex-manufacturing plant, for a specific tea (Snell, 2018).

This necessitates that the maker be transparent about his evaluation creation, his return from each evaluation/month (as irregularity and request factor into return), his acquisition rates, and his information expenses (field and production line). Further upstream, it requires the exporter to demonstrate operating costs, containerization, transportation, legal charges, and overheads (which may include processing prior to export).

To comply with increasingly stringent US Department of Agriculture Food Safety Modernization Act (FSMA) rules, the packer may be required to do chemical residue analysis and micro testing before to shipment. These are charges that few downstream understand to be valid. The importer will require access to the paperwork in order to customs clear the goods and perhaps incur additional expenses at the destination port. The importer may deliver the goods and finance them for a period of time at a finance rate that is not available or disclosed along the supply chain.

The packer/seller of this tea incurs a variety of costs, including packaging materials, fixed costs, packing charges, sales costs, and general and administrative costs (SG&A), to name a few. As a branded corporation, advertising costs and returns to shareholders are non-negotiable.

All of these are commercial realities; no one says they can be avoided; but, communicating them as transaction requirements from farmer to consumer fosters acknowledgment and trust, which are the pillars of meaningful cooperation. If that is all blockchain can achieve for the tea industry, the writer believes it is sufficient to make the sector healthier and more efficient (Snell, 2018).

2.9 Advancements of Smart Contracts in the Agricultural Sector

A smart contract is a self-executing system defined by clear terms, stored and executed on a blockchain (Chege et al., 2017). Parties must first agree on the contract's terms, which are then encoded into the blockchain. Smart contracts facilitate reliable transactions without intermediaries (Diannah & Joseph, 2012). They operate autonomously, executing automatically when preset conditions are met, according to their programmed rules (Adrien, 2020).

Shrewd agreements comprise of various fundamental parts: signatories, subject and explicit terms. Above all else, the signatories for example at least two gatherings that utilize the shrewd agreement and give their last 'go ahead' with respect to the proposed terms by means of their advanced mark. Second the understanding's subject itself that is restricted distinctly inside the shrewd agreement's current circumstance. Third the particular terms of the savvy contract. They must be depicted in point-by-point numerical terms and carried out in a programming language that is viable with the shrewd agreement's blockchain. In light of these terms, the agreement will execute itself (Carlo, 2020).

Smart contracts have three key components: signatories, subject matter, and specific terms. First, signatories are the parties involved who approve the contract with their digital signatures. Second, the subject matter is confined to the scope defined within the smart contract. Third, the specific terms are detailed in a programming language compatible with the blockchain, dictating how the contract will execute automatically based on these conditions (Carlo, 2020). A shrewd agreement additionally contains data about which members can follow up on a particular kind of information. For example, a transporter can't enlist a thing chronic number befuddle, while a collector can.

An incredible illustration of brilliant agreement utilization is Transactive Grid. This Blockchain- based application targets following and rearranging power from sunlight-based boards in an area. An application permits mechanizing the way toward purchasing selling of sunlight-based energy. The framework is made on Ethereum, which is generally utilized for building brilliant contracts (Chol et. al, 2021).

Under 3% of little ranchers in sub-Saharan Africa have sufficient admittance to agrarian protection inclusion, which leaves them powerless against unfavorable climatic circumstances like dry spells. Savvy contracts dependent on blockchain can likewise be utilized to give crop-protection, which can be set off given certain set conditions are met, empowering ranchers to get their homesteads and family work if there should be an occurrence of outrageous climatic occasions like floods or dry seasons.

SmartCrop, an Android-based versatile stage, gives reasonable harvest protection to in excess of 20,000 little homesteads in Ghana, Kenya, and Uganda through blockchain-based shrewd agreements, which are set off dependent on savvy climate expectations.

Following of resources, (for example, land vaults) and exchanges on the blockchain can likewise be utilized to check the ranchers' set of experiences, which can be utilized by elective financing organizations to offer advances or credits to ranchers – for example in situations when ranchers can't get such financing from conventional banks – changing the banking and monetary administrations accessible to ranchers.

2.10 Blockchain Advancements and Applications in Kenya

The blockchain technology is a groundbreaking innovation that can be used to revolutionize industries all over the world by improving the level of security, efficiency, and trust in online transactions. It has a decentralized and transparent structure due to its distributed ledger system, as the data is kept in several nodes, which guarantee its transparency and immutability. The verification of transactions is done by consensus mechanism, which removes the intermediates and peers with each other. This discussion paper will discuss the importance of studying blockchain development and usage in the socio-economic and technology landscape of Kenya.

The technology became popular with the introduction of Bitcoin, the first successful application of blockchain, and has since been developed to be applied in other fields other than cryptocurrencies. There is an increasing number of organizations and industries in Kenya that find the potential of blockchain technology to cope with the different challenges and innovate. In order to investigate this issue, the literature review is carried out to emphasize the developments and use of blockchain in Kenya.

A number of researches have studied the application of blockchain technology in the Kenyan financial services industry. As an example, (Ondieki & Waiganjo, 2019) explained that digital currencies and cross-border remittances using blockchain can drive financial inclusion and lower the cost of transactions. Also, Oduor et al. (2020)

examined how blockchain can be used in decentralized finance (DeFi) and why it can be beneficial to the Kenyan financial ecosystem (Oduor et al, 2020). BitPesa is a blockchain payment network operating on blockchain technology using the blockchain to facilitate fast and inexpensive cross-border payment between Kenya and abroad with the help of blockchain technology and safe and transparent transactions.

Blockchain technology has been promising in the management of land and properties concerning problems of transparency, efficiency, and fraud. Land Title Registration: Kenyan government has been considering exploiting blockchain technology in land title registration in an effort to curb land sector fraud and corruption. The system will be more transparent, secure, and inaccessible to manipulation by recording land transactions in a blockchain, decreasing the chances of a land dispute and enhancing the confidence in property rights. Gatimu and Mureithi (2019) considered the possibility of using blockchain to improve transparency and streamline property transactions in land registries in Kenya. Likewise, Ochieng et al. (2021) evaluated the possibilities of blockchain in the management of land titles in Kenya in a transparent, safe, and reliable way.

Another sphere in which blockchain has become popular in Kenya is supply chain management. The researchers like Misiko et al. (2019) have discussed the opportunities of blockchain in the supply chain traceability and emphasize how it can improve transparency and eliminate fraud in the Kenyan agricultural industry (Misiko et al, 2019). Trade finance using blockchain and digitalization of processes along the supply chain are also explored (Ouma et al, 2020).

In healthcare, blockchain has the potential to transform health records management and enhance patient privacy and data security. Health Information Exchange: Kenya's

Ministry of Health has been exploring blockchain technology to enhance the sharing of medical data and improve healthcare services. This enables better coordination of care and more accurate diagnoses. The work of Kariuki et al. (2018) discussed the benefits of blockchain in health information exchange and interoperability, improving access to quality healthcare services in Kenya (Kariuki et al, 2018). Additionally, Mucheru et al. (2021) examined the application of blockchain in drug traceability to combat counterfeit medicines in the Kenyan pharmaceutical sector (Mucheru et al, 2021).

Ubrica is a Kenyan-based company that utilizes blockchain technology to empower patients to have ownership and control over their health records. Through their platform, individuals can securely store and share their medical data with healthcare providers, facilitating better healthcare decision-making and continuity of care.

Blockchain's potential impact on social impact and governance in Kenya has also been explored. Studies such as Kibari et al. (2019) discussed the use of blockchain in voting systems to ensure transparency and prevent electoral fraud (Kibari et. Al, 2019). Additionally, researchers have investigated how blockchain technology can enhance accountability and transparency in government operations and public service delivery (Obonyo et. al, 2020).

The achievements of blockchain on Kenya's agriculture sector has also been investigated. Rambim and Awuor (2020) proposed a farmer-centric blockchain-based network to safeguard farmers from predatory and unscrupulous intermediaries in the milk supply chain that exploit illiterate and ignorant farmers. . MDBM is built as a permissioned blockchain managed by a consortium composed representatives from both the dairy farmers and the NADAFA, and representatives from the cooperative's society of Kenya and the milk product manufacturers. The role of the consortium is to validate the users and blocks created in the network. The members elect their representative to this consortium. This paper assumes that members are intrinsically motivated to join the platform due to inherent benefits and that the consortium members are also intrinsically motivated to work together on creating and maintaining the platform.

In this regards, MDBM can be used as a promissory note or a collateral by smallholder famers who may not be able to prove their credit worthiness to qualify for a credit service. This approach also works towards improving milk quality delivered as the payment to the farmer could be pegged on the quality of milk delivered. This, therefore, would be an incentive to ensure that famers work towards delivering quality milk to the NADAFA.

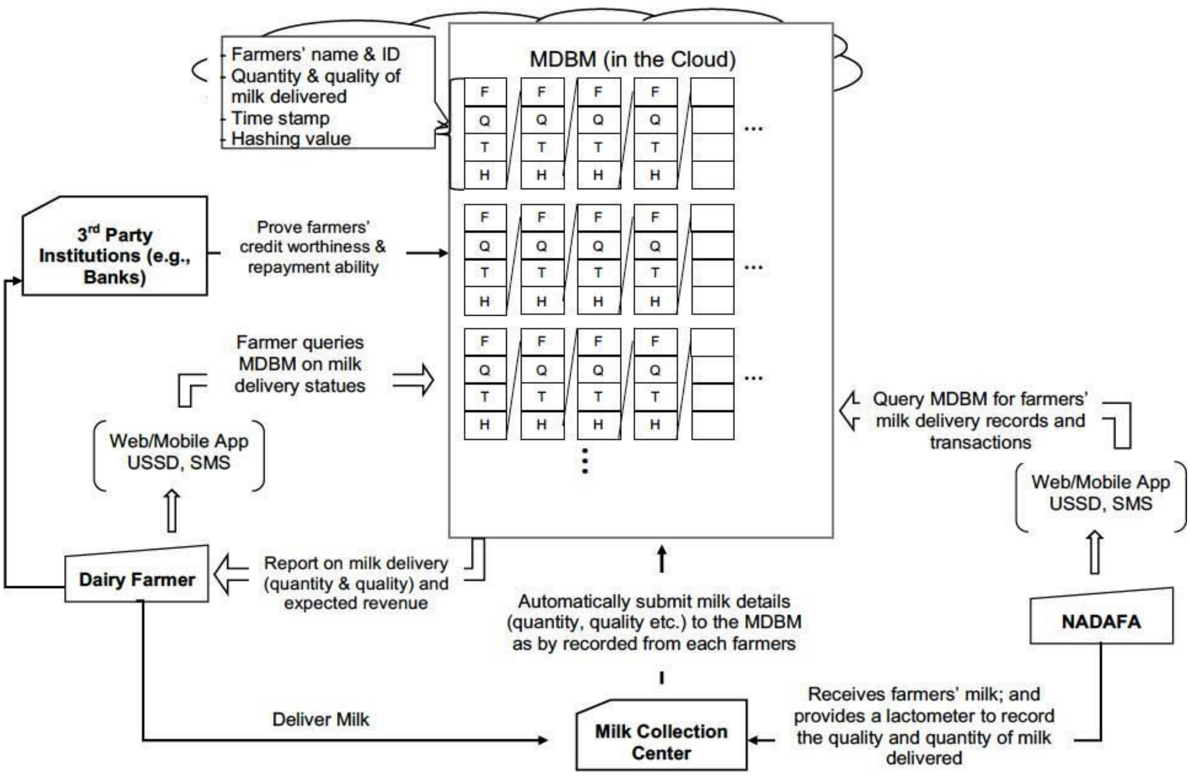


Figure 0.6: MDBM Architecture: Distributed Blockchain Based Milk Delivery Ledger.

Twiga Foods, a Kenyan Agri-tech company, has integrated blockchain technology into its supply chain operations. They use blockchain to track and verify the movement of produce from farmers to vendors, ensuring transparency and reducing inefficiencies in the supply chain. This helps to improve trust, reduce food waste, and enable fairer pricing for both farmers and vendors.

2.11 The Application of Blockchain Technology in the Kenyan Agriculture

Blockchain technology has been adopted in several aspects in the agricultural sector. This section describes the various applications that are currently being used the agricultural sector to enhance the smooth blockchain adoption.

Farmshine: Farm-to-Consumer Traceability Platform Farmshine is a blockchain-based platform in Kenya that focuses on improving transparency and traceability in the agriculture sector. It enables farmers to record and track the entire journey of their produce, from planting to the end consumer. This enhances trust and allows consumers to make informed choices about the products they purchase (Farmshine, n.d.).

Twiga Foods: Supply Chain Management and Financing Twiga Foods, a Kenyan agri-tech company, has incorporated blockchain technology into its supply chain management and financing operations. The company uses a blockchain-based platform to streamline the supply chain for fresh produce, connecting farmers with vendors through a digital marketplace. The platform enables farmers to receive fair prices for their produce and provides vendors with a reliable and transparent supply of high-quality goods. Additionally, Twiga Foods offers blockchain-based supply chain financing solutions, allowing farmers to access credit based on their transactions and produce records stored on the blockchain (Twiga Foods, n.d.).

FarmERP: Blockchain-based Agricultural Management System FarmERP is an agricultural management system that integrates blockchain technology to enhance efficiency and transparency in farm operations. The platform enables farmers to record and manage data related to crop cultivation, resource utilization, and financial transactions. By leveraging blockchain, FarmERP ensures the integrity and immutability of data, reducing the risk of manipulation or fraud. This enables farmers to have a transparent and secure system for managing their agricultural operations, improving productivity and decision-making (FarmERP, n.d.).

TruTrade: Blockchain-based Commodity Trading Platform TruTrade is a social enterprise that uses blockchain technology to facilitate fair and transparent commodity trading for smallholder farmers in Kenya. The platform enables farmers to record and track their sales transactions on a blockchain, ensuring transparency and eliminating intermediaries. TruTrade provides farmers with fair market prices, timely payments, and access to a wider network of buyers. The immutable nature of blockchain ensures that transaction records are securely stored and can be audited, which helps build trust among farmers and other stakeholders in the agricultural value chain (TruTrade, n.d.).

BeefLedger: Livestock Traceability and Food Safety BeefLedger is an Australian company that has partnered with Kenyan stakeholders to implement blockchain technology for livestock traceability and food safety. The company uses blockchain to create a secure and immutable record of the entire lifecycle of livestock, from breeding to processing. By recording information such as the animal's breed, health records, feed sources, and transportation details on the blockchain, BeefLedger ensures transparency and enhances consumer trust. This enables consumers to verify the origin and quality of beef products, ensuring food safety and supporting sustainable farming practices (BeefLedger, n.d.). These examples illustrate how blockchain technology is being utilized in the agriculture sector in Kenya to improve transparency, traceability, supply chain management, financing, and food safety. By leveraging the unique features of blockchain, such as immutability, decentralization, and transparency, these initiatives aim to address challenges and create.

2.12 Blockchain Technology Application in the Tea sector in Kenya

The tea business is significant to the economy of Kenya as the tea business is one of the main exports of agriculture in the country. Nonetheless, the industry is faced with several challenges, such as the questions of the transparency, chain of supply chain inefficiency, the questions of trust and traceability. The use of blockchain technology has become a promising solution to all these challenges as it offers a decentralized and unchangeable system in which tea production, supply chain management, and trade are conducted. The traceability, trust, fair trade practices, and sustainability of tea sector can be enhanced by blockchain technology..

For instance, the Institute of Tea Research and Development in Kenya created the blockchain-based Chai platform, which aims to improve traceability and transparency in the tea supply chain. Production procedures, quality certificates, and transaction information can all be recorded on the blockchain. Chai provides stakeholders with verifiable and trustworthy information, fostering transparency and fair-trade practices (Institute of Tea Research and Development, n.d.).

Bext360 is another company that has implemented blockchain technology in the tea sector in Kenya. Their platform enables farmers to record the entire journey of their tea, including cultivation practices and supply chain intermediaries, on the blockchain. This data provides buyers and consumers with verified information about the tea's origin and quality. Additionally, Bext360's blockchain-based payment system ensures transparent and timely payments to farmers, promoting financial inclusion (Bext360, n.d.).

Farmer Connect is a blockchain-based platform that connects tea farmers directly with buyers and consumers, eliminating intermediaries and promoting fair trade practices. By recording data about tea production on the blockchain, including cultivation practices, certifications, and transaction details, Farmer Connect establishes a transparent and immutable record. This empowers farmers, promotes fair prices, and enhances consumer trust (Farmer Connect, n.d.).

The Kenya Tea Development Agency (KTDA) created Masterchain, a blockchain-based platform that simplifies supply chain management and trade finance for the tea industry. It enables real-time tracking of tea shipments, automates document verification and processing, and facilitates secure payments through smart contracts. This improves supply chain transparency, reduces paperwork, and ensures timely payments (KTDA, n.d.).

The Africa Tea Blockchain Association (ATBA) is a consortium of tea stakeholders in Kenya working together to explore and implement blockchain solutions. ATBA facilitates collaboration, research, and knowledge sharing among its members, aiming to drive blockchain adoption in the industry. Through ATBA, stakeholders exchange best practices, discuss challenges, and develop industry-wide standards for blockchain implementation (Africa Tea Blockchain Association, n.d.).

Overall, these blockchain advancements in the tea sector in Kenya offer potential solutions to enhance transparency, traceability, and efficiency. By leveraging blockchain technology, stakeholders can build trust, promote fair trade practices, and ensure the sustainability of the tea industry.

2.13 Recommendations for Effective Blockchain Adoption in Supply Chain Management

A one-size-fits-all solution for supply chains doesn't exist; instead, a customized plan should be developed for each scenario to effectively deploy the technology. Thus, the following guidelines should be seen as broad, with processes that can be modified to suit individual business scenarios.

Overall, Tarasenko (2020) states that the first step in using blockchain is to identify use cases. A detailed description of the blockchain's application reasons and objectives is essential. Next, focus on architectural development to determine the appropriate blockchain type for deployment. Then, select an application approach, deciding who should be involved and how to implement the technology. Finally, execute the project, considering additional support and development.

Frank Yiannas, former VP of Food Safety at Walmart, recommends letting the business lead, understanding the business case, having strong human resources, crafting a compelling vision, engaging in tech forums, and starting with a proof of concept (Walmart Case Study - Hyperledger Foundation, 2021). Understanding the business case and choosing the right blockchain type are crucial, as outlined in the decision framework adapted from Unnu, K. et al. (2019).

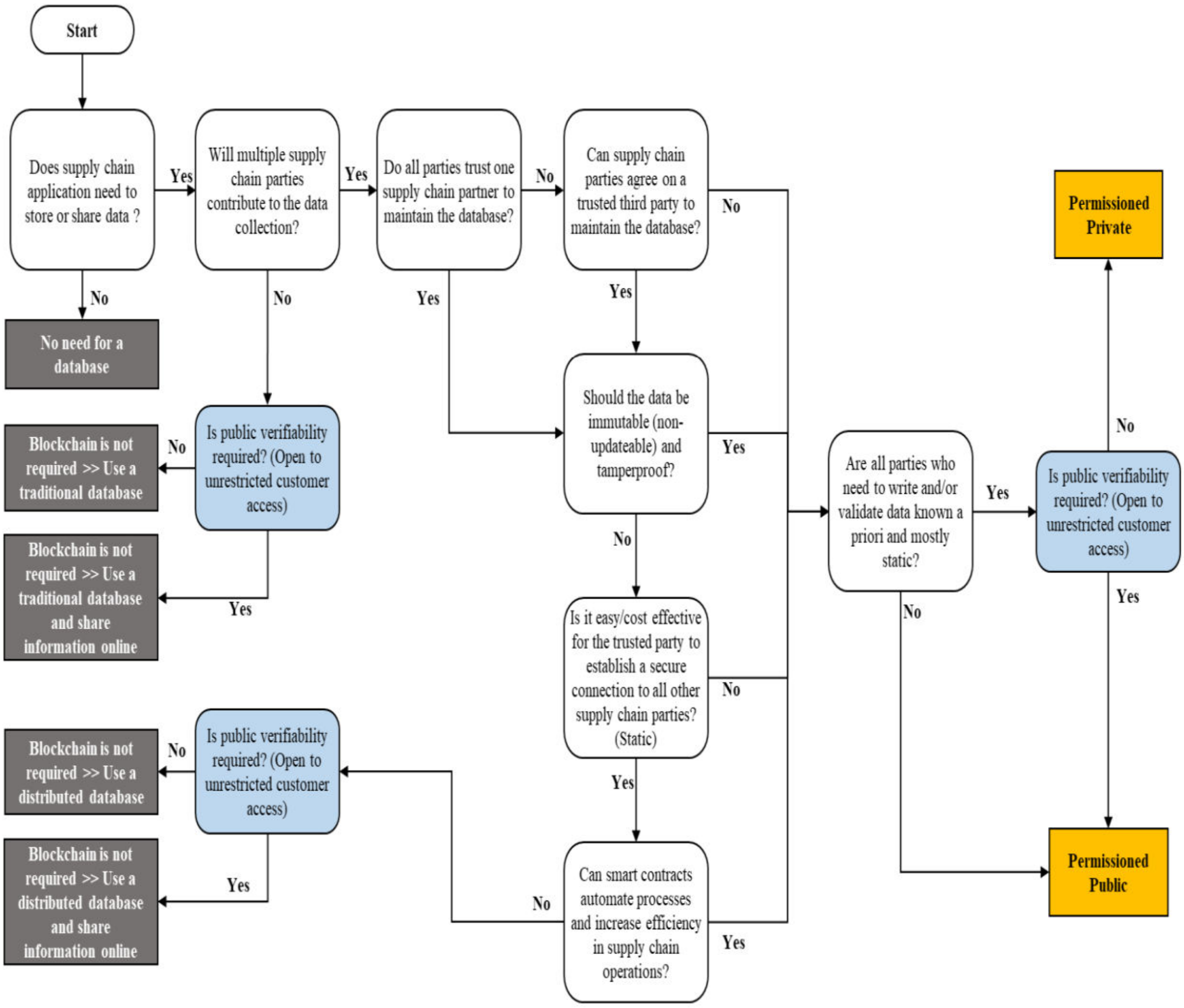


Figure 0.7: Decision Framework for selecting blockchain in supply chain: Source Unnu, K. et al. (2019)

2.14 Theoretical Framework

Without sensemaking, supply chain companies would have struggled to adapt to disruptions, blockchain adoption, and strategic growth (Wang & Singgih, 2019). Sensemaking theory helps them develop blockchain solutions tailored to their needs. Theories like network theory, principal-agent theory, resource-based view, and transaction cost analysis are used to investigate the function of blockchain in supply chain management (SCM) (Treiblmaier, 2018). The impact of blockchain on transaction costs and governance is examined using transaction cost theory (Schmidt & Wagner, 2019). Six organizational theories are included in research on blockchain in

SCM: resource-based view, agency theory, institutional theory, network theory, information theory, and transaction cost analysis (Kummer & Herold, 2020).

2.14.1 Principal Agent Theory

According to Jensen and Meckling (1976), agency costs in Principal–Agent Theory consist of the principal's monitoring expenses, the agent's bonding costs, and the residual loss. These costs arise when principals seek to monitor, control, and oversee agents to ensure they act in the principals' best interests. Because principals often lack complete information about the agents' actions, a certain level of trust becomes necessary. Fayezi and Zutshi (2012) reviewed 86 supply chain management (SCM) studies related to agency theory and principal–agent relationships, highlighting its broad application in SCM research. At its core, the principal's key challenge lies in selecting the right agent and building a relationship founded on trust.

PAT, which examines the relationship between principals (e.g., tea producers or farmers) and agents (e.g., tea processors or exporters), is foundational to understanding how blockchain technology can mitigate agency problems in the tea supply chain. In this framework, blockchain serves as a transparent, tamper-proof system that reduces information asymmetry between principals and agents, thereby enhancing trust and reducing the potential for fraud. The theory informs the ICT infrastructure construct in the model, as robust technology helps ensure transparency and accountability, which directly addresses the challenges posed by agency conflicts in the supply chain.

2.14.2 Transaction Cost Analysis Theory

According to Transaction Cost Analysis, the production and transaction costs of different forms of governance mechanisms are affected by the choice of the most effective inter- and intra-organizational structures (Coase, 1937). Transaction costs encompass initiation (information gathering and negotiation) and post-initiation costs (control and adjustment). Different governance systems, such as markets or hierarchies, may arise based on these costs (Williamson, 1987). Transaction Cost Analysis (TCA) provides a theoretical foundation for SCM, addressing issues like outsourcing, investment allocation, and supply chain coordination (Grover & Malhotra, 2003). Examples in SCM include purchasing portfolio management (Luzzini & Caniato, 2012), suppliers' environmental practices (Tate & Dooley, 2011), governance effectiveness (Wacker & Yang, 2016), and transaction challenges (Stranieri & Orsi, 2017).

TCA is concerned with minimizing the costs associated with exchanges between parties, including information costs, bargaining costs, and enforcement costs. In the context of blockchain, TCA highlights how the technology can reduce these transaction costs by automating contract execution, ensuring data integrity, and eliminating intermediaries. This theory contributes to the data integration and automation component of the framework, emphasizing that blockchain's decentralized nature can streamline operations, reduce operational inefficiencies, and lower transaction costs within the supply chain.

2.14.3 Resource Based View Theory

The Resource-Based View (RBV) emerged as a counter to the positioning school, which emphasized organizational strategy (Porter, 1980). RBV argues that only certain resources provide a competitive edge, and an even smaller subset drives long-term performance. Halldorsson et al. note that the application of RBV to this topic is limited in existing literature. However, there is a growing body of research that emphasizes the relevance of this theoretical framework and associated opinions like material presence theory (Hunt & Davis, 2008), to supply chain management (SCM). Recent studies have explored various dimensions of SCM, inclucing the contribution of market information to gaining a competitive edge for transportation providers (Golicic & Fugate, 2012), the process of inter-organizational learning (Manuj & Omar, 2013), the achievement of closed-loop supply chain designs (Miemczyk & Howard, 2016), and the identification of antecedents for supply chain information integration.

RBV posits that a firm's competitive advantage is derived from its unique resources, including technological capabilities. In this framework, blockchain technology is viewed as a valuable, rare, and difficult-to-imitate resource that can provide sustainable advantages in managing the tea supply chain. The RBV theory informs the security and privacy aspect of the model, as the technology ensures the protection of proprietary information and sensitive data, thereby enhancing the firm's resource pool and contributing to competitive differentiation.

2.14.4 Network Theory

By focusing on the interpersonal connections between the parties and the mutual development of trust through cooperative interactions and trade activities, network theory aims to explain the dynamics of inter-organizational networks (Halldorsson & Kotzab, 2007). To access external resources, businesses must form partnerships, which create both stable and dynamic networks. Networks are established through exchanges (social, business, informational) and adaptations (products, production, routines), which strengthen connections within a firm's network (Johanson & Forsgren, 2015). Network theory (NT) has been utilized in various SCM areas, including joint ventures in manufacturing (Carnovale & Yeniyurt, 2014). The impact of strategic partnerships (Klint & Sjöberg, 2003), network centrality in environmental SCM (Wichmann & Carter, 2015), and the difference between networked and non-networked enterprises in the software industry (Kulmala & uusi-Rauva, 2005).

Table 2.1 compares the major features of the four hypotheses. They all assume some level of constrained rationality but approach the problem from a different perspective when exploring the underlying item of interest. PAT focuses on crafting optimal contracts to address issues from asymmetric knowledge. TCA examines organizational boundaries to determine optimal size and governance systems. RBV explores internal competencies for competitive advantage, while NT analyzes dyadic interactions within networks (Halldorsson & Kotzab, 2007).

Network Theory focuses on the importance of relationships and interactions among stakeholders within a network. In the context of the tea supply chain, blockchain technology can foster greater collaboration and coordination among the various stakeholders, from small-scale farmers to retailers. This theory contributes to the collaboration construct in the framework, highlighting how blockchain can facilitate real-time data sharing, improve communication, and strengthen relationships across the supply chain network. By enhancing network ties, blockchain technology can reduce the risks associated with supply chain disruptions and improve collective decision-making.

Table 2.1 outlines key aspects of each theory, such as their focus, type of relationships, and main area of interest. Each theory offers a unique perspective on SCM phenomena, and using multiple theories together allows for a more thorough analysis of complex research topics than relying on just one theory (Georgi & Darkow, 2010).

Table 0.1; Contrasts the Major Characteristics of the Four Theories.

Characteristics	PAT	TCA	RBV	NT
Behavioral assumptions	Bounded rationality, asymmetric information, goal conflicts	Bounded rationality, opportunism	Bounded rationality, trust	Bounded rationality, trust

Problem orientation	Contract design	Efficient governance structure	Internal competence development	Dynamic relationships embedded in networks
Key questions	What is the most efficient contract?	Why do firms exist?	Why do firms differ?	How do networks evolve?
Primary focus of Analysis	Contracts and incentives	Transaction Attributes	Resource Attributes	Inter-firm relations
Nature of relations	Division of labor, ownership, control	Market failures	Access to complementary Resources	Access to heterogeneous resources
Primary domain of interest	Incentive alignment in dyads	Transactions	Organizational resources and capabilities	Exchange and adaptation processes

Source: (Halldorsson & Kotzab, 2007)

A thorough theoretical analysis of blockchain lays important groundwork for future theoretical advancement and practical study. Decentralized decision-making, distributed processing, dependability, peer-to-peer communication, data immutability, automation, quick transaction processing, minimal fees, transparency with pseudonymity, and irreversibility are some of the key characteristics of blockchain technology (Iansiti & Lakhani, 2017). Thanks to these characteristics, more general ideas like data provenance, security, privacy, authenticity, integrity, enforcement, consensus, availability, and responsibility are generated, which have important managerial implications (Tapscott & Tapscott, 2016). These elements can have a significant impact on the logistics and supply chain management industries.

Table 2.2 illustrates the integration of blockchain features into the four theories using the framework from Table 2.1. This table's structure, adapted from Halldorsson & Kotzab (2007) for third-party logistics, applies the characteristics of the four theories in Table 2.1 to blockchain technology. The most important findings state that smart contracts CAN eliminate information similarity from a PAT perspective (ISDA, 2017).

TCA can assist in explaining how blockchain technology will impact organizational borders and how it will change the costs of both intra- and interorganizational transactions (Cocco & Pinna, 2017). RBV can aid in resource allocation to acquire a competitive advantage. Certain advantages are projected to become obsolete as a result of blockchain's special qualities, while fast adopters may also benefit from strategic opportunities. Finally, the blockchain's claim to generate "trustless trust" (Werbach, 2017) can be thoroughly examined using NT.

There has been an increasing need for middle-range theories (Stank & Pellathy, 2017). Unlike broad, general theories, middle-range theories are more narrowly focused, aiming to provide a detailed understanding of the reasons, mechanisms, and conditions under which specific outcomes arise (Astbury & Leeuw, 2010). Additionally, theories can be categorized based on their methodological approach, “which may involve analysis, explanation, prediction, a combination of explanation and prediction, or prescription (Gregor, 2006).

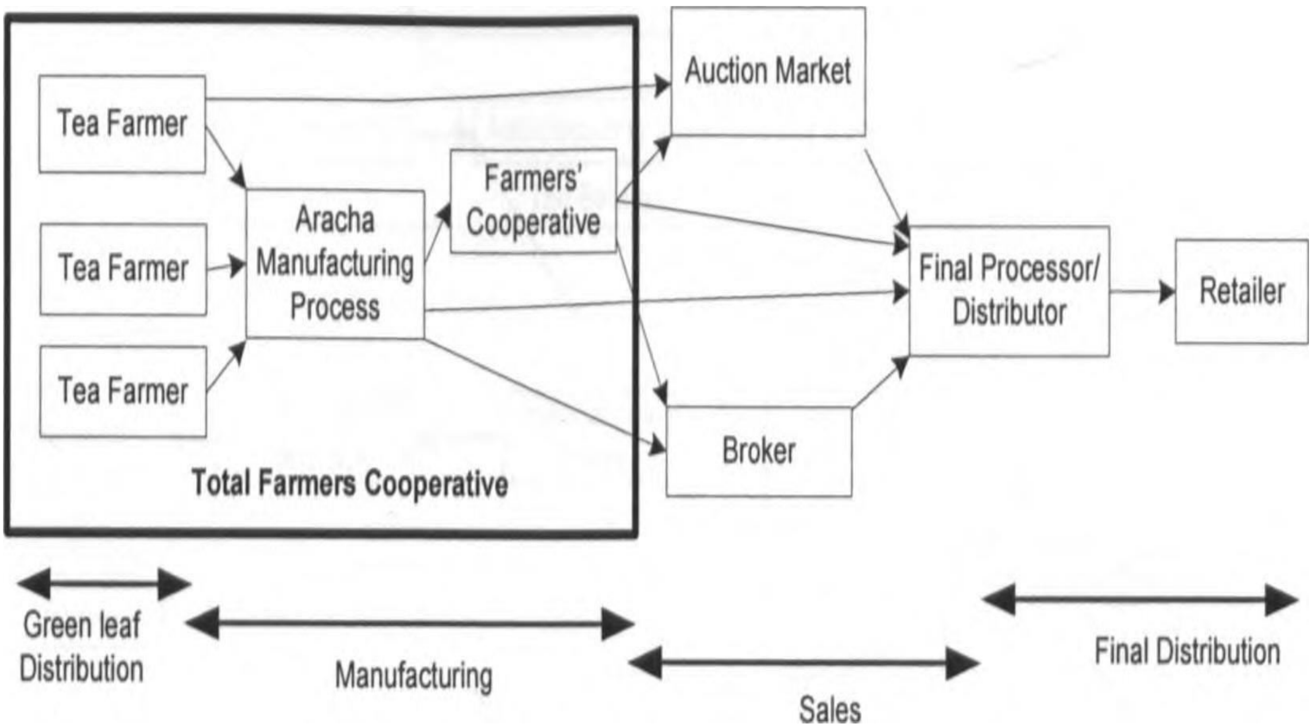
Table 0.2: The Theoretical Framework applied to blockchain-based SCM research

Characteristics	PAT	TCA	RBV	NT
Behavioral assumptions	Increased information transparency	Contractual agreements Investments, divestments	Trust in transactions, knowledge Transfer	Inter-organizational trust, information sharing
Problem orientation	Contract design and execution, supervision	Outsourcing and insourcing	Resource allocation and development	Design of communication and transactions
Key questions	How does the blockchain impact contract efficiency?	How does the blockchain change transaction costs?	What blockchain-related resources generate competitive advantage?	To what extent does the blockchain replace personal trust?
Primary focus of analysis	Smart Contracts to control agent	Costs of intra- and inter-organizational transactions	Competitive consequences of resource reallocation	Relationships in the network
Nature of relations	Harmonizing conflicting goals	Arm's length relationships vs strategic relationship	Blockchain as a new competence, complementary resources	Contractual relations, personal Relations
Primary domain of interest	Alignment of conflicting interests with smart contracts	Optimization of transaction costs, asset specificity, change of costs	Identification and development of core competencies	Mutual adaptation of relations through blockchain technology

Source: (Treiblmaier H. , 2018)

2.15 Related Frameworks and Supply Chain Models

Studies on information flow within the tea industry have been conducted across several countries. A common observation in many models is that farmers often lack adequate information about market trends and feedback from processing factories. The models reviewed in the literature include those from Japan, Sri Lanka and Bangladesh. The current state of information flow is as follows:



2.15.1 Japan Supply Chain Management

This model was designed to investigate the structure of the value chain in the tea industry, as well as the issues that occur in developing countries. The Japanese tea industry's value chain starts with the tea grower and finishes with the tea processing factory. It is owned by a group of farmers who operate the business cooperatively. Farmers harvest green leaves according to the processing plant's capability on that given day. This is dictated by the selected management structure. The production facilities handle the processing of green tea leaves, while the agent collaborates with the factory to negotiate the price and assess the quality of the processed tea. These agents maintain communication with both the processing companies or distributors and the cooperative farming association responsible for selling the tea. The distributor then undertakes additional processing, grading, and selling of the products to retailers. Torresen (2020) indicates that the primary communication channel is the internet.

2.15.2 Bangladesh Supply Chain Model

In Bangladesh, the tea industry is structured around plantations rather than cooperative farming systems. Each tea estate manages its own manufacturing operations, from leaf harvesting to processing and delivering the final product to brokers. Estates also bear the delivery and partial storage costs. Unlike Japan's cooperative models, where risks are collectively shared, Bangladeshi estates assume the full risk themselves (Huque & Rahman, 2007). independently. The sale of black tea in Bangladesh occurs through

Figure 0.8: Shizuoka Prefecture Tea Market Value Chain. Source: (Snell, 2018).

open auction markets. Although the current model lacks details on communication methods, a model utilizing the internet has been suggested.

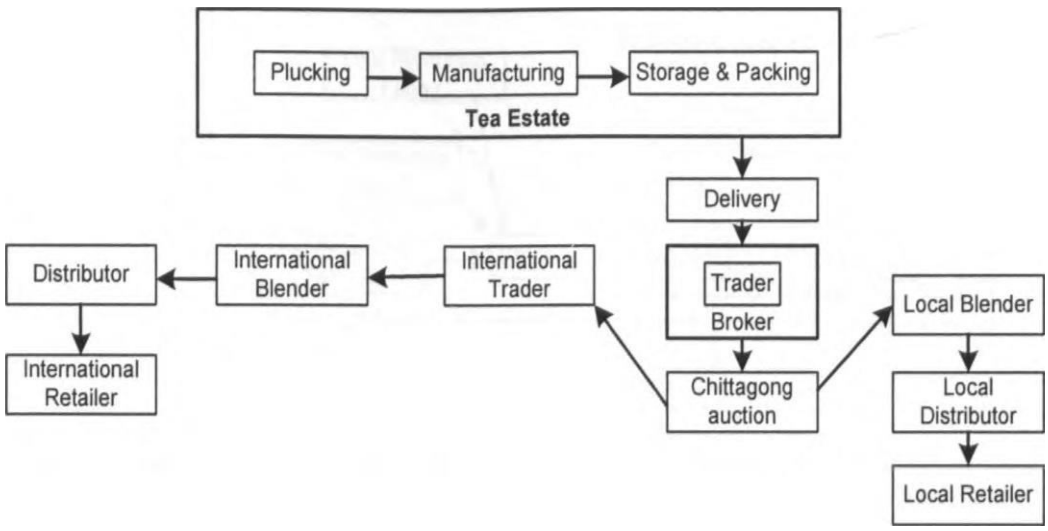
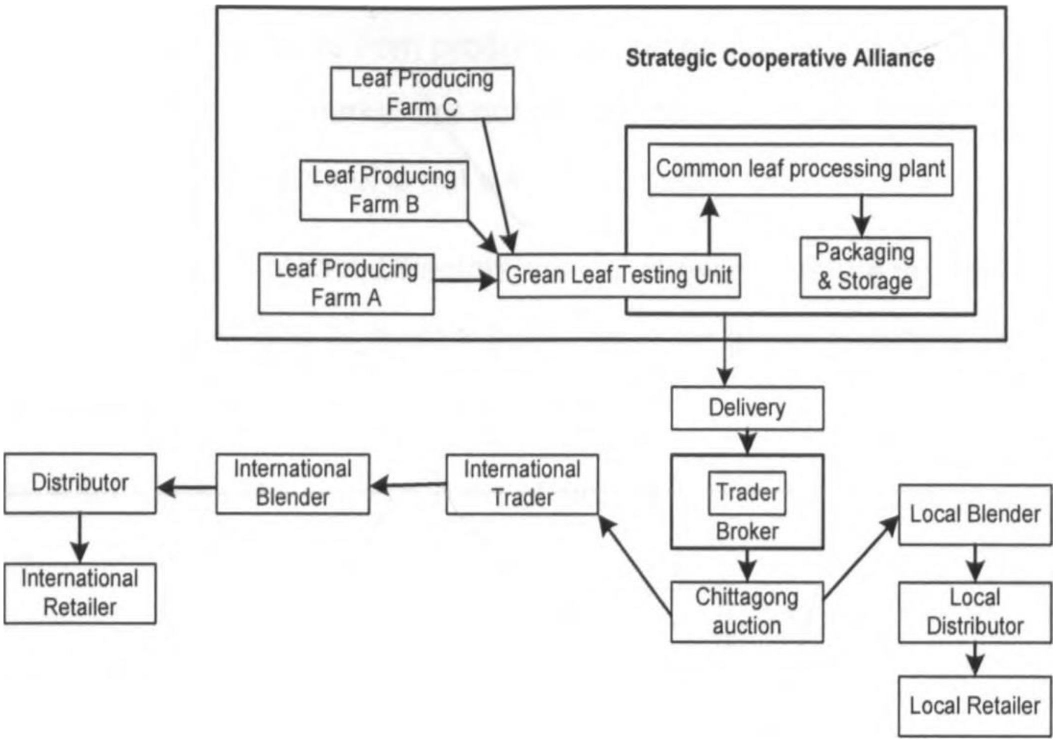


Figure 0.9: Value chain of Bangladesh Tea Industry Source: (Snell, 2018)

2.15.3 Modified Strategic Value chain in Bangladesh.

Strategic changes in the Bangladesh tea value chain involve farmers forming cooperative alliances among tea estates, sharing leaf processing facilities with quality measurement tools. By pooling resources in a common processing plant, estates can reduce the fixed costs associated with operating multiple factories. Key strengths of this approach include efficient smallholder participation and value addition through processing; however, weaknesses like lack of integration between stakeholders, limited market information, and inefficient logistics remain. Gaps such as limited product differentiation, lack of trust and transparency in value chain transactions hamper full potential. Blockchain can facilitate seamless stakeholder integration, enable real-time market information sharing, and enhance trust and transparency in value chain transactions (Huque, 2007; Rashid et al., 2024).



2.15.4 Kenya Supply Chain Model

Figure 0.10: Modified Strategic Value Chain in Bangladesh – Modified: Source: (Snell, 2018)

Smallholder growers can own tea factories by purchasing any KTDA stock and shares in factories; elected factory directors govern and manage tea factory firms; The KTDA's position has been redefined as a management agent for tea collection and processing, as well as having responsibility over the marketing of manufactured tea. The KTDA system faces challenges due to inadequate coordination and oversight between the Boards of Directors of farmers and industrial firms and the KTDA Board regarding service delivery to farmers. Information on tea marketing, revenue, and ownership transfers is unevenly shared between farmers and the KTDA Board, with the KTDA having significantly better access to market data compared to the farmers' limited bargaining power. Additionally, there is a lack of favorable agreements concerning final payments, which are often delayed, leading to conflicts of interest between industrial and KTDA directors to the farmers' disadvantage.

Strengths: Strong production capabilities, well-established cooperatives, export-oriented focus, Weaknesses: Inefficient logistics, limited access to finance, lack of market diversification, Gaps: Limited traceability, information asymmetry, inefficient payment systems, Blockchain Application: Blockchain can improve traceability, enable secure and efficient payment systems, and enhance information sharing across the supply chain, leading to better market diversification.

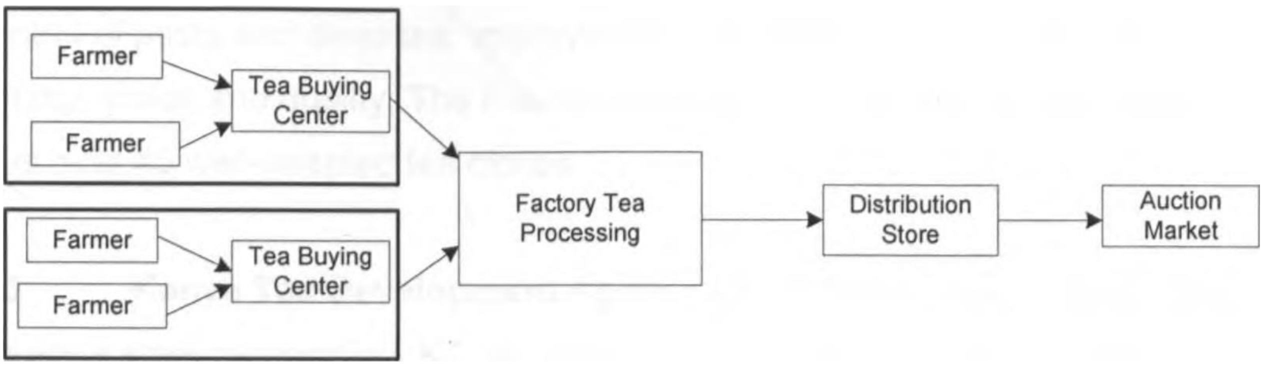


Figure 0.11: Supply Value Chain in Kenya – Modified Source: (Snell, 2018)

Table 0.3: Summary of Existing Models in the Tea SCM

S/No	Model Used in the Tea Sector	Strengths	Weaknesses	Gaps	How Blockchain Can Address
1	Japan Supply Chain Model	Emphasizes collaboration and efficiency	Limited integration and data sharing	Lack of real-time information	Enables real-time information sharing and data transparency
2	Bangladesh Supply Chain Management	Cost-effective and scalable operations	Limited traceability and transparency	Lack of visibility in the supply chain	Provides traceability and transparency
3	Modified Strategic Value Chain (Bangladesh)	Efficient coordination and resource optimization	Limited technology adoption and data management	Lack of trust and verification in transactions	Enhances trust and transparency in transactions
4	Kenya Supply Chain Model	Well-established infrastructure and networks	Lack of coordination and information sharing	Inefficiencies in logistics and delivery	Improves coordination and logistics efficiency

Table 2.3 illustrates the key challenges with present methods for tracking and tracing agricultural supply chains, as well as how blockchain technology could solve them.

Table 0.4: Main problems of current technologies and blockchain contribution in agri-supply chain Management

Issue	Blockchain Contribution
Data integrity, tampering, and single points of failure are caused by the centralized infrastructures on which a large number of IoT-based traceability systems for agricultural supply chains are built (Kshetri, 2018).	A verified and validated data remains permanently stored in the blockchain (Pant & Prakash, 2015) Alteration of the database on a single node of the blockchain is not possible, then stability and reliability are guaranteed (Pant & Prakash, 2015).The blockchain technology eliminates the need for a third party or an intermediary, responsible for controlling the system. In fact, based on a transparent consensus mechanism, it ensures the execution of only valid transactions (Caffyn, 2015). All the operations are visible to the nodes of the network, then participants' malicious actions are avoided (Caffyn, 2015).
In the agri-food supply chains, many conventional logistic information systems monitor and record orders and delivery, but they often overlook the following aspects: transparency, traceability, and auditability.	A consensus that has been achieved by the majority of peers in the network forms the basis for all the records kept in a blockchain. The distributed ledger is visible and unchangeable as a result (Kshetri, 2018).

Asymmetry of information between the various parties involved in the present food supply networks (Allison, 2016). Because they do not have access to knowledge about the entire agricultural supply chain, consumers live in an asymmetric information environment about food (Shin, 2015).	A public blockchain ensures complete transparency when data is inserted. The consumer can fully access the information regarding the processes that the product, which is on the shelf, has undertaken, and the data is available in real-time (Allison, 2016).
Data format lacks standardization. The players don't follow any shared agricultural protocol (Allison, 2016). Each of the several parties involved in the supply chains for agriculture has a mechanism in place for recording data and tracking it. This results in a risky software and data structure incompatibility, which makes it impossible to fully ensure food traceability (Chang & Iakovou, 2019).	Blockchain is a single platform, shared among all the participants, then there are no data incompatibility problems

2.16 Research Gaps on application of blockchain in food supply chain management

In the supply chains industry, blockchain technology is becoming more and more popular. Although they are not a cure-all, blockchain and distributed ledger technology (DLT) may be able to address the great majority of current problems. This is especially true given that the agriculture supply chain is very susceptible to criticism and frequently functions under extreme duress. In addition, there are a number of societal, technological, and economical considerations that must be made while using blockchain technology.

T. Burke observes in (Snell, 2018) that the agriculture industry has its own unspoken norms and delicate connections that should not be shattered when it comes to the societal effects of blockchain adoption. To put it another way, the agri-food supply chain is extremely complicated and resistant to the adoption of blockchain technology for the following reasons:

a) A large number of stakeholders have poor levels of technological understanding.

b) Products go through numerous changes as they move up the chain.

c) There is a great deal of variation in the responsibilities and businesses of the numerous parties involved.

d) The food supply chain is dispersed over wide geographic regions, including many continents, which presents major interoperability and deployment challenges.

e) Technical concerns found include those pertaining to data management, which are crucial and need to be properly taken into account. In particular, these issues concern data ownership and retention inside the blockchain (Whipple & Roh, 2010).

Blockchains may be unchangeable ledgers from a technical standpoint, but it is impossible to ensure that data entered by people or sensors will be accurate. According to Kumar and Herold (2020), in the event of a sensor malfunction, the information dispersed throughout the blockchain becomes inaccurate. Monitoring, integrating, and evaluating certain data categories within the agriculture supply chain are generally challenging. For example, environmental data are difficult to find and evaluate with impartial techniques (Fayezi & Zutshi, 2012).

Maintaining the distributed nature of blockchains as a DLT in parallel while facilitating their smooth interaction with legacy traceability systems is another crucial technical concern. In bigger implementations and deployments, the scalability of these traceability systems continues to be an issue (Whipple & Roh, 2010). Another related problem is deciding which kind of blockchain to use—public, private, or permissioned—and putting it into practice. Numerous research projects focus primarily on conceptual concepts rather than providing specifics about how the blockchain will be implemented. Furthermore, public block chains are used in a lot of academic projects, and some commercial products also employ them. The performance trade-offs associated with this decision are often insufficiently evaluated. This is largely due to the fact that executing a transaction on a public blockchain can demand considerable time and processing resources, especially in agri-food supply chains involving multiple parties. Therefore, selecting the appropriate type of blockchain is crucial, as it can impact the effectiveness of the traceability system.

Financially speaking, blockchain technology may boost customer confidence and the openness of the food supply chain, but its use has significant energy and cost implications (Ethereum Governance | Ethereum.org, 2021). Businesses must spend a significant amount of money and effort training all employees and acquiring the necessary equipment. However, these time and financial commitments could result in significant tracing expenses that could eventually outweigh the product's price, thus a cost-benefit analysis is crucial.

Kay Behnke and Marijn Janssen conducted an insightful study identifying eighteen boundary conditions for food traceability—five of which align closely with capabilities provided by blockchain technology. The study emphasizes that many boundary conditions are related to internal supply chain processes, industrial standards, and regulatory requirements. To fully harness the benefits of traceability via blockchain, these areas must undergo substantial organizational change (Behnke & Janssen, 2020).

In a complementary framework, Kamilaris, Fonts, and Prenafeta-Boldú analyse the broader implications and challenges of blockchain in agricultural supply chains. They point out key obstacles, including bridging the digital divide, establishing sustainable governance, developing appropriate policy and regulatory guidelines, overcoming technical challenges, and improving accessibility to blockchain technologies. They also stress that government leadership in promoting digital public infrastructure, technology education, and regulatory clarity is essential for successful adoption (Kamilaris et al., 2019).

Table 0.5: Blockchain application gaps identified in food supply chain management from the literature

No.	Article	Author (s)	Common position (Benefits)	Gap (Challenges)
1	A China-specific agri-food supply chain tracking system utilizing blockchain and RFID technology	(Tian, 2017)	Transparency Information authencity Efficiency	Durability. Insufficient comprehension . collaboration among stakeholders. Commercial secrets. raw falsification of data.
2	Blockchain-based Agricultural Product Provenance: A Dispersed Platform with Shared and Duplicate Bookkeeping	(Hua et al., 2018)	Transparency Information authenticity Efficiency Sustainability	Inadequate Technology Insufficient comprehension. collaboration among stakeholders. Commercial secrets. unprocessed data modification. the limited capacity to scale
3	Blockchain use for information security in the food supply	(Tse & Zhang, 2017)	Transparency Efficiency Sustainability	There are still challenges of regulations/Laws Need to Be Updated System Architecture is another challenge
4	The hurdles that lie ahead for food traceability analysis using blockchain technology	(Galvez & Mejuto, 2018)	Transparency Efficiency	Potential for manipulating raw data before uploading it to a blockchain

Table 0.6: Summary of selected Blockchain Applications in Tea SCM

S/No	Article Title	Authors	Position on Blockchain in Tea Supply Chain Management	Gaps Not Addressed by Authors
1	"Blockchain-Based Traceability in the Tea Supply Chain"	Chen, L. & Wang, H.	Blockchain improves transparency and traceability	Integration challenges with existing supply chain systems
2	"Enhancing Efficiency in the Tea Supply Chain with Blockchain"	Kumar, R. & Singh, A.	Blockchain enhances efficiency and reduces intermediaries	Scalability concerns in blockchain implementation
3	"Exploring the Potential of Blockchain in Tea Supply Chain"	Li, J. & Zhang, Y.	Blockchain enhances trust and reduces fraud	Legal and regulatory frameworks for blockchain adoption
4	"Blockchain Technology for Sustainable Tea Supply Chain"	Gupta, S. & Sharma, R.	Blockchain enables sustainability and ethical sourcing	Standardization of blockchain protocols and interoperability
5	"Addressing Challenges in Tea Supply Chain with Blockchain"	Wong, M. & Lee, K.	Blockchain improves transparency and eliminates counterfeit	Data security and privacy issues with blockchain technology
6	"The Role of Blockchain in Ensuring Quality in Tea Supply Chain"	Patel, A. & Gupta, V.	Blockchain enhances quality assurance and product traceability	Challenges to adoption and opposition to change within the tea sector
7	"Blockchain-Based Authentication in the Tea Supply Chain"	Kim, J. & Park, S.	Blockchain improves authentication and anti-counterfeiting	ROI study and cost-effectiveness of integrating blockchain technology into the tea supply chain
8	"Transforming Tea Supply Chain through Blockchain Technology"	Sharma, P. & Verma, R.	Blockchain enhances transparency and supply chain visibility	Education and training for stakeholders on blockchain technology

2.17 Conceptual Framework

According to Creswell & Creswell (2018), the conceptual framework is a symbolic depiction of the relationships that a phenomena exhibits inside a system or process. It is laid out in a way that makes predictions possible. (Jajodia, Kunii, & Sølvberg, 2001) notes that a model is an idea that depicts how things function and is used to explain how observations and theories fit together. In line with the aforementioned definitions, (Ludewig, 2003) states that a model must have three primary characteristics, namely a) mapping, which indicates that the model is built on an original concept; b) reduction, which indicates that the model only includes a subset of the original attributes; and c) pragmatic, which indicates that the model must be functional enough to replace the original for a certain purpose. The analysis of the literature showed that the current systems for supplying tea have not been able to provide a high degree of information correctness, scalability, or system reliability. In addition, trade transparency is a significant concern, and the current framework makes it challenging to resolve traceability system problems. That example, because of a centralized or distributed architecture, it is nearly hard to stop counterfeiting or stop fraud (Büşra et al., 2022).

Additionally, there is still much reliance of the centralized cloud infrastructure for the use of current IOT solutions and this leads to the lack of transparency and faces security threats such as auditability, availability, and data lock in and confidentiality (Lo'ai Tawalbeh et al, 2020). Blockchain technology has proved to be promising in addressing these problems which in turn leads to control and secure traceability, immutability of data and creation of real trust in the IT solutions which have better low costs. However, Blockchain mechanism is largely dependent on excellent ICT infrastructure, data integration, collaboration between stakeholders, security and privacy of the whole management chain, and the automation of end-to-end processes.

2.17.1 ICT Infrastructure

The adoption of Blockchain smart contracts for tea supply chain management requires a technological infrastructure that is adequate, efficient, and accessible to all stakeholders. It must be compatible with the operations within the entire chain system, business processes, and other information systems. In terms of scalability, the technology must be large able to transact more information in one second. However, the Blockchain technology put in place should not be too complex for stakeholders to understand both in business and technical perspectives including the inability to solve transactional errors.

Further data suggests that innovation capabilities can reduce supply chain risks by lowering truckload and, consequently, cost, improving supply chain performance. This includes embracing new technologies like BLCT for converting and reconfiguring current resources (Wang, 2020). With the use of a shared database, secured system, and better decision making, the Blockchain eliminates the middleman, human mistake, and paperwork (Yadav & Singh, 2020b). At the moment, Africa's use of blockchain technology is limited by small ranchers' lack of specialized skills and flexible/web access. On the other hand, the application of BLCT might raise overall operation (Kamble, 2020).

In a similar vein, the expense of implementing technology and related systems may generally be prohibitive (Shi & Yan, 2016). The deployment of new technologies typically results in increased expenses because it requires specialized training for a larger number of users to become comfortable with complex technologies like blockchain (Gallardo, G., Hernantes, J., & Serrano, N, 2018). However, calculating the costs associated with the use of Blockchain technology is not simple or easy. Determining the expenses associated with transactions, operations, and maintenance is also necessary for supply chain management provided by blockchain technology (Wong et al., 2020a).

2.17.2 Data Integration and Automation of End-to-End Processes

2.17.2.1 Data Integration

Data integration allows for inter-communication and interoperability across a system that ensures data sharing among the stakeholders within the supply chain management.

This enhances verification by players in the industry, increases information accuracy, eliminates duplication during sharing, and makes data accessible at all levels of the supply chain. In addition, integration improves the Blockchain systems accountability, quality of data, and addresses challenges of sharing information.

One arrangement is for the organizations being referred to consent to concentrate their information on creation and stock allotment choices in a typical storehouse. Nevertheless, consider the kind of cooperation it would require: Regardless of whether they are rivals or allies, all complex organizations would have to acknowledge focused choices and trust one other with their information. A Kanban framework would be used by organizations to manage creation and place orders with one another.

Moreover, integrative supply chain management can support businesses in achieving sustainable supply chain performance by fostering internal incentive to use green supply chain integration techniques and more effectively allocate resources in order to meet environmental objectives. While customers can drive demands linked to social issues by offering genuine product feedback, suppliers can split the expenses of going green and boost economic performance (Han, Z., & Huo, B, 2020). Blockchain technology can be a reliable means of maintaining records, but several studies have raised concerns concerning the processing of unprocessed data, like in the case of Internet of Things sensors. Consequently, it may be difficult to ascertain whether raw data is authentic in the first place (Jiang et al., 2020). In the meantime, suppliers might be strategically encouraged to assume accountability for their goods and give accurate information from the start by utilizing the unchangeable recording.

2.17.2.2 Automation of End-to-End Processes

The adoption of Blockchain technology for tea supply chain management require automation of process so as to enhance transparency, verification; improve trust among stakeholders, and accuracy of transactions. Automation will equally create a common data identifier for recording farmers' information. Even though Blockchain has only been around for ten years, it has already opened up a world of potential uses. If Blockchain hadn't been for its exceptional characteristics, such decentralization, the technology wouldn't have broken out from Bitcoin to develop into a disruptive innovation that affects numerous non-financial sectors in addition to finance. Blockchain technology is particularly well-suited for scenarios where ownership histories are necessary.

They would, for example, propose a strategy to combat music and movie piracy without making it illegal to purchase, sell, inherit, or give away digital media. They also set the stage for a variety of public services, such as welfare and health benefits, and they offer self-executing contracts that allow businesses to run independently of human oversight. By enabling voters to possess a copy of the voting records, they could be utilized for Blockchain-enabled electronic voting (BEV) (Di Angelo, M., Salzer, G, 2021). e-Science is another noteworthy Blockchain application that deals with the trust in scientific research by providing a way to audit and validate the validity of study findings.

However, a number of proposals have been made for using Blockchain in the healthcare industry, many of them have to do with electronic health records (EHRs). One of these ideas is to verify patients and healthcare providers using blockchain technology, allowing EHRs to be shared. Furthermore, because distributed data, proof of work, and cryptographic public/private key access are intrinsic features of cryptography, an interoperable Blockchain may be able to enhance data integrity while also safeguarding patients' digital identities.

Blockchain applications for bitcoin and other cryptocurrencies are by far the most well-liked ones. Therefore, it is believed that financial services would lead the way in implementing blockchain technology (Di Angelo, M., Salzer, G, 2021). Examples of these services include transaction validation and international payments. One of the relative benefits of cryptocurrencies is their ability to facilitate cross-border payments. They reduce the need for middlemen, allow instantaneous transfers at a reduced cost, and shorten the time it takes to validate funds. Digital tokens that can be issued by a reliable authority to meet the needs of participating parties can potentially represent the transacted asset through the use of a distributed ledger. This helps with payment processing, gets rid of paperwork for things like title transfers, and minimizes transactions getting interrupted (Cann, S., & Catmur, J, 2017). Regarding transaction validation, a system based on blockchain technology does thorough professional validation just once, using the validated identification document for all ensuing transactions. As property, attestations, licenses, and other forms of authoritative power accumulate over time, the identity may also change (Niforos, M., 2017b).

A consensus protocol—a method for upholding a single, universally accepted version of the transaction history—is necessary for blockchain. Cryptocurrency networks employ a sophisticated technique known as proof of work as they are peer-to-peer and decentralized. It guarantees that the majority of network users approve of every transaction, but regrettably, it also slows down the addition of new blocks. As a result, it is too late to even consider handling the number and speed of supply chain transactions. Fortunately, building consensus doesn't require the verification of-work technique if a Blockchain is private and permissioned. Who gets to add the next tile to the Blockchain can be determined using simpler techniques. A cooperative convention is one method that allows members to add a square pivot at their fixed request. Since all members are known, a malevolent entertainer would be found in the event that it utilized its chance to adjust the chain in an unsafe or ill-conceived way. Furthermore, debates can be settled effectively by members' approving past blocks.

2.17.3 Collaboration

Blockchain smart contracts for tea supply chain management require cooperation among all stakeholders, organizations. The support from government and its agencies is equally important in terms of provision of inceptives, legislation of the right policy framework for its adoption, and sensitization about the technology. There must be elaborate laws that will protect its users, define how issues are resolved, and impede interference of its usage**.** The stakeholders must ensure that the Blockchain system is has the relevant technical capacity to handle the technology and its applications to enhance its competitiveness for general improvement in productivity and performance of professionals and clerical employees. However, the Blockchain system adopted must be relatively affordable in both hardware and software facilities costs as well as the entire investment needed to implement it.

Furthermore, "one version of the truth" for every product is how blockchain is frequently described. It is a record-keeping system used to document financial transactions, such as bills of lading. Every step of the supply chain is covered; every stage is automatically recorded, from shipping and serialization to receiving and installation. The foundation of this system is unquestionably transparency, audibility, and trust. Every participant has equal access to the data. If an individual among the participants attempts to commit fraud, they will be immediately considered a threat and their system will be out of sync. It effectively discourages the actions of malware. If a participant attempts fraud, they are immediately out of sync with the system and flagged as a threat, effectively deterring malicious behavior. All supply chain parties, from raw material suppliers to customers, must use blockchain technology instead of paper documentation.

Stakeholders can provide data, check transactions, and register as authorized users to access historical information. As the ultimate users, customers will also be entitled to request and evaluate a product's history. Incorporating all pertinent stakeholders can enhance information efficiency and openness, but it can also pose difficulties due to differences in knowledge and infrastructure. The introduction of blockchain technology and infrastructure fees may make it more difficult for developing countries and small and medium-sized enterprises (SMEs) to adopt innovative ideas. Kamilaris et al. (2019) note that most blockchain projects are based in developed countries. To make blockchain accessible to SMEs, it should be easy to deploy, cost-effective, and user-friendly (Leong et al., 2018). Perboli et al. (2018) created a blockchain model for SMEs using Hyperledger Fabric, finding that cost savings from blockchain can outweigh its implementation costs. They suggested that integrating Blockchain into part of a system is often more practical than overhauling the entire system.

Because Blockchain is an open database, user rights and trade secrets need to be protected through policies. Tse et al. (2017) analyzed the external factors affecting blockchain deployment—political, economic, social, and technological—using PEST analysis. They recommended that governments use Blockchain to improve supply chain transparency and reduce food safety risks, noting interest and support from various nations and authorities (Tse et al., 2017). China, for instance, has started projects linked to blockchain technology and produced a White Book on the subject. Global Blockchain standards were another project that ISO Blockchain (TC307) was working on. Thus yet, the food supply chain domain lacks a rigorous Blockchain policy.

Furthermore, regulatory support points to laws and policies that are important for encouraging the use of blockchain technology (Shi, P., & Yan, B, 2016). Implementation is accelerated by adequate and pertinent regulatory support from the government and regulatory bodies (Wong et al., 2020); (Shi & Yan, 2016). The deployment of BLCT also requires financial support from pertinent regulatory agencies (Wong et al., 2020a). Studies on the application of blockchain technology require regulatory support. Priorities that must be addressed before BLCT deployment include regulatory uncertainty, other intellectual property concerns, and compliance (Wong et al., 2020). Technology readiness and supporting conditions are impacted by regulatory support, which also influences infrastructure implementation for BLCT adoption and fosters trust (Wong, 2020b). Effective technology implementation requires the support of top management (Dubey, 2018). Management will assist staff members in becoming knowledgeable about and utilizing blockchain technology if its adoption shows profitable and resolves cost issues (Wong et al., 2020a). Thus, TMSU, or top management support, is a crucial component of blockchain adoption.

Building confidence in gathering of accomplices with which to share information on a blockchain will involve conquering a few difficulties. One is the requirement for an administration instrument to decide the principles of the framework, for example, which can be welcome to join the organization, what information is shared, how it is scrambled, who approaches, how debates will be settled, and what the degree is for the utilization of IoT and savvy contracts. Another difficulty is figuring out how to make information about the quantity or age of products in the supply chain more visible in order to mitigate the potential influence that blockchain may have on decisions about pricing and inventory allocation. It is challenging to predict where the costs and benefits of this simplicity will be borne within the production network.

2.17.4 Security and Privacy

Blockchain smart contracts for tea supply chain management adoption require strong security and privacy for the sensitive information the platform will handle. The stakeholder must confidently feel secure sending or uploading their companies or organizations data on the platform. This is what will make the system stakeholders transacting business through the Blockchain mechanism.

Even with the security of the Blockchain record, there remains a risk that a tainted or fake product could be mistakenly labeled and added to the supply chain by dishonest actors. Another peril is off base stock information coming about because of mix-ups in filtering, labeling, and information passage. However, organizations are tending to these dangers in three ways. In the first place, they are rigidly leading actual reviews when items initially enter the inventory network to guarantee that shipments match Blockchain records. Second, they are developing decentralized applications (dApps) to track items throughout the supply chain, verify data integrity, and interact with the blockchain to prevent errors and fraud. The blockchain record helps trace the source of any suspected counterfeit goods or mistakes. Third, businesses are enhancing blockchain reliability by using IoT devices and sensors to automatically scan items and update records on the blockchain without human intervention (Tentama, 2020).

2.18 Summary of Literature Review

The literature review provides a synthesis of existing knowledge and theoretical perspectives on the application of blockchain technology in supply chain management, with a particular focus on its relevance to Kenya's tea industry. Drawing from the Resource-Based View (RBV), blockchain is conceptualized as a strategic asset that can enhance transparency, trust, and sustainable competitive advantage. The Transaction

Cost Analysis (TCA) framework positions blockchain as a mechanism for reducing coordination costs, mitigating information asymmetry, and improving contract enforcement across supply chain actors. Furthermore, insights from Network Theory (NT) illustrate how blockchain facilitates stronger inter-organizational collaboration through secure, decentralized, and immutable transaction records. Collectively, these theoretical foundations suggest that blockchain technology holds significant potential for addressing traceability, accountability, and efficiency challenges in agricultural value chains such as Kenya’s tea sector. The review highlights the significance of this research topic and its potential to address the challenges and inefficiencies in the tea sector's supply chain.

The review begins by discussing the importance of supply chain management in the tea sector and the issues it currently faces, such as limited transparency, traceability issues, and delays in decision-making processes. It emphasizes the need for innovative solutions that can revolutionize supply chain in the tea industry, leading to improved transparency, accountability, and efficiency.

Several examples of blockchain technology applications in the tea sector in Kenya are presented. These include platforms such as Chai, Bext360, Farmer Connect, and Master chain, which focus on enhancing transparency, traceability, direct trade, and supply chain management. These initiatives leverage blockchain's features to provide stakeholders with verifiable and trustworthy information, eliminate intermediaries, ensure timely payments, and establish transparent and efficient systems. The review also highlights the collaborative efforts of organizations, Initiatives like the Africa Tea Blockchain Association (ATBA) aim to advance blockchain technology in the tea sector. These collaborations promote knowledge sharing, research, and the development of industry standards for blockchain implementation.

There is a gap in this area that needs to be investigated further. By creating a thorough grasp of the possible advantages, difficulties, and implementation techniques of a blockchain-based smart contract model in the Kenyan tea supply chain, the research study seeks to close this knowledge gap. The study will add to the body of knowledge by performing empirical research and applying a Kenyan perspective. It will do this by offering helpful advice and practical insights for the successful adoption and application of the blockchain-based smart contract model in the tea industry.

The identified research gap emphasizes the importance of addressing the specific needs and challenges of the tea sector in Kenya through targeted research. By conducting this research, the study aims to contribute to the academic literature and provide practical guidance for tea sector stakeholders, policymakers, and researchers interested in leveraging blockchain technology for improved supply chain management.

Overall, the literature review emphasizes the transformative potential of blockchain technology in the tea sector's supply chain management in Kenya. It underscores the importance of transparency, traceability, trust, and efficiency in improving the sector's overall performance and sustainability. The review sets the stage for further research on the development and implementation of a blockchain-based smart contract model specifically tailored to the tea sector in Kenya, aiming to address the identified challenges and improve supply chain management practices.

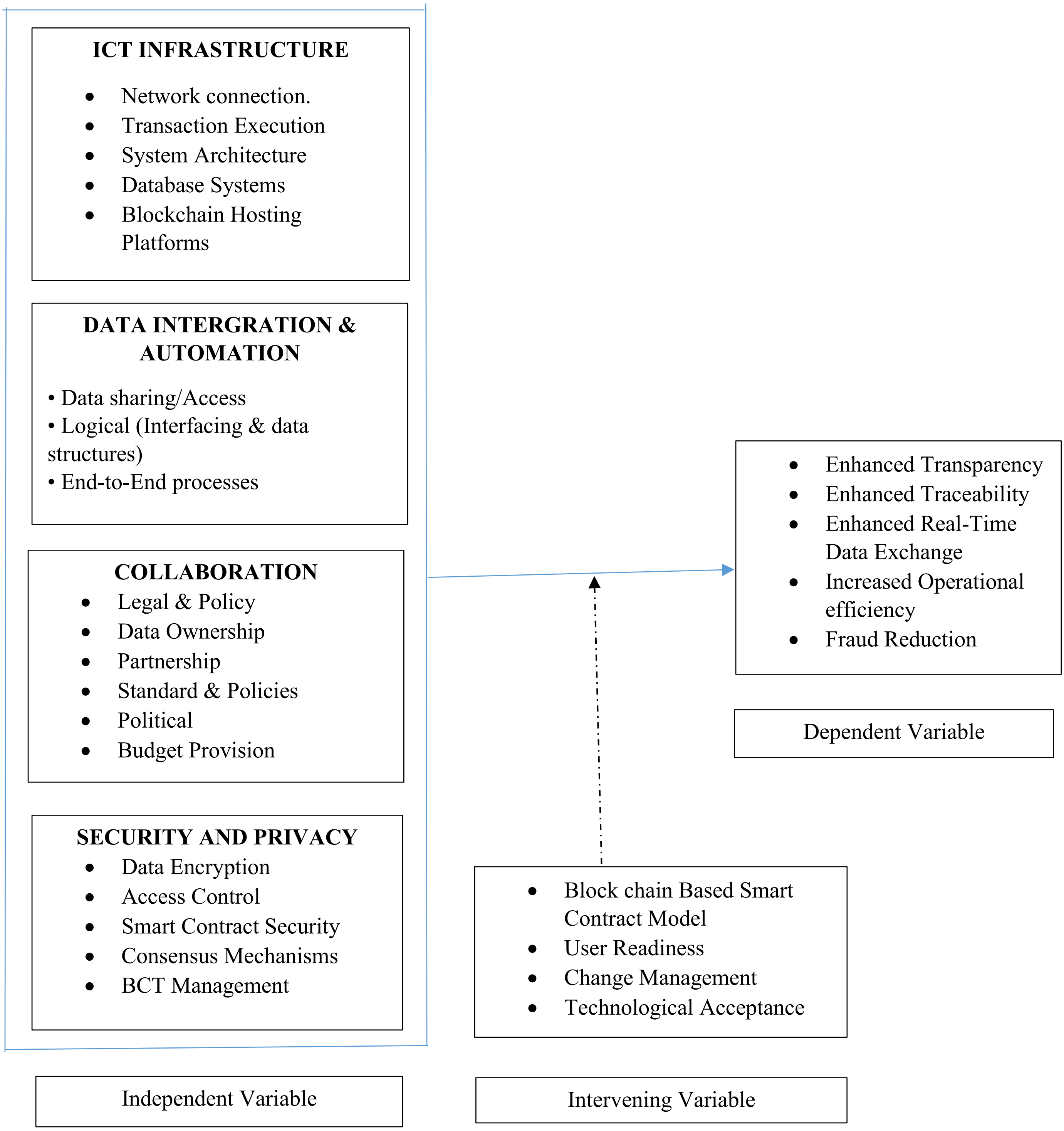


Figure 0.12: Blockchain Based Smart Contract Conceptual Framework

Source: (Author, 2023)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The primary goal of this study was to examine how the KTDA, the primary organization providing services to smallholder tea growers, delivers its system and how those services affect tea production. Generally speaking, primary and secondary data are used. The majority of secondary data pertaining to KTDA procedures is gathered from publicly available literature as well as other publications. The second method examined the effects of the KTDA's data distribution regarding farming of tea by using primary data from questionnaires and interviews.

There are four sections in this chapter. The study design and sampling methods are covered in Section 1; the overall strategy is covered in Section 2; data collection methods are covered in Section 3; and the administration of the research data is covered in Section 4. A synopsis of the study's methodology and ethical considerations concludes the chapter.

3.2 Philosophical Underpinning

The present study considered important assumptions, views, and opinions of the world. Regarding scientific enquiry, the assertion seeks to account for lived experience. (DeCarlo, 2018). Most scholars have classified these underpinnings philosophies as interpretivism and pragmatism (Krauss, 2005; McGuinness, 2011). Other different schools of thought also classify this underpinning into philosophies such as realism, positivism, pragmatism and interpretivism which influences the thinking of the researcher during the research process (Saunders, et al., 2009). The present study adopted a pragmatism approach given that it takes care of a number of thoughts such as strategies, approaches, choices and methodologies. This was chosen because it accepts the use of a mixed research methods and deductive / inductive approaches adopted in this study. These approaches are illustrated in the table below:

Table 0.1: Underpinning Research Philosophies

Philosophy	Research Approach	Research Strategy
Positivism	Deductive	Quantitative
Pragmatism	Deductive / Inductive	Qualitative and Quantitative
Interpretivism	Inductive	Qualitative

3.3 Research Design

A plan and structure of investigation that are developed and used to assist a researcher in answering questions is known as research design (Creswell & Creswell, 2018). A cross-sectional survey approach was used in the study as a model to direct the investigation. In order to provide a "snapshot" of the variables of interest at a particular moment in time, a cross-sectional survey involves a researcher gathering data from a sample selected from the population at one point in time over a brief period of time (Iacobucci & Churchill, 2005). Cross-sectional studies examine the associations between variables by selecting a sizable sample of respondents from the target population, which is predetermined, and then gathering data from the respondents.. The Figure below illustrates the research design process of the present study.

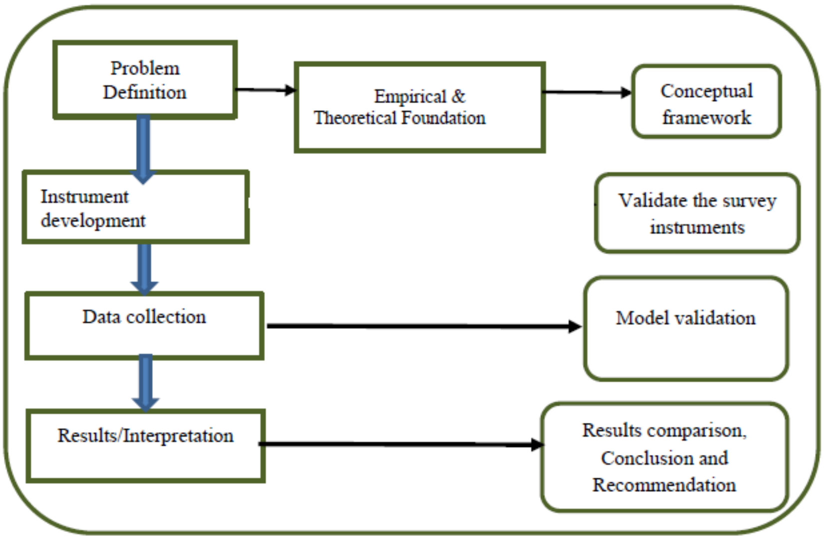


Figure 0.1: Research Process Source: (Iacobucci & Churchill, 2005).

3.3.1 Research Approaches

At the start of any research procedures and plans should be evident which will enable the determination of the design of any research. This will explain in case the research should use an inductive approach or deductive approach. Several authors have postulated that the deductive approach mainly concentrates on using observations and literature which results in two identification of research problem therefore forming patterns formulating questions from which eventually a theoretical framework is developed (Saunders, Lewis, & Thornhill, 2009). This is the approach adopted in the present study. In contrast to the inductive approach which involves data collection or guided by an existing theory from data analysis. The present study focuses on factor analysis theory testing in which theories are fast identified as a framework of answering the research questions. This study has adopted a mixed method approach in which both deductive and inductive approaches are used. The study investigated the use of blockchain technology by various tea processing companies taking in consideration the role of various stakeholders. This led to an extensive literature review from already existing data and hence a triangulated theoretical framework to guide theory formulation. The data collected from this process was tested and validated hence informing how the research questions and hypothesis what answered. This study employed methodological triangulation by integrating both quantitative and qualitative approaches to provide a comprehensive understanding of blockchain adoption in the tea supply chain. The quantitative strand involved the use of structured questionnaires analyzed through Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Structural Equation Modeling (SEM). These methods established the statistical relationships among the independent variables—ICT infrastructure, data integration and automation, collaboration, and security and privacy—and their influence on blockchain adoption.

On the other hand, the qualitative strand relied on in-depth interviews with key stakeholders in the tea supply chain, which generated thematic insights into practical experiences, challenges, and opportunities of implementing blockchain technology. Respondents highlighted issues such as middlemen interference, need for automation, ICT system failures, and the potential of blockchain to enhance transparency, accountability, and efficiency.

Triangulation was achieved by comparing, contrasting, and integrating findings from both quantitative and qualitative strands to enhance the validity, reliability, and transparency of the study. For instance, while quantitative analysis revealed that data integration and automation had the strongest statistical influence on blockchain adoption (H2: $\beta = .970$, $p = .047$), qualitative evidence corroborated this by highlighting stakeholders' urgent call for automation to improve efficiency, transparency, and accountability. Similarly, the significant relationship between ICT infrastructure and blockchain smart contracts (H1: $\beta = .488$, $p = .040$) was reinforced by interview insights pointing to persistent ICT system failures and the need for more robust infrastructure. The positive and meaningful effect of collaboration (H3: β = .843, p = .036) was validated by qualitative accounts stressing the importance of a shared platform accessible to farmers, cooperatives, regulators, and exporters. Likewise, the influence of security and privacy (H4: β = .105, p = .022) was echoed in concerns over data integrity and immutability, showing alignment between statistical associations and real-world experiences. This triangulated approach increased transparency by demonstrating how the "what" revealed by quantitative data aligns with the "why" uncovered through qualitative insights, ensuring that the hypothesized model was not only statistically valid but also grounded in practical realities of the tea supply chain. Consequently, the integration of both datasets enriched interpretation, improved trust in the findings, and confirmed that the hypothesized model incorporating ICT infrastructure, data integration, collaboration, and security satisfactorily fits the dynamics of blockchain adoption in tea supply chain management.

3.3.2 Research Strategy

The research strategy is a fourth layer of Sanders research onion (Saunders et al, 2009).. Any service strategy is usually associated with a deductive approach (Saunders et al, 2009). The present study adopted this strategy since it most frequently answers where, what, who, how much and how many of any study (Al Zefeiti & Mohamad, 2015). In view of the above arguments the present study adopted a cross-sectional utilization of the mentioned strategies. A descriptive survey was deemed an appropriate option.

3.4 Location of the Study

Most tea is grown in high altitude regions with year-round access to sufficient rainfall. Parts of Kenya's Rift Valley, Central, Eastern Kenya and upper Nyanza—are home to tea plantations. Here is the factory distribution: Nyanza 9, Eastern 11, Central Kenya 26, the Rift Valley 8, and the Western one.

For research purposes, data was collected mainly from farmers and factories management. The key areas for collecting data were KTDA owned factories and the privately owned factories. The selected stakeholders in those particular factories constituted the sample size from where the response was retrieved. Data collected from three selected counties factories was a reflection of the whole country. The reason why data was collected in these counties is because of the various institutions under them both privately owned and KTDA owned factories.

3.5 Study Population

The total group of units for which inferences are to be drawn from the study data is known as the target population. The units for which the study's conclusions are intended to be generalized are referred to as the target population (Stimson, 2007). Tea Manufacturers in Kenya are divided into four main sections namely; The KTDA managed which has 72 factories, Secondly, Large Scale Tea Manufacturers which has four companies namely Ekatarra Tea Kenya (Owns 8 tea factories), Finlays Kenya Limited (Owns 6 tea factories), Williamson Tea Kenya Limited (owns 4 factories) and Eastern Produce Kenya Limited (Owns 7 tea factories) (KTDA, 2022). Thirdly, Medium Scale which has a total of 43 factories and finally specialty which has a total of 42 tea factories. Small-scale tea farmers (out-growers) and KTDA factory management employees, in particular the Field Service Coordinator, ICT, Sales Representatives-Auction and managers, were the study's target audience. The table below shows the population of respondents in various Tea Processing companies from where the sample data was collected. A total of eight Tea Processing companies formed part of the study with a total population of 758 staff.

Table 0.2: Study Population

S/N	MANUFACTURERS	COMPANIES	REGISTERED BUYING CENTRES	FARMERS (OUT-GROWERS)	FACTORY MANAGEMENT	MANAGER/ SALES REPRESENTATIVE AUCTION	ICT OFFICERS	TOTAL
1	KTDA MANAGED	Kaptumo Tea Factory	77	70	33	20	10	210
2	Large Scale Manufacturers Finlays Kenya Limited	Changana Tea Factory	67	56	20	10	5	158
3	Large Scale Manufacturers Ekaterra Tea Kenya PLC (Unilever Tea Kenya Ltd)	Kericho tea factory	40	62	18	20	15	155
3	Large Scale Manufacturers Williamson Tea Kenya Limited	Kaimosi Tea Estate	7	19	15	7	4	52
4	Large Scale Manufacturers Eastern Produce Kenya Limited	Savani Tea Factory	16	30	11	10	2	53
5	Medium-Scale Manufacturers	DL Koisagat Tea Estate	7	25	10	10	2	54
6	Medium-Scale Manufacturers	Nandi Tea Estates Ltd	3	10	8	7	2	32
7	Specialty	Kericho Tea East Africa Ltd	7	15	10	9	3	44
		Total	**224**	**287**	**125**	**93**	**43**	**758**

(Source: KTDA, 2023)

Table 3.2 shows that Buying Centers, Farmers (Out-Growers) and Factory Management formed a larger population in all the companies selected in this study. Furthermore, it shows that Managers and Sales Representatives together with ICT officers formed the smallest population in all the companies. The population of farmers was chosen based on the farmers who had android phones registered to the company-farmer tracking application. Therefore the representative farmer population was purposive in nature.

3.6 Sampling Technique and Sample Size

3.6.1 Sampling Techniques

The study employed a combination of clustered, stratified, and random sampling techniques. Given the dispersion and regional distribution of enterprises across Kenya, clustered sampling was first applied to group enterprises based on their geographical location. Within these clusters, stratified sampling was used to ensure representation of different categories of enterprises, after which random sampling was employed to select respondents from each stratum. This study was limited to Meru, Nandi, and Kericho counties because they are among the leading tea-producing regions in Kenya and account for a significant share of national output. Their inclusion provided a balanced representation of both large-scale estates and smallholder cooperative systems, thereby capturing the diversity of operations in the tea supply chain. The selection of these counties also ensured that variations in farming practices, governance structures, and market linkages were reflected, making the findings relevant and broadly generalizable to other tea-growing areas.

In addition, focusing on three counties offered practical advantages. Conducting a nationwide study across all tea-producing regions would not have been feasible given time, financial, and logistical constraints. Narrowing the scope allowed the application of rigorous sampling techniques—clustered, stratified, and random sampling—while keeping the study manageable. It also enabled more detailed data collection and analysis, thereby strengthening triangulation and providing reliable insights into the tea supply chain dynamics. Selecting the Tea Buying Centers involved the use of stratified sampling. This made sure that the sample was distributed uniformly within the factory's legal jurisdiction. To offer a fair selection process, farmers were chosen by random sampling. It was assumed that farmers, representing a wide range of characteristics, are dispersed equally and accurately represent the total population. These groups' data offered an accurate representation of the sample.

The population was grouped into four strata namely Field Service coordinator, Factory management staff (ICT Team), and Sales Representatives-Auction/Managers and small-scale famers. According to Kothari, stratified sampling is typically used to obtain representative samples when the population from which the sample is to be obtained is not homogeneous. The population is separated into multiple subpopulations, referred to as strata, that are each more homogeneous than the population as a whole under stratified sampling. Purposive sampling will be used in each stratum to select respondents who will be thought to be sufficiently reliable for the study after the groups have been stratified. In order to effectively accomplish the goals of the research, respondents who are highly informative enough to respond to research questions will be chosen, according to Yin (2003). For the KTDA factory management staff especially the ICT' strata the purpose of the selection is because they are aware of the information systems used and can propose the appropriate technology to be used for assisting in transparency of trade in the various factories. This study considered that identified Factory Production manager have experience in the production process and tea trade. For the ICT stratum, the study randomly selected non-experts and purposively chose expert users. Out-grower farmers provided valuable insights into trade processes and offered proposals to address the challenges they face.

3.6.2 Sample Size

According to Kothari, stratified sampling is typically used to obtain representative samples when the population from which the sample is to be obtained is not homogeneous. The population is separated into multiple subpopulations, referred to as strata, that are each more homogeneous than the population as a whole under stratified sampling. Stratified purposive sample was employed because the target population's respondents were heterogeneous in terms of their exposure, orientation, and academic background. Assume N1 and N2 units, respectively, are the fragmented groups from the two targeted tea companies. The target stratum is formed by N1 + N2 = N, as shown below, since these groupings, also known as strata, together compromise the entire population. The targeted company's values comprise the table 3.3 sampling frame. The sample size was determined using the following statistical procedure in order to obtain the necessary data with the least amount of sampling error.

Determining the Final Sample Size

Where e is the degree of accuracy (let's say 95% confidence level (±5% precision), N is the target population, and n is the sample size. The formula for the sample size that was used in this study is given below. The confidence interval of 85% with significance level of 15% was used.

$$n = \frac{z^2.p.q}{e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

z = 1.96 (standard variate for a given confidence level) p = sample proportion for of successes

q = 1-p

n = size of the sample

e = margin of error (Kothari, 2004)

Adjusting for a finite population: $n_a = \frac{nN}{n+N}$

Where:

n = size of the sample N = population size

The level of significance is 15% ± 5% Therefore:

p = 0.15

q= 0.85 N=758

The population in table 3.2 formed the basis for which sample representative population was selected to form part of the study. Table 3.3 below shows the sample frame for the sample size obtained from the main population.

Table 0.3: Sampling Frame

S/N	MANUFACTURERS	COMPANIES	REGISTERED BUYING CENTRES	FARMERS (OUT-GROWERS)	FACTORY MANAGEMENT	MANAGER/ SALES REPRESENTATIVE AUCTION	ICT OFFICERS	TOTAL
1	KTDA MANAGED FACTORIES	Kaptumo Tea Factory	16	14	7	4	2	43
2	Large Scale Manufacturers Finlays Kenya Limited	Changana Tea Factory	13	12	4	2	1	32
3	Large Scale Manufacturers Ekaterra Tea Kenya PLC (Unilever Tea Kenya Ltd)	Kericho tea factory	8	12	4	4	3	31
3	Large Scale Manufacturers Williamson Tea Kenya Limited	Kaimosi Tea Estate	2	3	3	2	1	11
4	Large Scale Manufacturers Eastern Produce Kenya Limited	Savani Tea Factory	3	4	2	2	1	12
5	Medium-Scale Manufacturers	DL Koisagat Tea Estate	2	4	2	2	1	11
6	Medium-Scale Manufacturers	Nandi Tea Estates Ltd	1	2	1	2	1	7
7	Specialty Kakuzi	Kericho Tea East Africa Ltd	2	3	2	2	1	9
		Total	**47**	**53**	**25**	**20**	**11**	**156**

Source: (Author, 2023)

3.7 Data Collection Methods

A data collection instrument is a device used to collect data objectively and systematically for research purposes. Questionnaires and interview schedules were used as data gathering instruments. Questionnaires are paper and pencil data gathering instruments that respondents complete for the goal of a research project (Abawi, 2013). Structured questionnaires are chosen because they capture a variety of viewpoints on the study subject, according to Dempsey (2004). As many respondents as feasible received follow-up phone calls in an effort to boost response rates.

3.7.1 Questionnaires

As stated in Appendices D, E, and F, questionnaires were given to farmers, field service coordinators, and factory managers in order to gather data. A five-point Likert scale was employed for the closed-ended questions: 1 for Strongly Agree, 2 for Agree, 3 for Not Sure, 4 for Disagree, and 5 for Strongly Disagree. Using the flexibility of the Likert scale, respondents indicated how much they agreed with each statement (Yin, 2003).

Furthermore, the questionnaire was employed as a data collection device for the study due to the advantages cited by (Kumar, 2011). For starters, it is less expensive since it saves time, which is a valuable human and financial resource for this project given its restricted funding. Second, it provides high anonymity because there is no face-to-face interaction between respondents and interviewers, which is desirable for this study. The third advantage is that it is a practical technique to reach a big number of people or a geographically diverse group, which is appropriate for this study because the target audience is heterogeneous. Fourth, a responder felt more comfortable answering a questionnaire than engaging in an interview. Finally, utilizing a questionnaire with closed-ended questions facilitates data processing and is therefore appropriate for this study.

3.7.2 Interviews

This study used interviews to obtain data from respondents, specifically senior cadre officers from the ICT directorates in the four counties who are members of the information systems expert staff category. The highest cadre officers were targeted because they oversee the ICT directorates, which are in charge of acquiring, managing, and maintaining information systems at both factory levels. The aim of conducting the interview was to evaluate the process of trade used by the current system. One on one interviews was used to cross-validate and check the consistency of questionnaires responses.

The interview guide included semi-structured questions, which were preferred due to their flexibility (Kothari, 2004). In accordance with the benefits stated by (Kothari, 2004), this study attempted to use an interview approach since it would provide more in-depth information, which would be useful for this study. Furthermore, this method provides additional flexibility because the option to restructure questions is always available, particularly in the case of unstructured interviews, making it suitable for use in this study. The interview was conducted at a time convenient for the ICT officer. The interview guide is presented in Appendix F.

3.7.3 Addressing study objectives.

Objective I: To assess the current ICT infrastructure, data integration challenges, and extent of process automation within the Kenyan tea supply chain

To achieve this objective, the researcher conducted a review of both primary and secondary sources. Literature, policy reports, and industry assessments were examined to determine the extent of ICT adoption, integration challenges, and the level of automation in tea supply chain processes. The researcher sought to establish gaps in ICT infrastructure, the degree of data standardization, and the effectiveness of automation systems in supporting operational efficiency.

The questionnaire covered items such as: the availability and adequacy of ICT resources (e.g., computers, internet connectivity, ERP systems), the extent of data integration across different tea value chain actors, and the level of automation in processes like tea collection, weighing, transportation, payments, and quality control.

Objective II: To analyze collaboration dynamics, legal frameworks, and policy constraints affecting transparency and accountability in the tea sector

To address this objective, the researcher analyzed policy and legal documents regulating the tea industry, focusing on governance frameworks, compliance requirements, and trade regulations. The study further examined collaborative relationships among stakeholders such as smallholder farmers, cooperatives, factories, regulators, and buyers. Reports from government agencies and industry associations were reviewed to understand how policy constraints and institutional frameworks affect transparency and accountability.

The questionnaire included questions such as: the level of collaboration between farmers, cooperatives, and buyers; the influence of regulatory policies on information sharing; the adequacy of existing legal frameworks in promoting accountability; and the barriers faced in enforcing compliance and transparency within the sector.

Objective III: To develop a blockchain-based smart contract model that incorporates data automation, security and privacy considerations for enhancing supply chain operations

To accomplish this objective, the researcher first synthesized findings from Objectives I and II, identifying critical gaps in ICT infrastructure, collaboration, and policy compliance. Secondary data from best practices in blockchain adoption in other agri-supply chains were studied. A draft conceptual model was developed, integrating blockchain smart contracts with considerations for security, privacy, and traceability.

The model development process involved: (1) mapping existing pain points in the tea supply chain, (2) defining smart contract functionalities such as automatic payment execution, data authentication, and traceability mechanisms, and (3) embedding security and privacy measures to safeguard sensitive data. Respondents were asked to give feedback on the practicality, security, and usability of the proposed blockchain model.

Objective IV: To test and validate the proposed blockchain-based smart contract model for improving real-time data exchange, traceability, and transparency in the Kenyan tea supply chain

For this objective, the researcher conducted a mixed-methods validation of the proposed blockchain-based smart contract model. Quantitative analysis using Structural Equation Modeling (SEM) confirmed that ICT infrastructure, data integration, collaboration, and security significantly influence blockchain adoption in the tea supply chain, with strong model-fit indicators supporting the framework's reliability. Qualitative feedback from stakeholders further validated the model's effectiveness in reducing record mismatches, minimizing paperwork, and improving communication, payment timelines, and compliance. Overall, the model proved effective in enhancing efficiency, transparency, and traceability within Kenya's tea supply chain.

The questionnaire included items assessing: whether the model improved real-time data sharing, whether it enhanced traceability of tea products across the value chain, whether it reduced errors or duplication, and whether it promoted transparency and accountability. Respondents were also asked about the perceived challenges and opportunities in adopting the model at scale. In conclusion, the objectives, research questions, and hypotheses are well-connected, forming a logical flow that guides the study's investigation into the adoption of blockchain technology in tea supply chain management in Kenya. Each element contributes to the overall goal of identifying factors that influence blockchain adoption and developing a smart contract model for the tea sector's supply chain.

3.8 Data Analysis Procedures

For the purpose of analysis of data collected in this study, SPSS Version 25 was used for descriptive statistics. For qualitative data, the researcher conducted thematic analysis.

In this study, data analysis was carried out with the support of distinct methodologies tailored to the nature of the collected data. Quantitative data, consisting of numerical information, underwent rigorous examination using SPSS Version 25. This process involved initial data cleaning to rectify errors and ensure consistency in coding and formatting. Subsequently, descriptive statistics such as means, medians, and standard deviations were computed to summarize central tendencies and variations within the dataset. Inferential statistics, including t-tests and factor analysis, were employed to test hypotheses and ascertain significant relationships or differences between variables. Visual representations such as charts and graphs were also generated to aid in interpreting patterns discerned from the statistical analyses.

Conversely, qualitative data underwent thematic analysis to derive insights from non-numerical information. Researchers immersed themselves in the qualitative data, initially familiarizing themselves with its content before generating initial codes that captured meaningful segments of text. These codes were then organized into overarching themes through a process of constant comparison and refinement, highlighting recurring patterns and connections within the dataset. Each identified theme was carefully defined and supported with illustrative quotes or excerpts from the data, culminating in a comprehensive narrative that synthesized findings and contextualized them within the broader research framework. Integration of both quantitative and qualitative analyses facilitated a more holistic understanding of the research topic, leveraging the strengths of each approach to enrich interpretations and implications drawn from the study.

Table 0.4: Summary of Methodology

Objective	**Research Question**	**Hypothesis**	**Data Collection Method**	**Data Analysis Procedure**
To assess the current ICT infrastructure, data integration challenges, and extent of process automation within the Kenyan tea supply chain.	What is the state of ICT infrastructure in the Kenyan tea supply chain, and how ready is it for blockchain integration in terms of data integration and process automation?	H1: ICT infrastructure readiness, data integration, and process automation have a positive and significant influence on the adoption of blockchain-based smart contracts in the Kenyan tea supply chain.	Literature Review, Questionnaires Interviews	Descriptive Statistics, Content Analysis, Exploratory Factor Analysis (EFA)
To analyze collaboration dynamics, legal frameworks, and policy constraints affecting transparency and accountability in the tea sector.	How do collaboration dynamics, legal frameworks, and policy constraints influence transparency and accountability in the Kenyan tea sector?	H2: Collaboration among stakeholders, as well as supportive legal and policy frameworks, positively affect transparency and accountability in the adoption of blockchain-based smart contracts in the tea supply chain.	Literature Review Questionnaires Interviews	Content Analysis, Descriptive Statistics, Multiple Regression
To develop a blockchain-based smart contract model that incorporates security and privacy considerations for enhancing supply chain operations.	How can a blockchain-based smart contract model that incorporates security and privacy considerations be developed to address inefficiencies in the tea supply chain?	H3: Security and privacy considerations significantly influence stakeholders' willingness to adopt a blockchain-based smart contract model in the Kenyan tea sector.	Questionnaires Interviews	Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), Structural Equation Modeling (SEM)
To test and validate the proposed blockchain-based smart contract model for improving real-time data exchange, traceability, and transparency in the Kenyan tea supply chain.	To what extent can the proposed blockchain-based smart contract model be tested and validated to enhance real-time data exchange, traceability, and transparency in the Kenyan tea supply chain?	H4: A blockchain-based smart contract model significantly improves real-time data exchange, traceability, and transparency within the Kenyan tea supply chain.	Questionnaires Interviews	Confirmatory Factor Analysis (CFA), Path Analysis, Multiple Linear Regression

Source: Research Data (2025)

The data was analyzed via structural equation modeling (SEM); the multivariate method that measures the multivariate causal relationships. The study utilized this method along with factor analysis (exploratory factor analysis (EFA) and confirmatory factor analysis (CFA)) and path analysis and multiple linear regression statistics (Fan et al., 2016) to assist in making an inferential analysis of the Blockchain Based Smart-Contract model of a supply chain management. Factor analysis was selected because this study as the study is a flexible tool which helps the researcher in investigating the latent structure of his or her data and reduces the complex relationship and provides an understanding of the latent constructs which cause the other variables to behave as they do. It was also applied in the validation of constructs of the study. It evaluated the validity of theoretical constructs through the evaluation of the effectiveness of the observed variables in relation to the proposed underlying factors. It also assisted in testing and polishing theoretical constructs.

Part path analysis measured the causality between the various factors or variables. EFA statistical technique, assisted in establishing the relationships between the model variables. CFA conversely, measured and tapped latent constructs with other variables and had the highest percentage of variance with the related variables. Also, it factored the correlations existing in the dataset. The analysis involved the use of the multiple linear regression algorithm to model the linear relationship between Blockchain Smart Contracts Tea Supply chain Management and tea management and a combination of independent variables (ICT Infrastructure, Data Integration, Collaboration, Security and Privacy, and Automation).

Thus, there are two parts of the SEM (the structure and the measurement). The latter is viewed indirectly and typically applied to determine the former (Kumar and Upadhaya, 2017). Moreover, the measurement model generates empirical data whereas the structural model developed using path analysis diagram was applied to either confirm or disapprove the hypothesis. SEM is not, however, always performant in the predictive performance as opposed to understanding and interpretation. Moreover, it possesses numerous coefficients across numerous directions, therefore, making them very complicated (Korstanje, 2021). Therefore diagram format is most suitable in representing, interpreting and knowing what each model entails. The constructs in this research were defined and subsequently CFA test was carried out to test manifest factors of each construct. As a result, the measurement model (path analysis) which proved that there were relationships was created and CFA was utilized to test the model validity by comparing the goodness of fit values of indexes like CFI, GFI, TLI, RMSEA and chi-square test values. Lastly, multiple linear regression model estimation was done. Both moment structures were analyzed by use of (AMOS)-26.0 and SPSS version 26..

3.8.1 Validation and Assessment of the Proposed Research Model

A three-step statistical method was used for hypothesis testing, including 'exploratory factor analysis (EFA)', 'confirmatory factor analysis (CFA)', and SEM (Structural Equation Modelling). EFA, a statistical method, was useful in discovering the interrelationships between the model variables. It created a more transparent construct model by analyzing the type and pattern of constructs and lowering the number of constructs from a vast set of latent constructs. The key advantage of using CFA in SEM for increased clarity is that the validity of the predicted construct model can be evaluated using multiple goodness-of-fit indices. To assess the major changes in the CFA model, SEM is applied by evaluating moment structures using (AMOS)-26.0 software factor loading estimates and path coefficients. The Confirmatory Factor Analysis (CFA) method was applied to validate the model. Prior to running the structural model, Confirmatory Factor Analysis (CFA) was employed to assess the relationships between different parameters. The SPSS-Amos software facilitated the evaluation of the statistical significance of each hypothesis by analyzing path coefficients, represented as standardized betas. The study utilized a sample size of 156, and the samples were analyzed to determine the significance levels of the relationships between constructs. The path coefficients derived from the structural models were subsequently presented.

3.9 Pilot Study

Before conducting the main study, a pilot study was undertaken to refine methodologies and assess feasibility. The pilot study involved a small-scale implementation of data collection procedures and analysis techniques to identify and rectify potential challenges and ambiguities in the research design. The pilot study involved 62 randomly selected participants from 3 tea processing factories. These factories did not form part of the final data collection. For the quantitative aspect, a subset of participants or data points was selected to test data collection tools and procedures. This involved administering surveys or conducting interviews to ensure clarity of questions and ease of response, while also checking for any logistical issues in data handling and processing using SPSS.

Simultaneously, the qualitative pilot study tested the thematic analysis approach on a subset of qualitative data. Researchers engaged with a smaller sample of transcripts or documents to refine the coding process, validate initial codes, and iteratively develop themes. This process aimed to enhance the reliability and validity of the qualitative analysis methodology, ensuring that themes identified were robust and reflective of the data.

Throughout the pilot study, feedback was solicited from participants and researchers involved, enabling adjustments to be made to data collection instruments, interview protocols, or coding frameworks as necessary. Insights gained from the pilot study informed refinements to the main study's procedures, contributing to the overall rigor and effectiveness of data collection and analysis methods deployed in the subsequent full-scale investigation.

3.10 Validity and Reliability

3.10.1 Validity

The researcher relied on the endorsements of Waltz and Bausell to determine the content validity. The researcher employed the content validity index (CVI) in order to determine the validity of the existing information. The items were rated by experts based on a Likert scale of four points in relevance and transparency. All the items had a reasonable CVI of 0.782 or higher. (Abawi. 2013). The design of the instrument was reviewed by expert individuals in organizations involved in the use of Blockchain Technology, and scholarly groups to ensure that the design reflected the measurement of the items needed to be undertaken in the study.

Upon attaining this measurement, the researcher used a series of analytical procedures. The researcher applied internal and external validity tests to establish whether the findings of the study could be applied to other similar situations. Internal validity involves establishing the cause relationship between the variables like the dependent and the independent variables.

As soon as data were collected and coded preliminary assessments of data validity were conducted to determine the quality and accuracy that they have in measuring the constructs to the structural equation model (SEM). The validity is the faithfulness of the test result, and it can be interpretable accurately (Jain and Chetty, 2021). The correlation between the responses of different factors of each construct was determined with the help of convergent validity. Moreover, it shows whether the manifested factors are related to latent construct, which is measured. High results are observed when the factors are strongly linked to their latent constructs (Hamid, 2017). To determine convergent validity, the average variance extracted (AVE) was evaluated because it showed how much items are shared by constructs and then thresholds were developed based on AVE =0.50 and above respectively (Sujati, 2020; Ahmad, 2016). The AVE of all the manifest factors of each latent construct was greater than.5. The result of convergent validity is presented in Table 3.6.

Table 0.5: Convergent Validity using (AVE)

Success Factor	AVE
BCTmanagement <--- ICTinras	.740
BCTmanagement <--- Dintegration & Automation	.647
BCTmanagement <--- Collaboration	.489
BCTmanagement <--- Security	.953

3.10.2 Reliability

The final stage of the questionnaire's design, where reliability was assessed, was completed by the researcher before it was distributed. The method used by the researcher to do that was to compute the Cronbach's alpha coefficient, a measure of internal consistency that ranged from 0.0 to 1.0 with a cut-off point of 0.7 (Yin, 2003). Even if the same data were gathered by a different researcher, the study ensured results were repeatable.

The consistency of the measuring outcomes was tested to ascertain the likelihood of its reliability. This was done using composite method to reveal how well factors underlying construct constructs behaved in structural equation modeling (Karakaya-Ozyer, 2018). This was conducted using confirmatory factor analysis (CFA). The estimation was based on the interpretation of the factor loading values for all the manifest factors for each latent construct (Lerdpornkulrat et al., 2017). A factor should have composite reliability (CR) value greater than 0.5 to be considered reliable and plausible (Tentama & Anindita, 2020). Therefore, all the manifest factors that had reliability coefficient equal or greater than 0.7, for each latent construct were deemed good. Comparatively, the CR values of all the constructs surpassed the expected benchmark. However, the AVE of collaboration) construct is 0.489 < 0.50 but is closer and plausible.

Table 0.6: Composite Reliability (CR)

Success Factor	CR
BCTmanagement <--- ICTinfras	.842
BCTmanagement <--- Dintegration & Automation	3.711
BCTmanagement <--- Collaboration	.719
BCTmanagement <--- Security	2.292

3.10.3 Normality Testing

To assess if a data set is modeled for a normal distribution or a nearly normal distribution, normality tests are utilized. (Creswell & Creswell, 2018). Excess kurtosis and skewness were utilized in this investigation to test the data's normalcy. The skewness value may be zero, negative, or even undefinable. The data are exactly symmetrical if the skewness is 0. The data distribution for this study was 0.01, which means that it was almost symmetrical and only slightly skewed to the right. The distribution is significantly skewed if the skewness falls between -0.5 and +0.5. Kurtosis and skewness values of +/-2 and +/-4 at 0.05 significance, respectively, may be employed as reference values for the determination of considerable non-normality, according to (West, Flinch, & Curran, 1996).

Table 0.7: Test of Normality

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
BCTmanagement← ICTInfras	.110	173	.291	.966	173	.152
BCTmanagement← DIntegration& Automation	.065	173	.428	.992	173	.182
BCTmanagement← Collaboration	.117	173	.304	.949	173	.121
BCTmanagement← Security	.083	173	.116	.984	173	.239
Smart BCT	.188	173	.121	.912	173	.211

a. Lilliefors Significance Correction

The KS results in Table 3.7 show that all components were normally distributed and hence not statistically significant at the 5% level of significance, implying that the data for the respondents' questionnaire had a normal distribution. In contrast, the SW results in Table 3.7 demonstrate that all components were normally distributed and thus not statistically significant at the 5% level of significance. The findings indicate that we accept the null hypothesis that the data for respondents' questionnaires came from a normal distribution and was normally distributed.

3.10.4 Ethical Issues

All oversight and organizational clearances for the study were handled by the ethical review boards of the participating institutions. The Graduate School and School of Computing and Informatics at MMUST provided key clearances for the work (see Appendix C). In addition, NACOSTI gave permission to conduct research (see Appendix G).

A letter of introduction from MMUST was obtained to facilitate data collection; it explained the study's aims and emphasized the necessity of cooperating with the researcher. The researcher also acquired a letter of endorsement from the MMUST Research ethics review board.

3.11 Summary

This chapter outlined the methodological framework for investigating blockchain adoption in the tea supply chain. Anchored on a pragmatic research philosophy, it combined deductive and inductive approaches within a mixed-methods design that integrated quantitative surveys and qualitative interviews under a cross-sectional strategy. The study targeted 371 stakeholders, including the Tea Board of Kenya, factory managers, cooperative leaders, government officials, exporters, and buyers, from which a representative sample of 156 was determined using Kothari's formula. Data were collected through structured questionnaires and interviews, with instruments refined through pilot testing, reliability confirmed via Cronbach's alpha, and validity established through Exploratory and Confirmatory Factor Analyses, Composite Reliability, and Average Variance Extracted. Analysis employed descriptive statistics (means, frequencies, standard deviations) and inferential techniques, including regression analysis, Structural Equation Modeling (SEM), and hypothesis testing, with robustness ensured through normality, multicollinearity, and model fit tests. Ethical standards, including informed consent, confidentiality, and academic integrity, were upheld throughout.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1 Overview

This chapter discusses the factors influencing blockchain adoption in tea supply chain management, focusing on developing a blockchain-based smart contract model. It explores enhancement strategies for implementation, grounded in theoretical frameworks. The study's objectives, detailed in Chapter 1, include addressing transparency challenges, exploring blockchain provisions, identifying key factors for blockchain-based models, and developing a smart contract model for tea supply chains.

4.2 Respondents Distribution

4.2.1 Response Rate

Table 4.1 shows the response rate of the respondents who participated in study. The participants were drawn from different companies and within those companies they fell in different categories. The categories included Buyers, Farmers, Sales Representatives, Factory Management and ICT Officers. The overall response rate to study was 89% which according to Fincham (2008) in which any value above 70% response rate is considered good representation of views of the respondents.

Table 0.1: Summary of Response Rate

Company	Buyers	Farmers	Sales Reps	Factory Management	ICT Officers
Uniliver	34%	26.4%	20%	28%	18.2%

James Finley	27.7%	22.6%	10%	16%	27.2%
KTDA	17%	22.6%	10%	16%	91%
Nandi Tea Estate	4.3%	7.5%	10%	8%	9.1%
DL Koisagat Tea Estate	6.4%	7.5%	10%	8%	9.1%
Kakuzi	4.3%	2%	10%	4%	9.1%
Eastern Produce Kenya Companies	2%	5.7%	10%	8%	9.1%

The sample respondents were drawn from Uniliver, James Finley, KTDA, Nandi tea estate; DL Koisagat tea estate, Kakuzi, and Eastern produce Kenya companies. They composed of buyers 47 (30.1%), farmers 53 (34%), factory management team 25 (16%), sales representatives 20 (12.8%), and company ICT officers 11 (7.1%). In terms of distribution of buyers, Uniliver, James Finley, KTDA, Nandi tea estate; DL Koisagat tea estate, Kakuzi, and Eastern produce Kenya had 34%, 27.7%, 17%a, 4.3%, 6.4%, 4.3%, 2%, and 4.3%. Farmers sample were 26.4% Uniliver, 22.6% for James Finley and KTDA, 5.7% for Eastern produce Kenya, 7.5% for Nandi and DL Koisagat tea estates, and 2% for Kakuzi. On the other hand, factory managers' proportions were 28% Uniliver, 16% for James Finley and KTDA, 8% for Nandi, DL Koisagat, and Eastern produce Kenya, and 4% for Kakuzi. Sales representatives' samples were 20% Uniliver and KTDA and 10% each for all other remaining six companies. Lastly, ICT officers' distribution was such that Uniliver had 18.2%, KTDA 27.2%, and the other six firms had 9.1% respectively.

The data shows in table 4.1 shows that Uniliver, James Finley and KTDA contributed a larger percentage of the respondents compared to other companies which implies that the companies had bigger populations compared to other companies. It further shows that all companies had comparable fewer ICT officer and management officials and therefore the findings of the study largely dependent of the respondents from Farmers, buyers and Sales Representatives who interact with the system to a greater extent in their operations.

4.3 Respondents Demographic Data

The respondents were asked to give information about themselves with regard to Gender, Age, and Level of Education. The results are presented in Table 4.2.

Table 0.2: Respondents Demographic Data

VARIABLE		Frequency	Percent%
Gender	Male	96	61.5
	Female	60	38.5
Age	Below 30 Years	20	12.8
	31 - 40 Years	32	20.5
	41 – 50 Years	54	34.6
	51 – 60 Years	32	20.5
	Above 60 Years	18	11.5
Level of Education	Ph. D	7	4.5
	Masters	21	13.5
	Degree	59	37.8
	Diploma	44	28.2
	Others	25	16.0

From table 4.2, majority of the respondents were male (61.5%) while female were 38.5%. Most respondents were between 41-50 years represented by 34.6% while minority were those above 60 years as represented by (11.5%). Furthermore, most respondents were degree holders as represented by 59 (37.8%) while minority were PhD holders 7 (4.5%). The demographic data confirms that the sample captured a wide range of perspectives across gender, age, and education. It demonstrates that responses came from individuals well-positioned to understand organizational and technological dynamics in the tea supply chain. These demographics also provide a basis for interpreting variations in blockchain adoption—e.g., whether age, gender, or education influences perceptions and readiness.

4.4 Descriptive Statistics

4.4.1 Adoption of Blockchain Platform in Tea Supply Chain

Table 4.3 shows the levels of adoption of Blockchain Technology in the operations of tea supplies amongst different companies. The respondents varied in opinion on the adoption of blockchain platform in tea supply chain but generally felt was a good idea. 77.4% agreed that there should be a blockchain based transparency model using smart contracts in the tea supply chain management, only 15.5% disagreed while 7.1% were neutral. Additionally, 76.2% agreed that blockchain based transparency model will improve trust and verification as 14.8% were not convinced while 9% were neutral. When asked about the use of ICT technologies and how it plays a vital role in the supply chain management in terms of data sharing, 80.6%% affirmed so, 11.6% were noncommittal as 7.8% disagreed. Furthermore, 79.4% felt that the overall accuracy of supply chain management will improve once the smart contract blockchain based is in place, 7.7% disagreed as 12.9% remained neutral. On the question about the duplication during generation and recording of data once blockchain model is implemented, 36.9% agreed, 49.1% disagreed and 14% were noncommittal. When asked about the need of adopting a common data identifier during recording of the farmers' data, 77.4% approved the idea, 12.3% did not, as 10.3% stayed neutral.

Table 0.3: Adoption of Blockchain platform

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
There should be a blockchain-based transparency model using smart contracts in the tea supply chain management	45.6%	31.8%	7.1%	12.1%	3.4%
Blockchain-based transparency model will improve trust and verification	47.1%	29.1%	9.0%	12.8%	2.0%
ICT Technologies play a crucial role in supply chain management and data sharing	51.8%	28.8%	11.6%	6.8%	1.0%
Overall accuracy of supply chain management will improve once the smart contract blockchain-based model is implemented	50.2%	29.2%	12.9%	6.3%	1.4%
There is duplication during generation and recording of data	12.8%	24.1%	14.0%	39.8%	9.3%
There is a need to adopt a common data identifier during recording of the farmers' data	41.9%	35.5%	10.3%	9.0%	3.3%

Source: Research Data (2023)

As per Table 4.3, the majority of respondents (77.4%) agreed that there should be a blockchain-based transparency model using smart contracts in the tea supply chain, with 15.5% expressing disagreement. This suggests that many stakeholders believe there is currently a lack of transparency in the operations and technologies applied in managing the supply chain. Additionally, most respondents (80.6%) agreed that *ICT technologies* play a crucial role in supply chain management and facilitate data sharing, indicating a strong preference for incorporating efficient and reliable technologies into tea supply chain processes.

Moreover, the majority of respondents (79.4%) agreed that the overall accuracy of supply chain management would improve once the blockchain-based smart contract model is implemented, reinforcing the belief that blockchain could significantly enhance the operational efficiency and transparency of the supply chain.

On the issue of data duplication, 36.9% of respondents agreed, while 49.1% disagreed, suggesting that the issue may not be pervasive but is still a concern for some. Furthermore, there is strong agreement (77.4%) that adopting a common data identifier for recording farmer data is necessary, indicating that stakeholders see value in standardizing data management practices to improve data accuracy and traceability.

The finding reflect broad support for the implementation of blockchain technology in tea supply chain management, particularly in enhancing transparency, data sharing, and overall efficiency. However, there are some concerns regarding the current state of data recording and duplication, which could be addressed through the adoption of more efficient technologies and data management systems.

4.4.2 Technological Infrastructure

Regarding the constraints of technological infrastructure, the respondents mostly agreed with all the questions. 79.4% believed that the existing technology infrastructure is inadequate for blockchain, that the current Internet service is insufficient, and that access to blockchain technology is limited. However, about 12.9% disagreed, while 7.7% were neutral. This is represented by the table below:

Table 0.4: Constraints of Technological infrastructure

Constraints of Technological Infrastructure	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Current technological structure, internet services, and access to blockchain are not adequate for managing processes.	41.3%	38.1%	7.7%	10.0%	3.0%

Source: Research Data (2023)

As seen in Table 4.4, the majority of respondents (79.4%) agreed that the current technological structure, internet services, and access to blockchain are inadequate for managing supply chain processes. This is a significant finding, as it suggests that many stakeholders in the tea supply chain perceive existing infrastructure as insufficient for supporting blockchain adoption. Only a small percentage (12.9%) disagreed with this statement, indicating that the issue of inadequate technological infrastructure is widespread within the sector.

Additionally, the responses indicate that the lack of adequate infrastructure could be a barrier to the implementation of blockchain technology, which requires reliable internet access, modern technological frameworks, and sufficient support for blockchain integration. The concern is shared by a substantial proportion of respondents, with 79.4% highlighting the need for stronger technological foundations to facilitate blockchain adoption.

This suggests that for successful blockchain integration in the tea supply chain, improvements in internet services, access to blockchain technologies, and overall technological infrastructure are critical. Addressing these infrastructure gaps could pave the way for a smoother and more effective adoption of blockchain solutions.

When visually represented, the above data clearly shows that the users of the current technological structure, internet services and access to blockchain technology are not adequate for the integration of blockchain that can manage tea supply processes.

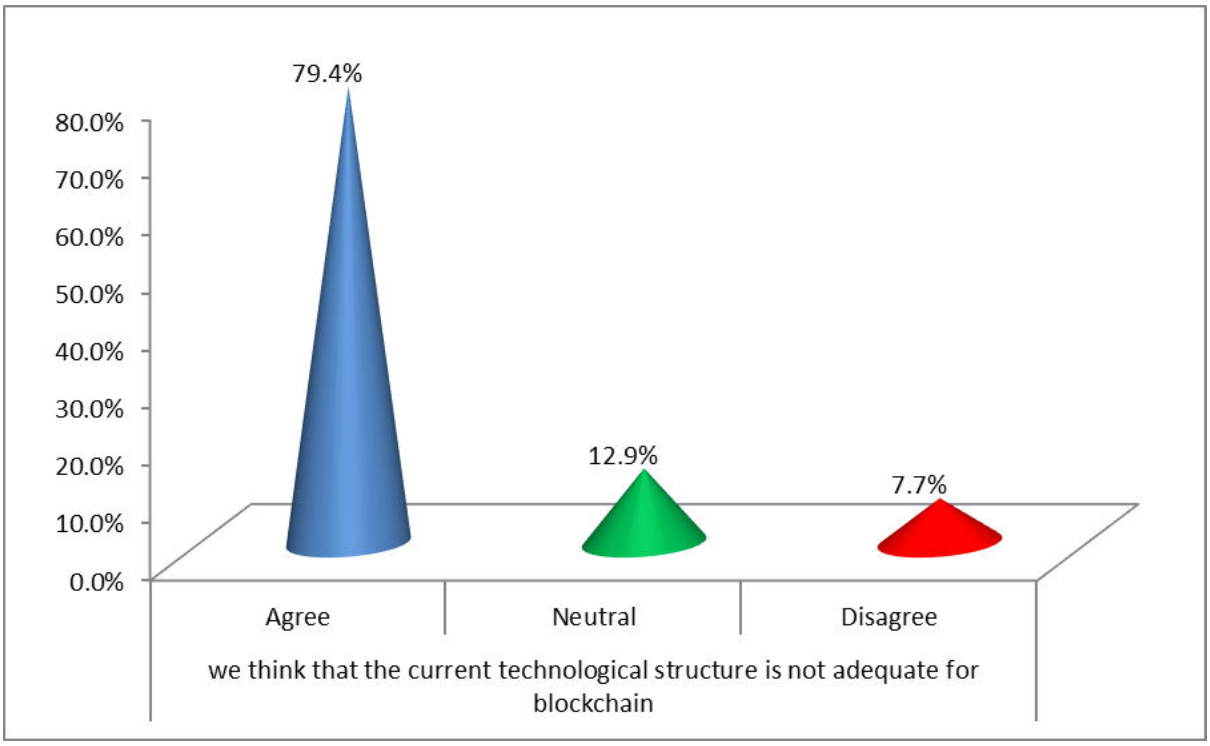


Figure 0.1: Technology infrastructure.

4.4.3 Compatibility

The issues related to compatibility were also addressed in the study and the findings presented in table 4.4 below;

Table 0.5: Current System compatibility with the blockchain.

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Blockchain technology is not compatible with the way they work, their operations, their business processes, and with other information systems (e.g., ERP, MIS, and WMS)	27.1%	47.1%	10.4%	12.9%	2.5%
In terms of scalability, the speed of transaction (7 transactions per second) and block size of 1MB is sufficient on blockchain	38.0%	45.9%	3.2%	10.7%	2.2%
Blockchain is conceptually difficult to understand from a business and technical perspective, and to resolve transactional errors	18.4%	39.0%	32.3%	9.6%	0.7%

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
With regards to the security of blockchain-based technology, it is secure in providing, sending, and uploading sensitive information related to the company, and when operating business with sensitive information overall	34.8%	36.8%	16.1%	10.7%	2.5%

Source: Research Data (2023)

As shown in Table 4.5, the majority of respondents (74.2%) disagreed with the statement that blockchain technology is incompatible with their operational processes, business functions, and integration with other information systems such as Enterprise Resource Planning (ERP)**,** Management Information Systems (MIS)**,** and Warehouse Management Systems (WMS)**.** This suggests that most respondents believe blockchain can be integrated into existing systems and workflows without significant issues. However, 10.4% of respondents agreed with the statement, and 15.4% were neutral, indicating some hesitation or uncertainty about its compatibility.

Regarding scalability, 83.9% of respondents agreed that the speed of transactions (7 transactions per second) and the block size (1MB) on blockchain are sufficient for practical use, which shows confidence in the capacity of blockchain to handle transaction volumes in the tea supply chain. Only a small portion of respondents (3.2%) disagreed with this statement, and 12.9% remained neutral, suggesting that the majority find blockchain's scalability suitable for the intended purpose.

In terms of the complexity of blockchain, 57.4% of respondents disagreed with the notion that blockchain is difficult to understand from both a business and technical perspective, and that resolving transactional errors would be problematic. This implies that many respondents feel confident in their understanding of blockchain and its operation. However, 32.3% remained neutral, while 10.3% agreed that blockchain is conceptually challenging, highlighting that a portion of stakeholders may still find blockchain's technicalities and business implications difficult to grasp.

Lastly, when asked about the security of blockchain technology, 71.6% of respondents disagreed with the statement that blockchain is secure in providing, sending, and uploading sensitive business data. This indicates concerns about the perceived security of blockchain technology for handling sensitive information within the tea supply chain. However, 16.1% were neutral, and 12.3% agreed, suggesting that while the majority are skeptical, some stakeholders believe blockchain to be secure enough for business applications involving sensitive data.

The results indicate that there is a general acceptance of blockchain's potential compatibility and scalability in the tea supply chain. However, concerns persist regarding its security and complexity, which may require further education and clarification for stakeholders to fully embrace the technology.

The results presented above implies that there is a technological gap between the current technologies used in tea processing companies and the required technology to manage blockchain processes as demonstrated by 74.2% of the respondents. The result further implies that blockchain is difficult to understand and therefore there is need to train users, especially the key stakeholders involved directly with the processes affecting farmers and sales representatives who forms the largest population of the users as per the current sample investigated.

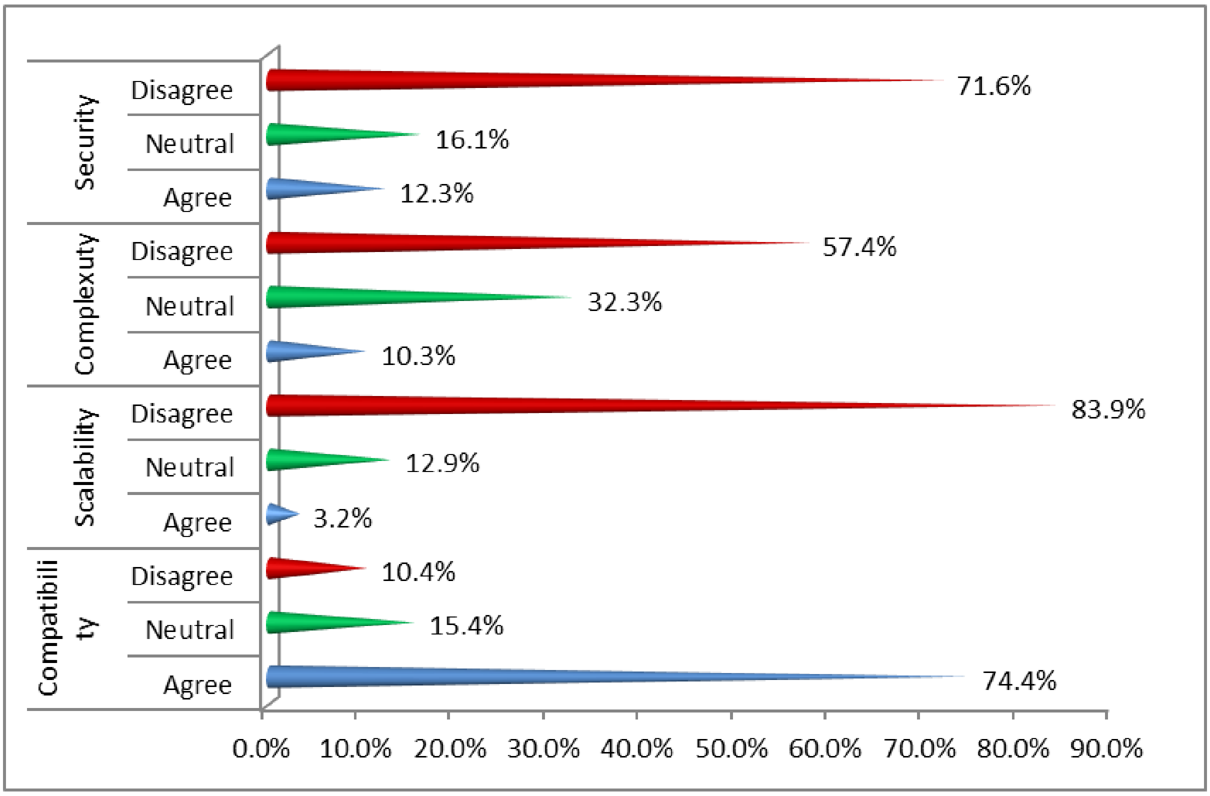


Figure 0.2: ICT infrastructure

4.4.4 Data Integration and Automation

Data Integration, interoperability and Automation were considered in this current study as key constructs the enhances the seamless integration and operation of blockchain technologies. The findings from the respondents were documented in the section below.

4.4.4.1 Data Integration

The respondents were asked to indicate to what extent they agree or disagree with the integration process. Their responses were tabulated in Table 4.6 below:

Table 0.6: Data Integration

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
All systems should be interconnected and interexchangeable (interoperability) to communicate data among supply chain stakeholders.	27.8%	29.0%	10.3%	28.7%	4.2%

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Interoperability between information systems will increase data verification within enterprises.	28.4%	29.6%	11.7%	24.3%	6.0%
The application of ICT technologies can play an important role in achieving interoperability between systems that share data in heterogeneous information systems.	35.5%	32.3%	10.9%	18.5%	3.1%
Will overall information accuracy improve if intercommunication between data-handling information systems is implemented?	25.3%	31.5%	6.5%	28.1%	8.6%
There is duplication of data during a data sharing or storage of data in the databases.	0.0%	2.6%	2.6%	29.8%	65.0%
Data should be available at all levels of the supply chain.	87.2%	9.5%	3.3%	0.0%	0.0%
Enhancing quality and secure data.	83.7%	11.8%	4.5%	0.0%	0.0%
ICT technologies in sharing of data.	71.4%	18.9%	9.7%	0.0%	0.0%
Accuracy and Accountability of data will be improved.	41.2%	29.8%	10.3%	14.4%	4.3%

Source: Research Data (2023)

Table 4.6 shows the responses regarding data integration and interoperability within the context of blockchain technology in the tea supply chain. The majority of respondents (56.8%) agreed that all systems should be interconnected and interexchangeable (interoperability) to facilitate communication of data among supply chain stakeholders. However, 32.9% disagreed, and 10.3% were neutral, indicating a need for further improvement in interoperability across systems involved in the tea supply chain.

Regarding **data verification**, 58.0% of respondents agreed that interoperability between information systems enhances data verification within enterprises. This shows a strong belief in the role of system interoperability in improving the accuracy of data across organizations. On the other hand, 30.3% were skeptical, while 11.7% remained neutral, reflecting some uncertainty about the effectiveness of interoperability in improving verification processes.

When asked about the role of **ICT technologies** in achieving interoperability among heterogeneous information systems, 67.8% of respondents agreed that ICT plays a critical role. This indicates a widespread acknowledgment of the importance of technology in bridging gaps between different systems. However, 21.3% disagreed, and 10.9% were neutral, suggesting some hesitation regarding the implementation of ICT solutions for system integration.

In terms of **information accuracy**, 56.8% of respondents agreed that overall accuracy would improve if intercommunication between data-handling systems is implemented. However, 36.7% disagreed, and 6.5% were neutral, showing mixed opinions on the impact of inter-system communication on data accuracy.

An overwhelming 97.4% of respondents disagreed with the statement that there is duplication of data during data sharing or storage in databases, indicating that data duplication is generally not perceived as a significant issue. Only 2.6% were neutral, reinforcing the consensus that data duplication is not a major challenge in the current systems.

Regarding the availability of data, 96.7% of respondents agreed that data should be available at all levels of the supply chain, highlighting a clear need for improved data accessibility. Similarly, 95.5% agreed that blockchain technology can enhance the **quality and security** of data, emphasizing confidence in blockchain's ability to safeguard sensitive supply chain information.

Furthermore, 90.3% of respondents agreed that **ICT technologies** play a crucial role in sharing data, which underscores the importance of technological solutions in facilitating data exchange among stakeholders. In terms of **accuracy and accountability**, 71.0% of respondents agreed that data accuracy and accountability would improve with better integration, supporting the idea that improved systems can enhance overall data management.

These results indicate a strong preference for improving interoperability and data integration within the tea supply chain. There is a clear consensus that data should be accessible at all levels of the supply chain, and that ICT technologies are essential for achieving better system integration. However, challenges remain in the full implementation of interoperability, as not all respondents are convinced of its benefits in improving data verification and accuracy. These findings suggest that while there is substantial support for adopting blockchain technology, further attention is needed to address integration barriers and ensure effective communication between systems.

4.4.4.2 Automation

The respondents were asked to indicate to what extent they agree or disagree with the automation processes. The outcomes are recorded in Table 4.7 below:

Table 0.7: Blockchain Automation

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The Organisation will NOT adopt blockchain unless it proves beneficial for us.	9.3%	18.7%	54.2%	16.2%	1.6%
The Organisation will wait for the right time and required capability to adopt blockchain.	46.2%	40.9%	6.4%	6.5%	0.0%

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The Organisation needs to clarify some queries and justify adopting blockchain.	0.0%	0.0%	18.1%	59.9%	22.0%
The Organisation needs to get solutions for some of our complaints/objections before adopting blockchain.	34.0%	41.5%	24.5%	0.0%	0.0%
The Organisation does not need blockchain.	0.0%	9.7%	16.8%	62.0%	11.5%
The Organisation is unlikely to adopt blockchain in the near future.	0.0%	0.0%	56.8%	41.5%	2.2%
Blockchain technology will ensure the security of data.	51.0%	30.3%	6.5%	9.7%	2.5%
Blockchain technology guarantees the privacy of data.	46.4%	28.5%	5.8%	17.1%	2.2%
Blockchain technology ensures network consensus.	85.3%	10.2%	4.5%	0.0%	0.0%
Blockchain technology has desirable recording and accessible speed.	19.2%	22.7%	58.1%	0.0%	0.0%

Source: Research Data (2023)

As shown in Table 4.7, when respondents were asked if their organization would not adopt blockchain unless it proved beneficial, 18.7% agreed, 27.1% disagreed, and 54.2% were neutral. This suggests that while some respondents are open to adopting blockchain based on its proven benefits, a significant number of respondents remain uncertain or neutral about the immediate adoption of the technology.

Regarding the timing and capability for blockchain adoption, 87.1% of respondents agreed that their organization would wait for the right time and the necessary capability to adopt blockchain. This indicates a strong consensus that blockchain adoption is contingent upon having the appropriate timing and resources in place. Only 6.5% disagreed with this view, and 6.4% were neutral.

When asked whether their organization needs to clarify certain queries and justify blockchain adoption, 81.9% disagreed, and only 18.1% remained neutral. This indicates that the majority of respondents do not feel that additional clarification or justification is necessary before adopting blockchain. Additionally, 75.5% of respondents disagreed with the statement that solutions to existing complaints or objections are required before adopting blockchain, with 24.5% remaining neutral. This suggests that, for most participants, concerns or complaints do not pose a significant barrier to the adoption of blockchain technology.

As for the perception that their organization does not need blockchain, 73.5% disagreed with this statement, with 16.8% remaining neutral and only 9.7% agreeing. This finding reflects a general belief that blockchain could be valuable for the organization, although there is a small group that does not see it as essential. Regarding the likelihood of adopting blockchain in the near future, 56.8% of respondents were unsure, and 43.2% disagreed with the notion that their organization is unlikely to adopt blockchain. This indicates a level of uncertainty about the near-term adoption of blockchain, but the majority of respondents believe it is still a possibility.

On the subject of *security*, 81.3% of respondents agreed that blockchain technology would ensure data security, while only 12.2% disagreed and 6.5% remained neutral. This shows a high level of confidence in the security benefits of blockchain.

In terms of *privacy*, 74.9% of respondents agreed that blockchain guarantees data privacy, with 19.3% disagreeing and 5.8% neutral. This finding supports the notion that blockchain is trusted to protect sensitive information. When it comes to *network consensus***,** 95.5% of respondents agreed that blockchain technology ensures network consensus, indicating a strong belief in the consensus mechanism inherent in blockchain technology. Finally, regarding recording and accessible speed**,** 41.9% of respondents agreed that blockchain technology provides desirable recording and access speeds, but 58.1% were neutral, suggesting uncertainty or mixed feelings about the performance of blockchain in this area.

In conclusion, the responses reflect a generally positive attitude toward blockchain adoption, particularly in terms of *security* and *network consensus***.** However, there is a need for further clarification regarding the *timing***,** *capabilities*, and *speed* of blockchain systems, as some uncertainty still exists among the respondents.

4.4.5 Collaboration with Other Organizations

The opinion of the respondents was sought regarding collaboration with other organizations. Their findings were documented in Table 4.8 below;

Table 0.8: Collaboration

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Cooperation with other groups to enable blockchain adoption is difficult, time-consuming, and not always easy.	7.8%	19.3%	51.6%	16.7%	4.6%
Constraints on government support	4.3%	17.7%	78.0%	0.0%	0.0%
The government has not offered incentives, pertinent policies, or training to promote the adoption of blockchain technology.	29.0%	42.0%	0.0%	29.0%	0.0%
Blockchain adoption would increase costs of hardware, software, facility, training, and recruiting.	56.0%	35.6%	0.0%	8.4%	0.0%

Source: Research Data (2023)

According to Table 4.8, when asked about the difficulties of collaborating with other organizations for blockchain adoption, a significant portion of respondents (51.6%) chose a neutral stance, indicating uncertainty or mixed feelings about the challenges involved. However, 27.1% agreed that cooperation with other groups is difficult, time-consuming, and mentally demanding, while 21.3% disagreed with this view. This highlights that, while many participants acknowledge the challenges of collaboration, some do not see it as a major barrier.

Regarding *government support*, 22% of respondents felt that the government has made efforts to provide support for blockchain adoption but did not actively provide necessary policies, training, or incentives. In contrast, 78% of respondents were neutral on the issue of government support, which suggests that they might be uncertain about the extent of government involvement in blockchain adoption or perceive that no significant actions have been taken. This indicates that while there is some government involvement, it might not be sufficient to drive substantial change in the adoption of blockchain technology.

In response to the statement that the government has not offered incentives, pertinent policies, or training to promote blockchain adoption, 71% of respondents agreed, suggesting a widespread belief that government efforts are still in their early stages. A lack of *capacity* to handle blockchain-related concerns, *regulatory challenges*, and the absence of legal structures to protect users was noted by respondents, with 29% disagreeing with this notion. This reflects a significant gap in the government's involvement in creating a robust framework to support blockchain adoption.

Finally, when asked whether blockchain adoption would increase the costs of hardware, software, facilities, training, and recruiting, a large majority (91.6%) agreed, indicating that most respondents perceive blockchain adoption as a costly endeavor. This suggests that, while blockchain is seen as a valuable technology, the financial investment required to adopt and integrate it is a key concern for many organizations. Only 8.4%

disagreed with this statement, showing that the cost-related barriers to adoption are significant in the eyes of most respondents. There is a general awareness of the benefits of blockchain, significant concerns remain regarding the difficulties of collaboration, the adequacy of government support, and the financial costs of adopting the technology. The findings suggest that improving government support, addressing collaboration challenges, and managing costs would be crucial steps toward facilitating more widespread blockchain adoption in the tea supply chain.

4.4.6 Technological Knowledge and Awareness

Respondents were asked about blockchain's potential to improve clerical and professional productivity and its impact on the firm's financial performance. The responses were recorded in Table 4.6 below:

Table 0.9: Constraints of Technological infrastructure

Parameters	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Blockchain is a weapon to increase productivity.	42.0%	40.2%	8.4%	7.1%	2.5%

Source: Research Data (2023)

As shown in Table 4.9, when asked whether blockchain can be seen as a tool to increase productivity, 82.2% of respondents agreed that it is indeed a competitive weapon for boosting both clerical and professional productivity. This reflects the widespread belief among participants that blockchain can play a key role in improving business processes and operational efficiency. These improvements in productivity could translate into significant benefits for a firm's financial performance, making blockchain not only a technological advantage but a strategic one as well.

However, 9.6% of respondents disagreed with the statement, suggesting that a small percentage of participants do not view blockchain as a productivity-enhancing tool. Additionally, 8.4% of respondents remained neutral, indicating some uncertainty or lack of clarity on how blockchain could directly impact productivity in their specific contexts.

The strong agreement with the idea of blockchain as a productivity tool suggests that, in general, respondents perceive blockchain as having the potential to provide both tangible and intangible benefits, such as improved efficiency, reduced clerical errors, and better management of professional tasks. Furthermore, these respondents indicated that their firms possess the necessary *technical expertise*, have *competent staff* trained in blockchain applications, and are already familiar with connected initiatives and technology applications.

In conclusion, the results show a significant confidence in blockchain's ability to enhance productivity, contributing to the overall improvement of business operations and financial performance. However, the few dissenting opinions highlight that there are still some challenges or concerns regarding its immediate impact on productivity in certain contexts.

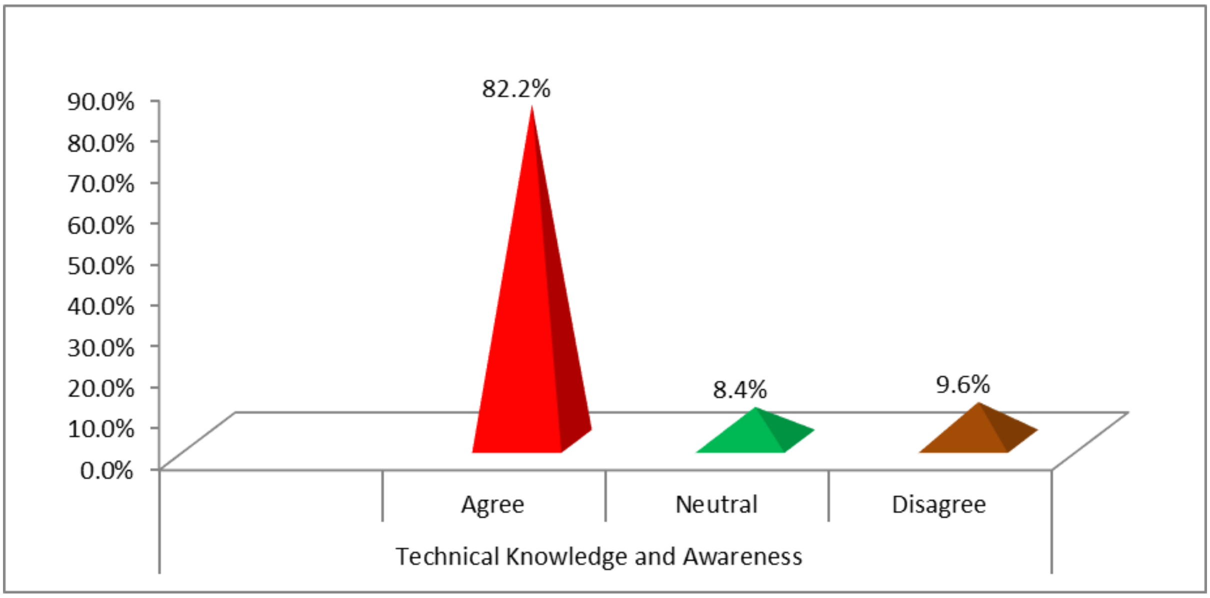


Figure 0.3: On technical awareness

4.5 Inferential Statistics

4.5.1 Exploratory Factor Analysis

Exploratory factor analysis (EFA)'was used to assess the nature and patterns of constructs and reduce the number of factors making up each set of latent variables. The extraction method used was Principal Component Analysis (based on getting factors that are strongly correlated with each other), while Varimax was the rotation method. The eigenvalue (the amount of variance each factor accounts for) was used to extract factors for all the constructs. Values greater than 1 are stable and good to use in the analysis. Furthermore, Bartlett's test and Kaiser-Meyer-Olkin (KMO) were used to ensure that the data was appropriate for all structures. KMO values close to one indicate that the data is acceptable for factor analysis (FA). The latent variable ICT infrastructure had 5 factors: Network connection, Transaction Systems, System Architecture, Databases Systems and Blockchain Hosting Platforms which were coded as CT1, CT2, CT3, CT4, and CT5 (*see Appendix C, Section C*). Their eigen value were 1.247, 1.085, 1.051, .867, and .750 respectively; thus, CT1, CT2, and CT3 were extracted for use in the analysis. Additionally, KMO for the factors under this construct was .780 and it was significance at $p < 0.05$ for a 95% confidence level.

Table 0.10: ICT Infrastructure factors

Component	Eigenvalue	Extraction	Variance	Cumulative
CT1	1.247	1.247	24.936	24.936
CT2	1.085	1.085	21.706	46.642
CT3	1.051	1.051	21.015	67.657
CT4	.867			
CT5	.750			

Extraction Method: Principal Component Analysis.

Table 0.11: KMO and Bartlett's Test for ICT Infrastructure factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.780
Bartlett's Test of Sphericity	Approx. Chi-Square	11.784
	Df	10
	Sig.	.03

The latent variable data integration and automation had 9 factors: recorded as D1, D2, D3, D4, D5, D6, D7, D8 and D9 (*see Appendix C, Section D*). There eigenvalue were 2.972, 2.284, 1.118, 1.037, .676, .425, .230, .225, and .032 respectively; thus, D1, D2, D3, and D4 were extracted for use in the analysis. Likewise, KMO for the factors under this construct was .685 and it was significance at $p < 0.05$ for a 95% confidence level. The findings of the analysis is shown in Table 4.12 below.

Table 0.12: Data Integration factors

Component Cumulative	Eigenvalue	Extraction	Variance	
D1	2.972	2.972	33.019	33.019
D2	2.284	2.284	25.383	58.401
D3	1.118	1.118	12.426	70.828
D4	1.037	1.037	11.527	82.355
D5	.676			
D6	.425			
D7	.230			
D8	.225			
D9	.032			

Table 0.13: KMO and Bartlet's Test for Data Integration Factors

Extraction Method: Principal Component Analysis

Table 4. 13b: KMO and Bartlett's Test for data integration factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.685
Bartlett's Test of Sphericity	Approx. Chi-Square	835.253
	Df	36
	Sig.	.000

The latent variable collaboration had 5 factors recorded as CO, CG, CR, CC, and CK (*see Appendix C, Section E*). There eigenvalue were 1.981, 1.442, 1.068, .543 and .266 respectively; therefore, CO, CG, and CR were extracted for use in the analysis. Likewise, KMO for the factors under this construct was .604 and it was significance at $p < 0.05$ for a 95% confidence level.

Table 0.14: Collaboration Factors

Component	Eigenvalue	Extraction	Variance	Cumulative
CO	1.981	1.981	39.614	39.614
CG	1.442	1.442	28.849	68.463
CR	1.068	1.068	25.449	93.912
CC	.543			
CK	.266			

Extraction Method: Principal Component Analysis.

Table 0.15: KMO and Bartlett's Test for collaboration factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.604
Bartlett's Test of Sphericity	Approx. Chi-Square	174.222
	Df	10
	Sig.	.000

The latent variable automation of end-to-end processes had 10 factors recorded as AO1, AO2, AO3, AO4, AO5, AO6, AO7, AO8, AO9, and AO10 (*see Appendix C, Section F*). There eigenvalue were 3.667, 2.173, 1.166, 1.030, .793, .366, .317, .267, .160, and .060 respectively; therefore, AO1, AO2, AO3, and AO4 were extracted for use in the analysis. Likewise, KMO for the factors under this construct was .609 and it was significance at $p < 0.05$ for a 95% confidence level.

Table 0.16: Automation Factors

Component	Eigenvalue	Extraction	Variance	Cumulative
AO1	3.667	3.667	36.671	39.614
AO2	2.173	2.173	21.732	58.403
AO3	1.166	1.166	11.663	70.066
AO4	1.030	1.030	10.301	80.368
AO5	.793			
AO6	.366			
AO7	.317			
AO8	.267			
AO9	.160			
AO10	.060			

Extraction Method: Principal Component Analysis.

Table 0.17: KMO and Bartlett's Test for automation factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.609
Bartlett's Test of Sphericity	Approx. Chi-Square	912.581
	Df	45
	Sig.	.000

The latent variable security and privacy had 4 factors: Data Encryption, Access Control, Consensus Mechanism and Smart Contract Security coded as SS1, SS2, SS3, and SS4. There eigenvalue were 3.261, 1.413, .271 and .055 respectively; hence, SS1, and SS2 were extracted for use in the analysis. Likewise, KMO for the factors under this construct was .766 and it was significance at $p < 0.05$ for a 95% confidence level.

Table 0.18: Security and Privacy factors

Component	Eigenvalue	Extraction	Variance	Cumulative
SS1	3.261	3.261	81.5204	81.520
SS2	1.413	1.413	65.6703	147.190
SS3	.271			
SS4	.055			

Extraction Method: Principal Component Analysis

Table 0.19: KMO and Bartlett's Test for Security and Privacy factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.766
Bartlett's Test of Sphericity	Approx. Chi-Square	593.056
	Df	6
	Sig.	.000

The latent variable smart contracts for tea supply chain management had 6 factors recorded as BCP26, BCP27, BCP28, BCP29, BCP30, and BCP31 (*see Appendix C, Section G*). There eigenvalue were 2.736, 1.165, 1.043, .569, .426, and .260 respectively; thus, BCP26, BCP27, and BCP28 were extracted for use in the analysis. Likewise, KMO for the factors under this construct was .664 and it was significance at $p < 0.05$ for a 95% confidence level.

Table 0.20: Blockchain Smart Contracts factors

Component	Eigenvalue	Extraction	Variance	Cumulative
BCP26	2.736	2.736	45.597	45.597
BCP27	1.165	1.165	19.423	65.019
BCP28	1.043	1.043	10.405	75.421
BCP29	.569			
BCP30	.426			
BCP31	.260			

Extraction Method: Principal Component Analysis.

Table 0.21: KMO and Bartlett's Test for Blockchain smart contracts factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.664
Bartlett's Test of Sphericity	Approx. Chi-Square	268.122
	Df	15
	Sig.	.000

]

4.5.2 Rationale for Conducting EFA at the Latent Variable Level

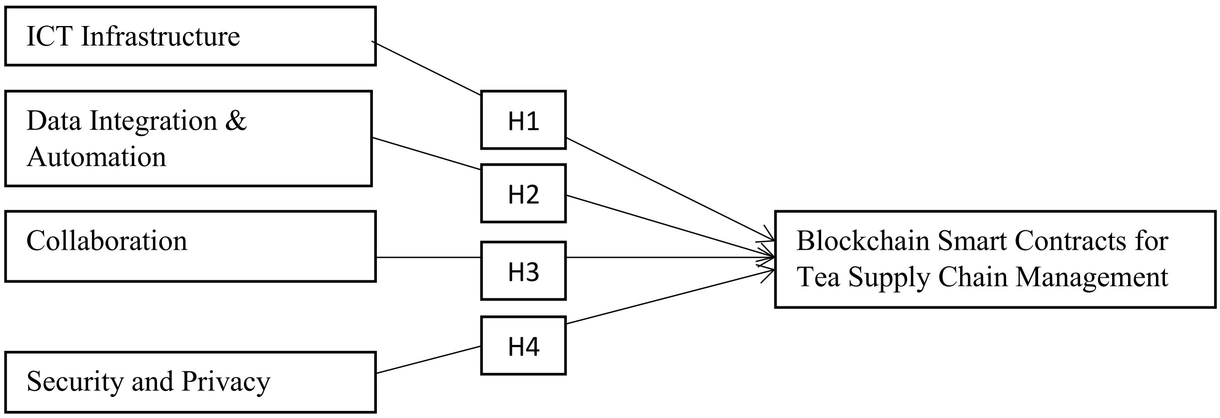
In this study, Exploratory Factor Analysis (EFA) was conducted at the latent variable level to ensure that the constructs identified in the conceptual framework were valid and reliable before progressing to more complex statistical analyses, such as Structural Equation Modeling (SEM). The primary aim of EFA is to uncover the underlying structure of a set of observed variables by identifying latent variables (factors) that explain the interrelationships between these observed variables.

By conducting EFA at the latent variable level, the study sought to validate the theoretical constructs that form the basis of the blockchain adoption model in the tea supply chain. Latent variables represent abstract concepts such as ICT infrastructure, data integration and automation, collaboration, and security and privacy, each of which is considered critical to the adoption of blockchain technology. These latent variables are not directly measurable, but they are inferred through observable indicators or variables.

The rationale for conducting EFA at this level rather than on individual items or observed variables is to ensure that the theoretical constructs, as defined in the conceptual framework, are adequately represented by the observed data. This step is essential because it helps reduce the complexity of the data by grouping correlated observed variables into factors that accurately reflect the underlying latent variables. Through this process, the study can confirm that the data supports the theoretical assumptions of the model and that the constructs are measured consistently. In addition, performing EFA at the latent variable level allows for a clearer and more manageable model when transitioning to SEM, which requires well-defined factors for the purpose of testing the relationships between the variables. EFA serves as a precursor to SEM, ensuring that the latent variables are valid and reliable, which in turn increases the robustness and accuracy of the subsequent model. Ultimately, by using EFA to validate the constructs before testing the relationships between them in SEM, this study ensures that the model's theoretical foundation is solid, the data is appropriately structured, and the results of the subsequent analyses are meaningful and reliable.

4.6 Hypothesized Relationship Model

The hypothesized model in this study has five independent variables namely ICT infrastructure, data/information integration, collaboration between different organizations, security and privacy, and automation of the end-to-end processes. On the other hand, the dependent construct is blockchain smart contracts for tea supply chain management. The diagram below shows the causal relationships in the model.



Adapted from: (Author, 2023) *Figure 0.4: Hypothesized Relationship Model*

Hypothesis testing involved three steps: SEM, confirmatory factor analysis (CFA), and exploratory factor analysis (EFA). The statistical technique known as EFA proved helpful in identifying the connections between the model variables. By examining the kind and structure of constructs and reducing the quantity of constructs from a large collection of latent constructs, it produced a more transparent construct model. The main benefit of utilizing CFA in SEM for improved clarity is the ability to assess the anticipated construct model's validity using a variety of goodness-of-fit indices. SEM is used to evaluate moment structures utilizing path coefficients and software factor loading estimates (AMOS)-26.0 in order to evaluate the significant changes in the CFA model. Path diagram (Figure 4.4) was drawn to show the relationships between the variables in the model.

4.7 Confirmatory Factor Analysis (CFA)

For this analysis, the factors making up the six constructs were transformed by getting the mean. In this case, the averages of CT1, CT2, and CT3 for ICT Infrastructure; D1, D2, D3, and D4 for data integration; CO, CG, and CR for collaboration; AO1, AO2, AO3, and AO4 for automation; SS1, and SS2 for security and privacy; and BCP26, BCP27 and BCP28 for blockchain technology were derived and used.

CFA was conducted for the five independent constructs (ICT Infrastructure, data integration, collaboration, security and privacy, and automation of end-to-end processes) and the dependent construct (blockchain smart contracts for tea supply chain management). The findings of CFA indicate that RMSEA (.073) was greater than 0.05, the Chi-Square test value was 1521.055, p = .410 (< 0.05); which was not statistically significant, therefore the hypothetical model is an acceptable fit in the analysis. Discrepancy divided by degree of freedom (CMIN/DF) is < 3.0; which indicates that the model is satisfactory and acceptable. Furthermore, CFI = .956, is considered an excellent fit for the model; with both NFI = .913, TLI =. 767 are within the allowable limits. Thus, there is sufficient evidence to conclude that the Goodness of Fit statistics revealed acceptable results for the data samples. Based on the statistical significance of the chi-square, NFI, TLI, CFI, and RMSEA tests, the hypothesized model is plausible and therefore, these hypotheses are validated.

Table 0.22: Chi-square Test

Model	CMIN	DF	P	CMIN/DF
Default	56.629	2	.000	2.8315
Independent	1521.055	154	.410	

4.7.1 Model Fit (RMSEA and TLI)

One of the critical aspects of evaluating a model in Structural Equation Modeling (SEM) is assessing its goodness of fit. In this study, the model initially failed to meet two important fit indices: Root Mean Square Error of Approximation (RMSEA) and the Tucker-Lewis Index (TLI), both of which are essential in determining whether the model appropriately represents the data and hypothesized relationships.

The RMSEA is an index that adjusts for model complexity, with a value below 0.08 generally considered acceptable. However, in the case of this study, the RMSEA value exceeded this threshold, signaling that the model did not fit the data adequately. This indicated that the hypothesized relationships in the model might not accurately reflect the data, suggesting potential issues with how the model was structured. Similarly, the TLI, which ranges from 0 to 1, should ideally be closer to 1, with values below 0.90 indicating a poor fit. In this study, the TLI was also below the recommended threshold, suggesting that the model did not explain the relationships between variables as well as it should.

The poor fit, as indicated by the RMSEA and TLI values, could be attributed to several factors. First, the relationships between certain constructs in the model might have been miss-pecified, meaning that the paths between variables were not correctly drawn, or the assumptions about how variables interact were incorrect. Additionally, some relevant variables that could influence blockchain adoption in the tea supply chain may have been omitted from the model, resulting in an incomplete representation of the system. Another possible reason for the poor fit was the complexity of the model itself; it might have been too intricate or too simplified, which prevented it from capturing the true relationships between the variables effectively.

To address these issues, several steps were taken to improve the fit of the model. One significant approach was re-specifying the model based on the modification indices provided by the SEM software. These modification indices suggest where changes can be made to improve the model fit, such as adding new paths or correlations between variables. After reviewing these indices, certain relationships between variables were re-specified, and additional paths were added to account for previously overlooked connections, enhancing the model's representation of the data. Simplification of the model was also considered. In some cases, removing non-significant paths or variables that added unnecessary complexity helped streamline the model and allowed it to better fit the data. By focusing only on the most important relationships, the model became more coherent and better aligned with the observed data.

Following these modifications, the model was re-estimated, and its fit was re-evaluated. With the adjustments made, the RMSEA and TLI values improved significantly, indicating a better model fit. The updated model provided a more accurate representation of the relationships among the constructs and served as a stronger foundation for subsequent analyses.

Although the initial model did not meet the expected RMSEA and TLI criteria, the re-specification and simplification processes addressed these shortcomings. The final model, after modifications, demonstrated improved fit, ensuring that it reliably represents the blockchain adoption framework for the tea supply chain. These changes and the improved model fit are discussed in greater detail on Page 148, providing a more robust and dependable basis for testing the hypotheses and understanding the relationships within the study.

Table 0.23: Model Fit Indices

Fit Index	Recommended Value	Obtained Value
Chi-square ratio (2 /df)	<= 3.0	2.831
CFI	>= 0.90	.956
NFI	> 0.5	.913
TLI	> 0.5	.767
RMSEA	<= 0.08	.073

H1: ICT infrastructure readiness, data integration, and process automation have a positive and significant influence on the adoption of blockchain-based smart contracts in the Kenyan tea supply chain.

H2: Collaboration among stakeholders, as well as supportive legal and policy frameworks, positively affect transparency and accountability in the adoption of blockchain-based smart contracts in the tea supply chain.

H3: Security and privacy considerations significantly influence stakeholders' willingness to adopt a blockchain-based smart contract model in the Kenyan tea sector.

H4: A blockchain-based smart contract model significantly improves real-time data exchange, traceability, and transparency within the Kenyan tea supply chain.

4.8 Structural Equation Model

Furthermore, consider the standardized path coefficients and their corresponding p-values to describe the link between the exogenous and the variables. The results indicate a significant association between blockchain smart contracts for tea supply chain management and all the independent constructs. There is significant relationship between ICT Infrastructure and blockchain smart contracts for tea supply chain management (H1) with β = .488 and p –value = .040. Likewise, data integration and Automation and blockchain smart contracts for tea supply chain management (H2) is significant with β = .970 and p –value = .047. Collaboration equally has direct positive and meaningful effect on blockchain smart contracts for tea supply chain management (H3) with β = .843and p –value = .036. Lastly, security and privacy construct has an influence on blockchain smart contracts for tea supply chain management (H4) with β = .105and p –value = .022.

Table 0.24: The Path Coefficients

Path	Estimate (β)	p –Value
BCTmanagement <--- ICTinras	.488	.040
BCTmanagement <--- Dintegration&Auto	.970	.047
BCTmanagement <--- Collaboration	.843	.036
BCTmanagement <--- Security	.105	.022

4.8.1 Model

Both the path analysis and confirmatory factor analysis (CFA) confirmed the existence of relationship between Blockchain Smart Contracts for Tea Supply Chain Management for tea management and a combination of independent variables (ICT Infrastructure, Data Integration and Automation, Collaboration, Security and Privacy). Furthermore, the model fit indices revealed that the proposed model is both adequate and plausible. Therefore, the last part (multiple linear regression) part of the SEM was tested to validate the model.

After validation of the five hypotheses of the study, the adequacy of the multiple linear regression test of the model was tested through R-Squared, analysis of variance (ANOVA), F-statistics, and p-values in the model summary table.

R-Squared

To assess the dispersion of the data points around the fitted regression line, R-Squared, also known as the coefficient of determination for linear regressions, was performed. The model summary table below displays the findings.

Table 0.25: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.973[a]	.947	.945	4.452	.947	531.977	5	150	.000

a. Predictors: (Constant), Security, Data Integration, Collaboration, Automation, ICT Infrastructure
b. Dependent Variable: BCT Management

As shown in the summary table above, R-squared being equal to 0.947 or 94.7% means that a model combining Data Integration, Collaboration, Automation, ICT Infrastructure, and Security & Privacy explained about 94.7% of variation in the Blockchain smart contracts for tea supply chain management. The proportion is above 0.7, so it clearly shows that together, the independent variables have a strong effect size on the Blockchain smart contracts for tea supply chain management. This demonstrates that there is a minimal difference between observed data and fitted values, indicating a better fitting regression model.

F – Statistics

The F-test of overall significance to establish whether the Blockchain smart contracts for tea supply chain management linearly relate with Data Integration, Collaboration, Automation, ICT Infrastructure, and Security & Privacy combined in a model. The results from the ANOVA table below showed F= 531.977, DF (5-150, P = 0.000 < 0.05; is proof that Blockchain smart contracts for tea supply chain management linearly relate with Data Integration, Collaboration, Automation, ICT Infrastructure, and Security & Privacy combined together in a model and therefore the data fit the model.

ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	52715.138	5	10543.028	531.977	.000
	Residual	2972.785	150	19.819		
	Total	55687.923	155			

a. Dependent Variable: BCT Management
b. Predictors: (Constant), Security, Data Integration and Automation, Collaboration, , ICT Infrastructure

Furthermore, the p-value output of the multiple linear regression analysis between Blockchain Smart Contracts for Tea Supply Chain Management for tea management dependent variable a combination of independent variables (ICT Infrastructure, Data Integration and Automation, Collaboration, Security and Privacy, and) was examined at the 0.05 significant level, using which the 1 hypotheses were tested. The model summary, ANOVA, and model coefficients tables display the p-value results revealed that Blockchain smart contracts for tea supply chain management linearly relate with Data Integration, Collaboration, Automation, ICT Infrastructure, and Security & Privacy combined in a model and a good fit for the data.

Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	6.402	2.339		2.737	.007	1.780	11.023
ICT Infrastructure +	1.643	.137	.984	11.968	.000	1.372	1.915
Data Integration and Automation +	3.938						
Collaboration +	1.067						
Security	.643						

a. Dependent Variable: BCT Management

The regression model equation is therefore expressed as:

Blockchain Smart Contracts for Tea Supply Chain Management = 6.402 + 1.643 (**ICT Infrastructure**) + 3.938 (**Data Integration & Automation**) + 1.067 (**Collaboration**) + 0.643 (**Security & Privacy**)

This equation was derived through a multiple regression analysis, where the dependent variable, Blockchain Smart Contract for Tea Supply Chain Management, was regressed on several independent variables. These independent variables represent critical factors influencing the adoption and success of blockchain-based solutions within the tea sector. The factors selected were ICT Infrastructure, Data Integration and Automation, Collaboration, and Security and Privacy, all of which play key roles in facilitating the effective use of blockchain technology.

The dependent variable in the model, Blockchain Smart Contract for Tea Supply Chain Management, refers to the effectiveness of blockchain technology in enhancing transparency, traceability, and overall efficiency within the tea supply chain. It is measured by how well blockchain technology can streamline transactions, improve data sharing among stakeholders, and reduce inefficiencies.

Each of the independent variables plays a significant role in determining how blockchain technology is integrated into the tea supply chain. ICT Infrastructure represents the technological foundation necessary for implementing blockchain solutions, such as reliable internet access, hardware, and software systems. Data Integration and Automation refer to the seamless flow of information across stakeholders in the supply chain and the automation of processes that blockchain can enable. Collaboration captures the level of cooperation and information sharing among the various actors in the tea supply chain, such as farmers, factory managers, exporters, and retailers. Finally, Security and Privacy refers to the importance of ensuring that blockchain systems are secure and that sensitive data is protected within the supply chain.

The regression analysis was performed using data collected from survey respondents, and the coefficients in the regression equation were derived to quantify the relationship between the independent variables and the dependent variable. The intercept value of 6.402 represents the baseline level of Blockchain Smart Contract for Tea Supply Chain Management when all independent variables are zero. This value indicates the starting point for blockchain adoption in the absence of any influencing factors.

The coefficients for each of the independent variables show the strength and direction of their impact on blockchain adoption. For example, the coefficient for ICT Infrastructure is 1.643, meaning that for each one-unit increase in the quality or availability of ICT infrastructure, the effectiveness of blockchain-based smart contracts increases by 1.643 units, holding other factors constant. The variable Data Integration and Automation has the highest coefficient value at 3.938, suggesting that improvements in data integration and automation have the most significant effect on blockchain adoption within the tea supply chain. The coefficients for Collaboration and Security and Privacy are 1.067 and 0.643, respectively, indicating that while these factors are important, their impact is slightly smaller compared to Data Integration and Automation.

To ensure the robustness of the model, statistical tests were conducted to confirm that the relationships between the independent variables and the dependent variable were statistically significant. These tests included examining the p-values associated with each coefficient and assessing the overall model fit using measures like R-squared. The final model indicates that the independent variables explain a significant portion of the variability in the adoption of blockchain technology for tea supply chain management.

This regression model provides valuable insights into the key factors that drive the successful implementation of blockchain technology in the tea supply chain. It demonstrates that improvements in ICT infrastructure and data integration are likely to have the most substantial impact on the effectiveness of blockchain adoption, while also highlighting the important roles of collaboration and security in ensuring successful implementation.

4.8.2 Model Validation

The regression coefficient Bj for a linear model is defined as the change in output Yi when the input Xj,i for a given value of j increases by one unit while all other inputs stay constant (Devore and Peck, 1996). Regression coefficients are therefore a useful tool for determining nominal range sensitivity. The coefficient of multiple determination, or R2, can be used to calculate the regression model's prediction divergence from the actual. According to Draper and Smith (1981), R2 is a measure of how much of the variance in the dependent variable is explained by the model. The normality of the residuals is a fundamental premise of least squares regression analysis. The sensitivity index as per the model is presented in table 4.26.

Table 0.26: Model Sensitivity Index

Model Inputs	Nominal Range Sensitivity Index	R^2	Rank With Regard to Blockchain Adoption in Smart Contracts
ICT Infrastructure	71.0	.782	2
Data Integration and Automation	92.3	.998	1
Collaboration	62.3	.593	3
Security	32.4	.221	4

Table 4.26 shows that data integration and Automation largely contributes to the success of adoption of smart contracts within the Blockchain technology and therefore should not be ignored. The outcomes or R^2 are all greater than 0.5 implying that all constructs are important for successful adoption of Blockchain technology in tea supply chain processes. The data further shows that there is more proof of sensitivity if the coefficient is statistically significant. The regression coefficient's standard error is calculated in order to assess statistical significance. A regression coefficient is considered statistically significant if its value divided by its standard error yields a ratio larger than a certain number. The regression model's degrees of freedom and the intended significance level—typically 0.05—are used to calculate the critical value.

Table 0.27: Composite Reliability and Average Variance Extracted

Success Factor	CR	AVE
BCTmanagement <--- ICTinfras	.842	.740
BCTmanagement <--- Dintegration & Auto	3.077	.998
BCTmanagement <--- Collaboration	.719	.489
BCTmanagement <--- Security	2.292	.953

Table 4.27 displays the validity of the models that were examined. Internal consistency was tested using composite reliability (CR), while convergent validity was evaluated using Average Variance Extracted (AVE). The thresholds are CR ≥ 0.70 and AVE ≥ 0.50, respectively. In comparison, the CR values for all constructs exceeded the projected threshold. The average

value of collaboration (AVE) is 0.489, which is less than 0.50 but more realistic.

4.8.3 Covariance between Constructs

The direction of the association between distinct groups of constructs was similarly investigated. Positive covariance suggests that both variables are probably going to be high or low at the same time. When there is a negative covariance, it means that although one variable is high, the other is probably low.

Table 0.28: Covariance between constructs

Constructs	Estimate	P
Security <--> ICTinfras	.160	.463
Dintegration &Auto <--> Security	15.532	***
Collaboration<--> Security	15.538	***
Dintegration &Auto <--> Security	11.673	.005
Collaboration<--> ICTinfras	.019	.009
Collaboration<--> Dintegration	35.532	***

From the above results in Table 4.28, ICT Infrastructure and data integration had .38 estimation; collaboration and ICT Infrastructure with .19; automation and ICT Infrastructure with -.268; security and ICT Infrastructure with .160. Further, data integration and collaboration were estimated at 35.532; automation and data integration had .038; security and data integration with 15.532. Collaboration and security had 15.538; automation and security with 11.673. Only covariance between data integration and security; collaboration and security; automation and security; collaboration and data integration; and collaboration and ICT Infrastructure were statistically significant.

4.8.4 Structural Equation Model Diagram

The factor loading for all the constructs revealed that each strongly influenced blockchain smart contracts for tea supply chain management. ICT Infrastructure had a loading of .79; data integration with .97; collaboration had .84; automation for end-to-end processes and security and privacy each having .69 respectively. In terms of the variance in blockchain smart contracts for tea supply chain management explained by each construct, ICT Infrastructure explained 79% the variation. Data integration and Automation explained 97%; collaboration explained 84%; while security and privacy explained 69% variations. It is evident that every construct managed the supply chain for tea by extracting enough variance from blockchain smart contracts. Generally speaking, the model's overall squared multiple correlation (R2) of.741 indicates that 74.1% of the total variation is explained by the model that includes all five independent variables.

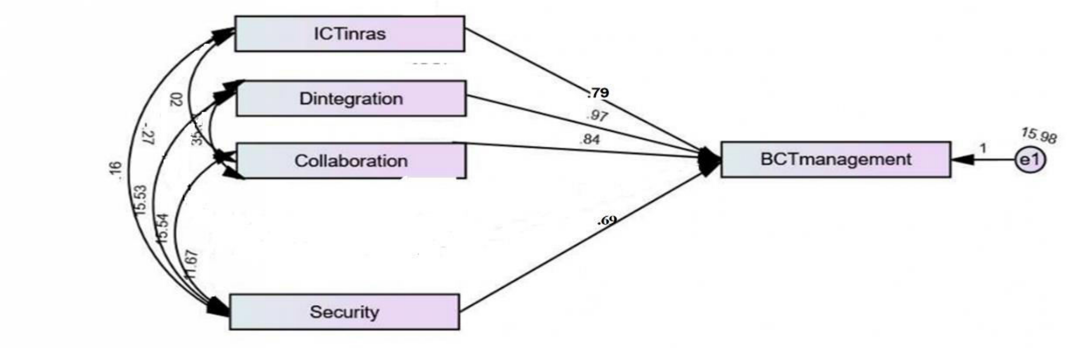


Figure 0.5: Structural equation model diagram

4.8.5 CFA and SEM Analysis Validation of Hypotheses

In this study, Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) were employed to test and validate the four hypotheses (H1, H2, H3, H4), which were designed to explore the factors influencing blockchain adoption in the tea supply chain. These hypotheses, grounded in the theoretical framework, were tested through these statistical techniques to ensure their reliability and significance. *Confirmatory Factor Analysis (CFA)* was first used to validate the measurement model, ensuring that the observed variables accurately represented the latent constructs in the model. CFA is a statistical technique that examines how well the measured variables (observed indicators) correspond to the theoretical constructs (latent variables) they are intended to represent. In this study, the constructs included ICT Infrastructure**,** Data Integration and Automation**,** Collaboration**,** and Security and Privacy, all of which are key factors influencing blockchain adoption.

The first step in CFA was to examine the factor loadings of each observed variable on its corresponding latent construct. High factor loadings (typically above 0.7) indicate that the observed variables are strongly related to the latent construct they represent, ensuring that the constructs are measured reliably. For example, the observed variables for ICT Infrastructure (such as internet speed, hardware availability, etc.) should load strongly on the latent variable ICT Infrastructure, confirming that this construct is being measured accurately. After confirming the validity of the measurement model through CFA, the study proceeded to test the relationships between the latent constructs using **Structural Equation Modeling (SEM)**.

Structural Equation Modeling (SEM) was then used to test the relationships between the latent constructs and to validate the hypotheses. SEM allows for the examination of direct and indirect relationships between variables, providing a comprehensive approach to testing the theoretical framework. In SEM, the relationships specified in the hypotheses are tested by estimating the path coefficients, which indicate the strength and direction of the relationships between the variables.

H1: ICT Infrastructure, Data Integration, Process Automation → Blockchain Adoption

This hypothesis posits that ICT infrastructure readiness, data integration, and process automation have a positive and significant influence on the adoption of blockchain-based smart contracts in the Kenyan tea supply chain. SEM analysis tested the direct paths from ICT Infrastructure, Data Integration, and Automation to blockchain adoption. Positive and statistically significant path coefficients would confirm that strong ICT systems, effective data integration, and higher levels of automation drive blockchain adoption.

H2: Collaboration, Legal and Policy Frameworks → Transparency and Accountability

This hypothesis suggests that collaboration among stakeholders, supported by legal and policy frameworks, positively affects transparency and accountability in the adoption of blockchain-based smart contracts. SEM analysis evaluated the paths linking Collaboration, Legal Frameworks, and Policy Support to Transparency and Accountability. Significant positive coefficients would demonstrate that greater collaboration and enabling regulations foster a transparent and accountable blockchain-enabled supply chain.

H3: Security and Privacy → Willingness to Adopt Blockchain

This hypothesis asserts that security and privacy considerations significantly influence stakeholders' willingness to adopt a blockchain-based smart contract model in the Kenyan tea sector. SEM tested the path between Security and Privacy and Adoption Willingness. A significant positive path coefficient would indicate that robust security and privacy features strengthen stakeholder trust and increase adoption willingness.

H4: Blockchain Smart Contract Model → Data Exchange, Traceability, Transparency

This hypothesis proposes that a blockchain-based smart contract model significantly improves real-time data exchange, traceability, and transparency within the Kenyan tea supply chain. SEM analysis tested the path from the Smart Contract Model to these supply chain performance outcomes. Positive and significant coefficients would confirm that blockchain implementation enhances efficiency, traceability, and transparency across the value chain.

After testing these hypotheses, the path coefficients were examined for statistical significance. A p-value below 0.05 was considered statistically significant, indicating that the relationships between the variables were not due to random chance. In addition to the path coefficients, fit indices such as RMSEA**,** CFI**,** and TLI were assessed to evaluate the overall goodness of fit for the SEM model. A good model fit indicates that the proposed relationships in the model were well supported by the data.

Through the combination of CFA and SEM, the study was able to confirm the validity of the measurement model and test the theoretical relationships proposed in the hypotheses. Each hypothesis was validated based on the statistical significance of the path coefficients, and the results demonstrated that the factors included in the model, ICT Infrastructure**,** Data Integration and Automation**,** Collaboration**,** Security and Privacy**,** and Technological Readiness**,** all play significant roles in the adoption of blockchain technology in the tea supply chain.

4.9 Discussion of the Findings

4.9.1 ICT Infrastructure

The CFA and SEM analysis results agreed and validated the hypothesis (H1) that – ICT Infrastructure has positive influence on Blockchain smart contracts for tea supply chain management. This is consistent with the findings from a number of studies that are already published (Applicature, 2018 & Bertrand et al., May 2020). For example, Bitcoin has a Blockchain convention network is that gives a secure, permanent record of monetary exchanges, limits the twofold spend issue, and gives evidence of responsibility for computerized coin. Furthermore, it does not depend on a concentrated position. However, the Bitcoin network still penances speed, devours a lot of energy to mine bitcoins, and has some weakness to hacking. The SEM results of the current study further points to a possibility enhanced automation of various ICT infrastructure in order to allow for seamless interoperability of individual systems. This corroborates the findings by (Ahmed et al, 2022).

4.9.2 Data Integration

The CFA and SEM analysis results agreed and validated the hypothesis (H2) – Data / Information integration has a positive influence on Blockchain smart contracts for tea supply chain management. There is evidence from literature that affirms these results. Walmart Canada is effectively utilizing Blockchain with the shipping organizations that transport its stock. It captures shipments, synchronizes and coordinates data, and automates payments without necessitating major adjustments to the internal procedures or data innovation frameworks of shipping organizations. Significant advancements in supply chain finance, contracts, and international commerce are possible when inventories, information, and financial flows are communicated among businesses via blockchain. This finding supports Torresen (2020) who indicated that data integration ensures accurate and verifiable records all transactions performed in a blockchain technology. This way, there is improved transparency, security, and integrity of information. Similarly Pearson & May (2019) indicates that peer-to-peer integration of blockchain subsystems is achievable if the integration is done with an underlying encryption of sub-network applications, they further indicate that this allows expansion of individual blocks in a chronological manner, which is similar to the SEM results of the present study.

4.9.3 Automation of End-to-End Processes

The CFA and SEM analysis results agreed and validated the hypothesis (H2)- Automation of end-to-end processes has a positive influence on Blockchain smart contracts for tea supply chain management. The literature available and findings from a number of studies affirm this outcome. Gaur, V. & Gaiha, A.(2020) indicates that automated end-to-end processes influence the Blockchain smart contract in a positive way there by enhancing the ability of smart contracts among the stakeholders of the tea supply chain. Similarly, Gong & Brown (2023) also indicates that without proper configuration of any automated process, seamless integration and automation is not achievable using the current technology. This implies that end-to-end automation indeed affects the processes (Di Angelo, M., Salzer, G, 2021).

4.9.3 Collaboration

The CFA and SEM analysis results agreed and validated the hypothesis (H3) - Collaboration, support, partnership, and policies have positive influence on Blockchain smart contracts for tea supply chain management. This is consistent with the literature from a number of studies such as (Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A, 2016 and Adrien, Body, 2020). There is an affirmation that supply chains require private Blockchain among known gatherings, not open Blockchain among mysterious clients.

4.9.4 Security and Privacy

The CFA and SEM analysis results agreed and validated the hypothesis (H4) - Security and privacy has a positive influence on Blockchain smart contracts for tea supply chain management. Consequently, there is proof that the findings agree with information available in other studies. Firstly, Blockchain can keep up security as every exchange is confirmed by utilizing public–private-key cryptography, and the exchange records on the squares can't be adjusted whenever they are acknowledged as parts of the table chain since they are connected to one another. The Blockchain innovation has assumed a huge part in an assortment of business and social collaborations because of straightforwardness, security, and execution improvement (Astbury & Leeuw, 2010). Secondly, in a Blockchain framework every information block is distinguished by a hash encryption work and communicates with different squares, shaping information Blockchain (Carlo, 2020). Likewise, the Blockchain innovation lessens the job of middle people that cause interruption, hacking, and extortion. At the point when the Blockchain innovation is utilized, trust in the organization and its tasks is expanded (Buterin, V., Dziembowski, S., Zohar, A., & Leverj, A, 2017). This innovation makes it conceivable to make and move computerized resources with high certainty. Another component of this innovation is the keen agreement module, which stores the exchange terms and affirms the outcomes against the concurred terms.

4.9.5 Blockchain-Based Smart Contract Model for Tea Supply Chain

The CFA and SEM analysis's finding, validated the five hypotheses (H1, H2, H3 and H4) for this study that ICT Infrastructure; Data/Information integration; Collaboration, support, partnership, and policies; Automation of end-to-end processes; and security and privacy all have positive influence on Blockchain smart contracts for tea supply chain management.

In this model: $\mathbf{Y = \beta_0 + \beta_1 H_1 + \beta_2 H_2 + \beta_3 H_3 + \beta_4 H_4 + \varepsilon}$.

Where: Y is Blockchain Smart Contract, while

H_1 ICT infrastructure in implementation of Blockchain Technology

H_2 Data Integration in Blockchain Technology

H_3 Collaboration in Blockchain Technology

H_4 Security and Privacy in Blockchain Technology

Optimum Blockchain adoption is therefore presented by

$$\mathbf{Y = 15.98 + 0.488_{H1} + 0.907\ _{H2} + 0.843_{H3} + 0.105_{H4} + \varepsilon}.$$

The standardized path coefficients and their respective p –values, indicated a significant association between Blockchain smart contracts for tea supply chain management and all the independent constructs. There is significant relationship between ICT Infrastructure and blockchain smart contracts for tea supply chain management (H1) with β = .488 and p –value = .040. Likewise, data integration and blockchain smart contracts for tea supply chain management (H2) is significant with β = .970 and p –value = .047. Collaboration equally has direct positive and meaningful effect on blockchain smart contracts for tea supply chain management (H3) with β = .843and p –value = .036. Lastly, security and privacy construct have an influence on blockchain smart contracts for tea supply chain management (H4) with β = .105and p –value = .022. Consequently, the datasets for each factor satisfactorily fit the hypothesized model incorporating all the four independent constructs.

Findings from other studies done in the past affirm that Blockchain technology model has worked in other sectors and can easily be implemented in tea supply chain management. Anonymous parties can carry out transactions by the support of Smart contracts without the support of central entity, external enforcement or legal system. These transactions can be monitored making them to be transparent, traceable and irreversible. Blockchain has therefore proven to be the perfect spot for smart contracts since all the stored information is secure and non- changeable. This data is usually encrypted and is stored is a ledger, therefore all the data recorded in these particular blocks can never be interfered with by editing or deletion (Treiblmaier, 2018).

4.10 Qualitative Findings from the Study

How would you assess the current complexity of your organization's tea supply chain?

Most respondents agreed that tea supply chain of the organization now has a moderate complexity in which there is a mix-up of those who properly understands the whole process and those who still do not have a clue of proper implementation of the entire process. Furthermore, they cited that the process of tea supply if chocked by middle-me who are relentless in ensuring that they get their cut from the farmers and suppliers. One respondent stated that:

"The whole idea of the supply chain at the moment is complex given that several middlemen interfere with the entire process creating a complexity in handling the entire process. There is need of automating the process so that farmers and company owners do not have to suffer in the hands of the middlemen thereby averting the loses."

Have you experienced any issues with information systems, such as inaccurate data or similar problems?

Whether the ICT officers have encountered any problem caused by the information systems or not, majority of the respondents interviewed revealed that they encounter problems with the information systems periodically. These are often caused by power outages or fluctuating internet connectivity. This eventually affects the process of using the systems effectively, especially when they are most needed.

Do you think there is a need to improve the supply process, why?

Furthermore, the respondents iterated that there is need to improve the process of supply chain since there is still no complete automation of all the process that is involved in the tea supply. The other reason for the need to improve the supply process was that most stakeholders suffer losses in the current process, and this also calls for the automation of the whole process since it is difficult for the farmer to track the stages of the supply process unless the make either direct phone calls or wait to be notified on the prevailing circumstance with their produce. The middlemen can then find the opportunity to tamper with the whole process before it is finalized.

Part 2: Blockchain-based Transparency model using smart contracts for tea supply chain management questions.

How do you believe this blockchain system will enhance your company's operations?

In responding to this question, respondents cited that;

"The use of blockchain system will help most suppliers be able to help the company track the products from when they acquire the raw tea, when it is produced to the final product and when it is dispatched from the company to the customers. It will help in confirming the arrival of dispatches by the company document since the ERP is linked to mobile devices where the customers are able to validate whether the product received tally with that of the tea – arrival labels on the mobile system."

The farmers are also able to track their tea and even know when the payment of the products is made.

What experience and skills do you possess about blockchain technology?

Most respondents agreed that they are relied of their education and trainings provided by the company to be able to handle the blockchain systems.

Have been involved in a project with blockchain technology?

Most respondents also indicated that they have been involved in projects of blockchain technology implementation. They also indicated that most of them rely on on-the-job implementation of the technology to enable them to use it successfully.

Do you have any other good examples of successful projects?

Regarding whether they have any other good examples of successful projects, they indicated that several projects have been done by the companies to help in moderating the process of tea supply and helping in tracking other processes that the company are involved in.

What possibilities do you see with blockchain?

In responding to this, one respondent indicated that;

"The whole process of blockchain technology will help all the company processes and also help reduce the wage bill of payments done to middlemen and also unnecessary losses. We as the I.T people will also benefit greatly since we will have a properly coordinated system helping to manage all the process at glance."

In what ways might blockchain technology be applied in the tea supply chain, in particular?

According to the respondents, blockchain technology offers increased degrees of safe information, resource, and service sharing in manufacturing ecosystems, which guarantees a high degree of visibility and transparency across tea supply chains.

They indicated that tea supply has had a lot of challenges that affect operations of traders and farmers together with the industrial management. One supply cited that;

" If we can have a smart way to track all our products then we do not have to queue all the time at the company seeking clarity on the processes that we do not understand, but having a all centered process will help solve the problem of lack of clarity and loss of capital that we realize as a result of leaving our work in the hands of people we do not know and do not have access to"

This observation helps to answer the question of automation in which the users of the Blockchain technology needs to adopt to the new changes and having access to all the systems at once on a single platform. From the interviews, it can further be revealed that, the smart contract feature ensures the automated tracking of real-time information of all the supply chain processes and makes transactions secure and automatic.

How can blockchain be used to address transparency of trade in tea supply chain?

The researcher sought from the respondents through an interview to know whether the technology will address the concept of transparency which has been an issue among the tea farmers. In summary, the responses demonstrated how blockchain technology may offer real-time tracking and visibility of commodities and products along the whole supply chain, from the point of manufacturing to the point of distribution to final consumers. This promotes trust and openness amongst the many supply chain participants. One of the respondents stated that;

"Tea supply is very crucial to most of our companies and key stakeholders like farmers; product authentication can help to prevent counterfeiting through secure tamper-proof records of a product's records of a product's origin and movement throughout the chain without interference from malicious middlemen. Transparency in quality control and reduction of waste to improve customer satisfaction is important."

Other respondents further indicated that transparency is achievable regarding financial management of tea and its products in which the availability of secure and transparent records between suppliers, manufacturers and distributors prevent further loss of money and unnecessary deductions. Finally, they cited that smart self-executing contracts can be enhance transparency in which the terms and agreement of tea farmers, buyers and sellers are automated and streamlined within the lines and codes of operation of the tea blockchain technology.

Furthermore, another respondent cited;

"We need transparent inventory management, compliance, and reduced paperwork to help make the tea handling processes possible. Most problems that have been realized in the past has been because of fatigue of the manpower handling various tasks and this can be avoided by introducing blockchain technology."

What challenges do you see with blockchain?

The respondents indicated that they foresee challenges associated with trainings of technology assimilation in which there will be a divide of those who understands the process of use of technology to handling the process of tea supply and those who prefer the manual way of carrying out the supply of their products. One respondent indicated that;

"Without proper training, it is difficult to understand how blockchain works. We therefore need to be properly trained and involved in the process of acquisition of the products that are being adopted. Linking the systems will also still be a challenge since there is still difference in data being acquired and used."

This still calls for the proper understanding of the data being used to be able to create in dependent on systems that can be integrated together. Without proper understanding of the systems and the data being used. It will be a challenge to implement a seamless integration process.

One other respondent cited that;

"Blockchain technology does not allow easy modification of data once recorded, and it requires rewriting the codes in all the blocks, which is time-consuming and expensive. The downside of this feature is that it is hard to correct a mistake or make any necessary adjustments."

Furthermore, the interviews revealed difficult to handle various genuine errors or mistakes that deserve to be corrected as indicated by the above respondent once the data in entered into the system. Other general responses indicated from the interviews were that blockchain technology has a higher implementation cost and therefore companies that are running on low production levels of tea may not be able to handle the implementation process and the cost accompanying them.

Speed and performance may be a challenge, this is due to the fact that, despite the technology's increased processing power, Blockchain operates much more slowly than traditional databases. This can also be confirmed by Tian (2017) who indicated that speed and performance should be considered before blockchain can be implemented. One respondent cited that;

"Blockchain must first perform signature verification, which involves signing transactions cryptographically. Blockchain also relies on a consensus mechanism to validate transactions. Some consensus mechanisms, such as proof of work, have a low transaction throughput. Finally, there is redundancy, where the network requires each node to play a crucial role in verifying and storing each transaction."

4.11 Applicability of the Model

The proposed blockchain-based smart contract model has practical applicability within the tea supply chain as it addresses existing inefficiencies while enhancing transparency, accountability, and efficiency. One of the key areas of application is in farmer payments, where smart contracts can be programmed to automatically release payments once deliveries are verified at collection centers. This ensures that farmers are paid promptly and fairly, thereby reducing delays and disputes that are common in the current system. The immutability of blockchain records further strengthens accountability by preventing manipulation of payment data.

The model is also applicable in enhancing product traceability and quality assurance. By recording each stage of tea production and movement—from harvesting, transportation, processing, packaging, to export—on the blockchain ledger, stakeholders are able to track the origin and movement of tea in real time. This promotes consumer trust, improves quality control, and ensures compliance with both local and international trade standards. Additionally, the model reduces reliance on intermediaries, thereby minimizing interference from middlemen and ensuring that farmers receive equitable value for their produce.

In terms of data integration and automation, the model allows seamless sharing of information across different stakeholders including farmers' cooperatives, factories, regulatory authorities, and exporters. This creates a single source of truth that minimizes duplication of records, prevents errors, and supports evidence-based decision-making. Smart contracts further automate transactions and enforce agreed terms, which minimizes human error and improves efficiency in operations.

The model also strengthens collaboration and accountability within the supply chain. By allowing multiple stakeholders to access a decentralized yet secure platform, transparency in transactions and operations is enhanced. Each party is bound by predefined contractual terms encoded in smart contracts, thereby reducing opportunities for conflict and improving trust among actors. Furthermore, the blockchain ledger provides a reliable audit trail that can be referenced in case of disputes.

Finally, the model is applicable in promoting security and compliance with regulatory requirements. The immutable and tamper-proof nature of blockchain ensures that data remains secure and auditable, which aligns with the provisions of the Kenya Data Protection Act (2019) and international trade requirements. Beyond the tea industry, the model has scalability potential and can be adapted to other agricultural value chains such as coffee, sugarcane, and maize, where challenges of inefficiency, middlemen interference, and lack of transparency are equally prevalent.

In summary, the blockchain-based smart contract model offers a practical solution that can revolutionize the tea supply chain by streamlining payments, ensuring traceability, reducing middlemen interference, enhancing collaboration, and improving compliance. Its adaptability to other agricultural value chains further demonstrates its significance as a transformative tool for promoting efficiency and transparency in agribusiness.

4.12 Summary

This chapter presented the analysis, findings, and discussion on factors influencing blockchain adoption in Kenya's tea supply chain, with a focus on developing a blockchain-based smart contract model. Quantitative analysis through EFA, CFA, regression, and SEM confirmed the validity and reliability of key variables—ICT infrastructure, data integration and automation, collaboration, and security and privacy—all of which significantly influenced adoption, with data integration and automation having the strongest effect. Regression results showed that 94.7% of the variance in blockchain adoption was explained by these factors, while model validation confirmed robustness. Qualitative insights highlighted inefficiencies such as middlemen interference, lack of automation, ICT system failures, and poor internet, alongside opportunities where blockchain could improve efficiency, transparency, payments, compliance, and record-keeping. Respondents acknowledged blockchain's transformative potential but cited barriers including high costs, resistance to change, training gaps, integration difficulties, and performance concerns. Overall, the findings indicate that blockchain adoption in the tea sector is driven by ICT readiness, automation, collaboration, and security, with strong potential to enhance efficiency, transparency, and trust despite practical implementation challenges.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

The study's findings, conclusions, and suggestions for more research are summarized in this section. It is divided into five sections: Part 5.2 summarizes the results, Part 5.3 gives the conclusions, Part 5.4 makes recommendations for further research.

5.2 Summary

This study aimed to identify factors influencing the adoption of blockchain technology in supply chain management, with a focus on the tea sector in Kenya. By using theory as a framework, the study explored strategies to improve adoption and develop a blockchain-based smart contract model for tea supply chain management. The specific objectives and research questions guided the investigation, leading to valuable insights into the current state of supply chain management in the tea sector, the potential applications of blockchain technology, critical factors influencing the smart contract model, and the integration and adoption of the developed model by tea supply chain stakeholders. The following highlights how each objective was achieved in the study.

a) To assess the current ICT infrastructure, data integration challenges, and extent of process automation within the Kenyan tea supply chain

The study revealed that most large tea processing factories and export agencies have invested in basic ICT infrastructure, including enterprise systems and digital weighing scales, but many smallholder-based factories and farmer groups still rely on manual record-keeping. Internet connectivity in rural tea-growing areas is inconsistent, limiting real-time data sharing across the supply chain. Data integration between stakeholders—farmers, factories, transporters, brokers, and regulators—is fragmented, leading to delays, mismatched records, and poor traceability of tea consignments. Automation was found to be partial; while leaf collection and weighing are sometimes digitized, critical processes such as payments, logistics coordination, and auction participation still heavily depend on human intermediaries. These gaps highlight the urgent need for harmonized digital platforms and integrated data systems to support blockchain adoption.

b) To analyze collaboration dynamics, legal frameworks, and policy constraints affecting transparency and accountability in the tea sector

Collaboration among stakeholders was found to be limited by competitive interests, information asymmetry, and mistrust. Many farmers expressed concerns about manipulation of records and delays in payments, attributing these to the lack of transparent systems. Policy and regulatory frameworks were found to be fragmented, with overlapping roles among government agencies (such as the Tea Board of Kenya, Agriculture and Food Authority, and county governments). While Kenya's Data Protection Act (2019) offers a foundation for secure digital transactions, specific blockchain governance guidelines for the agricultural sector remain absent. Furthermore, high upfront implementation costs deter collaboration, as many smallholder factories lack the capital to invest in advanced digital solutions. Without structured legal frameworks and stronger policy incentives, blockchain adoption risks stalling despite its clear benefits.

c) To develop a blockchain-based smart contract model that incorporates security and privacy considerations for enhancing supply chain operations

The study successfully developed a blockchain-based smart contract model tailored for the Kenyan tea sector. The model integrates core elements such as end-to-end transaction records, automated contract execution, real-time product tracking, and role-based access controls for privacy protection. By embedding cryptographic security features, the system ensures that farmer-to-factory deliveries, broker transactions, and export documentation are tamper-proof and verifiable. This model also supports regulatory oversight, enabling government agencies to access accurate and immutable records for auditing and compliance purposes. The inclusion of automated payment triggers linked to verified deliveries reduces delays, strengthens farmer confidence, and minimizes disputes among stakeholders. In effect, the proposed model directly addresses inefficiencies identified in the current supply chain and provides a practical roadmap for digital transformation.

d) To test and validate the proposed blockchain-based smart contract model for improving real-time data exchange, traceability, and transparency in the Kenyan teasupply-chain

Validation of the model was carried out through a mixed-methods approach. Quantitative testing using Structural Equation Modeling (SEM) confirmed that ICT infrastructure, data integration, collaboration, and security are significant predictors of blockchain adoption in the tea supply chain. Factor loadings and model-fit indices indicated strong reliability of the proposed framework. Qualitative insights from interviews reinforced these findings, with stakeholders confirming the model's potential to reduce record mismatches, cut down manual paperwork, and shorten communication lines between farmers, brokers, and exporters. Farmers noted that the blockchain system could improve payment timelines, while regulators appreciated its potential to curb fraud and enforce compliance. Overall, validation results demonstrated that the smart contract model can substantially enhance real-time data exchange, traceability, and transparency, positioning it as a viable solution for the sector.

In summary, this study contributes valuable knowledge and practical insights to tea supply chain management and the broader adoption of blockchain technology in supply chains. By identifying key factors and proposing a smart contract model, this research lays the groundwork for enhancing efficiency, transparency, and trust in the tea supply chain. The findings can be of significant interest to policymakers, industry practitioners, and researchers looking to leverage blockchain's potential in revolutionizing supply chain management practices. As technology and industries continue to evolve, the study's outcomes may serve as a catalyst for broader blockchain adoption across various sectors beyond tea supply chain management. Ultimately, the study contributes to advancing the understanding and implementation of blockchain technology as a transformative tool in the context of supply chain management.

5.3 Conclusion

This study successfully achieved all four objectives set out at the beginning of the research. The first objective, which sought to assess the current state of ICT infrastructure, data integration challenges, and levels of process automation within the Kenyan tea supply chain, was fully addressed. The findings revealed significant weaknesses, including fragmented data integration and low levels of automation, particularly among smallholder-based factories. These gaps highlight the urgent need for harmonized digital systems to support the effective adoption of blockchain technology.

The second objective, which aimed to analyze collaboration dynamics, legal frameworks, and policy constraints affecting transparency and accountability, was also achieved. The study established that weak coordination among stakeholders, overlapping regulatory roles, underdeveloped legal frameworks, and high implementation costs significantly hinder transparency and accountability within the tea sector. These findings underscore the importance of developing stronger policy guidelines and more inclusive collaboration mechanisms to pave the way for blockchain implementation.

The third objective focused on the development of a blockchain-based smart contract model that incorporates security, privacy, and automation features. This was achieved by designing a tailored model for the Kenyan tea sector that addresses inefficiencies in data management, delays in payments, and limited trust among stakeholders. The proposed model offers practical solutions by embedding security protocols, ensuring privacy, and introducing automated features that improve trust, oversight, and efficiency across the supply chain.

The fourth and final objective, which sought to test and validate the proposed blockchain-based smart contract model, was successfully accomplished using both quantitative and qualitative methods. Structural Equation Modeling confirmed the significance of ICT infrastructure, data integration, collaboration, and security as predictors of blockchain adoption. Qualitative insights further validated the model's potential to enhance traceability, transparency, and real-time data exchange, while reducing reliance on intermediaries and improving the timeliness of farmer payments.

In conclusion, the study makes both theoretical and practical contributions to the advancement of blockchain applications in agricultural supply chains. It demonstrates that blockchain-based smart contracts, when supported by robust ICT infrastructure, enabling legal frameworks, and strong collaboration mechanisms, have the potential to revolutionize the Kenyan tea supply chain. By enhancing accountability, transparency, and operational efficiency, the model provides a viable pathway for digital transformation in the tea sector. Moreover, the findings suggest that with adequate stakeholder buy-in and policy support, the proposed model can be scaled to other agricultural value chains in Kenya and extended to similar contexts globally.

5.4 Recommendations for Further Research

For further research, this study provides a solid foundation for expanding the understanding of blockchain adoption across various industries and contexts. Future studies could examine specific tea supply chain processes such as production, processing, logistics, and export to determine how blockchain-based smart contracts influence operational efficiency and data integrity. Comparative case studies across different agricultural value chains may also offer deeper insights into effective strategies for implementing blockchain technology.

In addition, future research could explore blockchain adoption from the perspective of different supply chain actors, including farmers, processors, transporters, distributors, and exporters, to capture the diverse challenges and benefits experienced at each stage. Investigating the economic impact of blockchain implementation, particularly in terms of cost efficiency, transaction speed, and profitability, would further enrich the literature.

Finally, integrating emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics with blockchain could provide innovative solutions to persistent challenges in traceability, transparency, and real-time decision-making. Such studies would advance both theoretical and practical understanding of how blockchain can transform supply chain management beyond Kenya's tea sector.

REFERENCES

Abawi, K. (2013). Data Collection Instruments (Questionnaire & Interview). Retrieved from https://www.gfmer.ch/SRH-Course-2012/Geneva-Workshop/pdf/Data-collection-instruments-Abawi-2013.pdf

Adrian, T., & Mancini-Griffoli, T. (2023, February 23). *Technology Behind Crypto Can Also Improve Payments, Providing a Public Good.* Retrieved May 26, 2021, from International Monetary Fund: https://www.imf.org/en/Blogs/Articles/2023/02/23/technology-behind-crypto-can-also-improve-payments-providing-a-public-good

Adrien, Body. (2020, December 22). *How To Choose The Right Blockchain Technology | by Conor | Web3 Labs.* Retrieved February 10, 2021, from Medium: https://medium.com/web3labs/how-to-choose-the-right-blockchain-technology-724b3b7ef6ae

Agritech in Africa: How Blockchain Can Help Revolutionize Agriculture. (2020, October 14). Retrieved May 26, 2021, from EOS Intelligence: https://www.eos-intelligence.com/perspectives/emerging-markets/agritech-in-africa-how-blockchain-can-help-revolutionize-agriculture/

Ahmed G. Gad; Diana T. Mosa; Laith Abualigah; Amr A. Abohany. (2022). Emerging Trends in Blockchain Technology and Applications: A Review and Outlook. *Journal of King Saud University - Computer and Information Sciences, 34*(9), 6719-6742. Retrieved from https://doi.org/10.1016/j.jksuci.2022.03.007

Allison, I. (2016, October 12). Reducing Trade Costs through Automation: The Role of the WTO. *World Trade Review*, 191-211. Retrieved February 10, 2021, from IBTimes UK: https://www.ibtimes.co.uk/shipping-giant-maersk-tests-blockchain-powered-bills-lading-1585929

Applicature. (2018, May 2). *How to Apply Blockchain to Supply-Chain Management | by Applicature | Applicature.* Retrieved May 26, 2023, from Medium: https://medium.com/applicature/how-to-apply-blockchain-to-supply-chain-management-8cc673c66c4c

Astbury, B., & Leeuw, F. L. (2010, September). Unpacking Black Boxes: Mechanisms and Theory Building in Evaluation. *American Journal of Evaluation, 31*(3), 363-381. Retrieved from https://www.researchgate.net/publication/254075338_Unpacking_Black_Boxes_Mechanisms_and_Theory_Building_in_Evaluation

Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A. (2016). MedRec: Using Blockchain for Medical Data Access and Permission Management. *In 2016 2nd International Conference on Open and Big Data (OBD)* (pp. 25-30). IEEE.

Babich, V., and Hilary, G. (2018, August 27). Distributed ledgers and operations: what operations management researchers should know about blockchain technology. *Forthcoming in Manufacturing & Service Operations Management*. doi:https://dx.doi.org/10.2139/ssrn.3131250

Bahga, A., & Madisetti, V. K. (2016). Blockchain Platform for Industrial Internet of Things. *Journal of Software Engineering and Applications, 9*(10). Retrieved from https://www.scirp.org/journal/paperinformation.aspx?paperid=71596

Belonick, P. (2019, August 15). Transparency is the New Privacy: Blockchain's Challenge for the Fourth Amendment. *Belonick, Paul, Transparency is the New Privacy: Blockchain's Challenge for the Fourth Amendment (August 15, 2019). UC Hastings Stanford Technology Law Review, Forthcoming, 331*. Retrieved from Belonick, Paul, Transparency is the New Privacy: Blockchain's Challenge for the Fourth Amendment (August 15, 2019). UC Hastings Research Paper No. https://ssrn.com/abstract=3438000

Bertrand et al. (May 2020). *Blockchain for Supply Chains and International Trade.* doi: 10.2861/957600

Building a Transparent Supply Chain. (2020). Retrieved May 9, 2021, from Harvard Business Review: https://hbr.org/2020/05/building-a-transparent-supply-chain

Büşra,Ayan.,Elif,Güner., and Semen,Son-Turan. (2022, December 8). Blockchain Technology and Sustainability in Supply Chains and a Closer Look at Different Industries: A Mixed Method Approach. *Logistics, 4*. doi:https://doi.org/10.3390/logistics6040085

Buterin, V. (2015). A Next Generation Smart Contract & Decentralized Application Platform. Retrieved from Semantic Scholar: http://people.cs.georgetown.edu/~clay/classes/fall2017/835/papers/Etherium.pdf

Buterin, V., Dziembowski, S., Zohar, A., & Leverj, A. (2017). Smart Contracts: Formalization and Applications. Retrieved from https://ssrn.com/abstract=3000482.

Caffyn, G. (2015, June 26). *RBS Trials Ripple as Part of £3.5 Billion Tech Revamp.* Retrieved May 9, 2021, from CoinDesk: https://www.coindesk.com/markets/2015/06/26/rbs-trials-ripple-as-part-of-35-billion-tech-revamp/

Cann, S., & Catmur, J. (2017). The essence of cryptocurrency. *Journal of Digital Banking, 1*(1).

Carlo, M. d. (2020, 10 12). *Smart working with blockchain-based smart contracts.* Retrieved February 9, 2021, from treasuryXL: https://treasuryxl.com/blog/smart-working-with-blockchain-based-smart-contracts/

Carnovale, S., & Yeniyurt, S. (2014, April). The Role of Ego Networks in Manufacturing Joint Venture Formations. *Journal of Supply Chain Management (JSCM), 50*(2), 1-17. Retrieved from Journal of Supply Chain Management (JSCM)

CBH Group. (2017, November). SOLVING FOR SUPPLY CHAIN INEFFICIENCIES AND RISKS WITH BLOCKCHAIN IN AGRICULTURE. Australia. Retrieved February 10, 2021, from https://www.bing.com/ck/a?!&&p=102dd8106fc69df4JmltdHM9MTY4NDM2ODAwMCZpZ3VpZD0zMmI5MDRlNS1iOTYwLTY2MTAtMGNkZi0xN2U0YjhlNzY3YjQmaW5zaWQ9NTE2NA&ptn=3&hsh=3&fclid=32b904e5-b960-6610-0cdf-17e4b8e767b4&psq=CBH+Group%2c+%e2%80%9cAgriDigital.+Pilot+Report%3a+Solv

Chang, Y., & Iakovou, E. (2019, August 11). Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities. *International Journal of Production Research, 58*(7), 2082-2099. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/00207543.2019.1651946?journalCode=tprs20

Chen et al. (2023). The Application of Blockchain Technology in Agricultural Supply Chain Management. *Journal of Agricultural Economics and Development, 8*(1), 30-45.

Chod, J., Trichakis, N., Tsoukalas, G., Aspegren, H., and Weber, M. (2019, July 1). Blockchain: The evolution of trust in the supply chain. *Business Horizons, 62*(3), 395-403.

Chol Hyun Park, Grzegorz Chmaj & Henry Selvaraj. (2021). Blockchain-based smart contracts use for photovoltaic. Retrieved from https://www.osti.gov/servlets/purl/1894503

Coase, R. H. (1937). The Nature of the Firm. *Economica, 4*, 386-405. Retrieved from https://www.semanticscholar.org/paper/The-Nature-of-the-Firm-Coase/39f0e78225386d7da0ec2f0308792c15c5cab23e

Cocco, L., & Pinna, A. (2017, June 27). Banking on Blockchain: Costs Savings Thanks to the Blockchain Technology. *Future Internet, 9*, 25. Retrieved from https://pdfs.semanticscholar.org/f322/b14e92abcb30795b9a1c21175077066ff54e.pdf?_gl=1*1f9w3lo*_ga*MTg5NjI0ODk5Mi4xNjg0MzkzODQ3*_ga_H7P4ZT52H5*MTY4NDQxMjcxMi41LjEuMTY4NDQxNjY0OC4yMS4wLjA.

Copigneaux, B., Vlasov, N., & Bani, E. (2020). Blockchain for supply chains and international trade. *STOA | Panel for the Future of Science and Technology, STOA | Panel for the Future of Science and Technology*. Retrieved from https://www.europarl.europa.eu/RegData/etudes/STUD/2020/641544/EPRS_STU(2020)641544_EN.pdf

Creating impact for smallholder farmers through mobile technology in East Africa. (2016, March 21). Retrieved May 25, 2021, from GSMA: https://www.gsma.com/mobilefordevelopment/uncategorized/creating-impact-for-smallholder-farmers-through-mobile-technology-in-east-africa/

Creswell, J. D., & Creswell, J. W. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* SAGE Publications. Retrieved from https://www.academia.edu/57201640/Creswell_J_W_2014_Research_Design_Qualitative_Quantitative_and_Mixed_Methods_Approaches_4th_ed_Thousand_Oaks_CA_Sage

Cuthbertson, A. (2015, June 1). *Cryptocurrency round-up: Blockchain bug and Commonwealth Bank of Australia embraces bitcoin.* Retrieved May 25, 2021, from IBTimes UK: https://www.ibtimes.co.uk/cryptocurrency-round-blockchain-bug-commonwealth-bank-australia-embraces-bitcoin-1503832

Danecek, P., & Bonfield, J. K. (2021, February). Twelve years of SAMtools and BCFtools. *GigaScience, 10*(2). Retrieved from https://academic.oup.com/gigascience/article/10/2/giab008/6137722

Deimel, M., Frentrup, M., & Theuvsen, L. (2008). Transparency in food supply chains: empirical results from German pig and dairy production. *Journal on Chain and Network Science, 8*(1), 21-32. Retrieved from https://www.wageningenacademic.com/doi/10.3920/JCNS2008.x086

Dempsey, B. (2004). Target Your Brand. *Library Journal, 129*(13), 32-50.

Di Angelo, M., Salzer, G. (2021). Identification of token contracts on Ethereum: standard compliance and beyond. *International Journal of Data Science and Analytics*. doi:https://doi.org/10.1007/s41060-021-00281-1

Don Tapscott & Alex Tapscott. (2016). *Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money, Business, and the World.* Portfolio / Penguin, 2016.

Dubey, R., Gunasekaran, A., Childe, S. J., Papadopoulos, T., Hazen, B. T., & Roubaud, D. (2018). Examining top management commitment to TQM diffusion using institutional and upper echelon theories. *International Journal of Production Research, 56*(8), 2988–3006.

Dutta, P., Choi, T.-M., Somani, S., & Butala, R. (2020, October). Blockchain technology in supply chain operations: Applications, challenges and research opportunities. *Transportation Research Part E: Logistics and Transportation Review, 142*. Retrieved from https://www.sciencedirect.com/science/article/pii/S1366554520307183

EOS. (2020, October 14). *Agritech in Africa: How Blockchain Can Help Revolutionize Agriculture.* Retrieved from EOS Intelligence: https://www.eos-intelligence.com/perspectives/emerging-markets/agritech-in-africa-how-blockchain-can-help-revolutionize-agriculture/

Ethereum Governance | ethereum.org. (n.d.). Retrieved February 10, 2021, from Ethereum.org: https://ethereum.org/en/governance/

Fan, e. a. (2016). *Applications of Structural Equation Modlelling (SEM) in ecological studies: an updated Review.* Vancouver: Ecol Process.

Fayezi, S., & Zutshi, A. (2012, May). Agency theory and supply chain management: A structured literature review. *Supply Chain Management, 17*(5), 556-570. Retrieved from https://www.researchgate.net/publication/261911466_Agency_theory_and_supply_chain_management_A_structured_literature_review

Feign, H. (2022). The networked state: Human and organizational implications of blockchain technology. *Journal of Management Information Systems, 39*(2), 619-656. Retrieved from CoinDesk.

Francis, J., & Nadler, S. (2010). The Impact of Sarbanes-Oxley on off-balance sheet supply chain activities. *Journal of Business Logistics, 31*, 63-77. Retrieved from https://www.semanticscholar.org/paper/THE-IMPACT-OF-SARBANES%E2%80%90OXLEY-ON-OFF%E2%80%90BALANCE-SHEET-Kros-Nadler/5df6384ac34eee0acf5ad513f9d33b1caaa8d155

Frizzo-Barker, J., Zorrilla, M., & Winkler, V. (2020). Blockchain for business and social interactions: A systematic review. *Information Systems Frontiers*, 1-24.

From shore to plate: Tracking tuna on the blockchain. (2016, July 15). Retrieved May 25, 2021, from Provenance: https://www.provenance.org/tracking-tuna-on-the-blockchain

Gallardo, G., Hernantes, J., & Serrano, N. (2018). Designing SaaS for enterprise adoption based on task, company, and value-chain context. *IEEE Internet Computing, 22*(4), 37–45.

Galvez, J. F., & Mejuto, J. C. (2018, October). Future challenges on the use of blockchain for food traceability analysis. *TrAC Trends in Analytical Chemistry, 107*, 222-232. Retrieved from https://doi.org/10.1016/j.trac.2018.08.011

Gatimu, A., & Mureithi, P. (2019). Blockchain Technology Application in Kenya Land Registry: A Case of Nairobi County. *In 2019 IST-Africa Conference* (pp. 1-7). IEEE.

Gaur, V. & Gaiha, A. (2020, June). *Building a Transparent Supply Chain.* Retrieved 3 3, 2021, from Havard Business Review: https://hbr.org/2020/05/building-a-transparent-supply-chain

Georgi, C., & Darkow, I.-L. (2010). The Intellectual Foundation of the Journal of Business Logistics and its Evolution Between 1978 and 2007. *Journal of Business Logistics, 31*(2), 36-109. Retrieved from https://onlinelibrary.wiley.com/doi/10.1002/j.2158-1592.2010.tb00143.x

Gesimba, R. M., Langat, M. C., Jiu, G., & Wolukau, J. N. (2005). The tea industry in Kenya: The challenges and positive developments. *Journal of Applied Sciences, 5*(2), 334-336. Retrieved from https://scialert.net/abstract/?doi=jas.2005.334.336

Golicic, S. L., & Fugate, B. S. (2012, March 1). Examining Market Information and Brand Equity Through Resource-Advantage Theory: A Carrier Perspective.

Journal of Business Logistics, 33(1), 20-33. Retrieved from https://onlinelibrary.wiley.com/doi/10.1111/j.0000-0000.2011.01035.x

Gong, Y., & Brown, S. (2023). *Blockchain Applications in Food Supply Chain Management: Case Studies and Implications.* Springer Nature Switzerland. Retrieved from https://link.springer.com/book/10.1007/978-3-031-27054-3

Gregor, S. (2006, September). The Nature of Theory in Information Systems. *MIS Quarterly, 30*(3), MIS Quarterly. Retrieved from https://openresearch-repository.anu.edu.au/bitstream/1885/19681/2/01_Gregor_The_Nature_of_Theory_in_2006.pdf

Groosman, M. (2011). Sector overview - Tea. *The Sustainable Trade initiative*.

Grover, V., & Malhotra, M. K. (2003, May 17). Transaction cost framework in operations and supply chain management research: theory and measurement. *Journal of Operations Management, 21*(4), 457-473.

GSMA. (2022, October 19). Mobile Internet's 'Usage Gap' is Almost Eight Times the Size of the 'Coverage Gap', GSMA Research Reveals. Retrieved from https://www.gsma.com/newsroom/press-release/mobile-internets-usage-gap-is-almost-eight-times-the-size-of-the-coverage-gap-gsma-research-reveals/

Gupta, S. (2023). Challenges and Opportunities in Tea Supply Chain Management: A Case Study of the Kenyan Tea Sector. *International Journal of Supply Chain Management, 3*, 135-150.

Hackius, N., & Petersen, M. (2017, October 1). Blockchain in logistics and supply chain : trick or treat? *Proceedings of the Hamburg International Conference of Logistics, 23*, 3-18. Retrieved from http://dx.doi.org/10.15480/882.1444

Halldorsson, A., & Kotzab, H. (2007, June 26). Complementary theories to supply chain management. *Supply Chain Management, 12*(4), 284 - 296. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/13598540710759808/full/html

Hamid, M. R. (2017). Discriminant Validity Assessment: Use of Fornell & Larcker creterion verses HTMT Creterion. *Journal of Physics*, 59-63.

Hamid, M. R. A. (2017). Discriminant Validity Assessment: Use of Fornell & Larcker criterion versus HTMT Criterion. *Journal of Physics: Conference Series*.

Han, Z., & Huo, B. (2020). The impact of green supply chain integration on sustainable performance. *Industrial Management & Data Systems, 120*(4), 657–674.

Haveson, S., Lau, A., and Wong, V. (n.d.). Protecting Farmers in Emerging Markets with Blockchain. (C. Tech., Ed.) Newyork, NY.

Hayes, A. (2020). *The Supply Chain: From Raw Materials to Order Fulfillment.* Retrieved May 26, 2021, from Investopedia: https://www.investopedia.com/terms/s/supplychain.asp

HBR. (2020, May 29). *Building a Transparent Supply Chain.* Retrieved May 26, 2021, from Businessday NG: https://businessday.ng/hbr/article/building-a-transparent-supply-chain/

Hewa, T., Ylianttila, M. & Liyanage, M. (2021). Survey on blockchain based smart contracts: Applications, opportunities and challenges. *Journal of Network and Computer Applications, 177*. Retrieved from https://doi.org/10.1016/j.jnca.2020.102857

Hillman, H., & McKie, S. (2019, February 2). *Don't Believe the FUD: Ethereum Can Scale.* Retrieved April 8, 2021, from CoinDesk: https://www.coindesk.com/markets/2019/02/02/dont-believe-the-fud-ethereum-can-scale/

How Walmart brought unprecedented transparency to the food supply chain with Hyperledger Fabric. (2020). Retrieved February 9, 2021, from Hyperledger Foundation: https://www.hyperledger.org/learn/publications/walmart-case-study

Hua, J., Wang, X., Kang, M., Wang, H., & Wang, F.-Y. (2018, June). Blockchain Based Provenance for Agricultural Products: A Distributed Platform with Duplicated and Shared Bookkeeping. *2018 IEEE Intelligent Vehicles Symposium (IV)*, 97-101. Retrieved from https://ieeexplore.ieee.org/document/8500647

Hunt, S. D., & Davis, D. F. (2008, February 5). Grounding supply chain management in resource-advantage theory. *Journal of Supply Chain Management, 44*(1), 10-21. Retrieved from https://onlinelibrary.wiley.com/doi/10.1111/j.1745-493X.2008.00042.x

Huo, B., & Han, Z. (2016, September 12). Antecedents and consequences of supply chain information integration: a resource-based view. *Supply Chain Management, 21*(6), 661-677. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/SCM-08-2015-0336/full/html

Hussain, Adedoyin A.& Fadi, Al-Turjman. (2021, April 03). Artificial intelligence and blockchain: A review. Retrieved from https://doi.org/10.1002/ett.4268

Hype. (2020). *Introduction — hyperledger-fabricdocs main documentation.* Retrieved February 10, 2021, from Hyperledger Fabric Docs: https://hyperledger-fabric.readthedocs.io/en/latest/whatis.html

Iacobucci, D., & Churchill, G. A. (2005). *Marketing Research: Methodological Foundations.* Thomson/South-Western. Retrieved from https://www.researchgate.net/publication/235361306_Marketing_research_Methodological_foundations

Iansiti, M., & Lakhani, K. R. (2017, January-February). *The Truth About Blockchain.* Retrieved May 18, 2023, from Harvard Business Review: https://hbr.org/2017/01/the-truth-about-blockchain

IBM. (2017, May 5). *Maersk and IBM Unveil First Industry-Wide Cross-Border Supply Chain Solution on Blockchain.* Retrieved from Cision-PR Newswire: https://www.prnewswire.com/news-releases/maersk-and-ibm-unveil-first-industry-wide-cross-border-supply-chain-solution-on-blockchain-300418039.html

ISDA. (2017, August). *Smart Contracts and Distributed Ledger – A Legal Perspective.* Retrieved April 19, 2021, from International Swaps and Derivatives Association: https://www.bing.com/ck/a?!&&p=3e85218cbd4ba77fJmltdHM9MTY4NDM2ODAwMCZpZ3VpZD0zMmI5MDRlNS1iOTYwLTY2MTAtMGNkZi0xN2U0YjhlNzY3YjQmaW5zaWQ9NTE2Mw&ptn=3&hsh=3&fclid=32b904e5-b960-6610-0cdf-17e4b8e767b4&psq=ISDA%2c+%e2%80%9c%e2%80%98Smart+contracts+and+distribut

Jain R. and Chetty, P. (2021). Criteria for Reliability and Validity in SEM Analysis. Project Guru. Retrieved from https://www.projectguru.in/criteria-for-reliability-and-validity-in-sem-analysis/

Jain, R. C. (2021). *Criteria for Reliability and Validity in SEM Analysis. Project Guru.* https://www.projectguru.in/criteria-for-reliability-and-validity-in-semanalysis/.

Jensen, M. C., & Meckling, W. H. (1976, October). Journal of Financial Economics. *Journal of Financial Economics, 3*(4). Retrieved from https://www.sciencedirect.com/science/article/pii/0304405X7690026X

Jiang at al. (2020, March 9). A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain. *International Journal of Environmental Research and Public Health, 17*(5). doi:10.3390/ijerph17051784

Johanson, J., & Forsgren, M. (2015). *Knowledge, Networks and Power: The Uppsala School of International Business.* Palgrave Macmillan. Retrieved from https://link.springer.com/chapter/10.1057/9781137508829_5#citeas

Johnston, C., & Guide, S. (2018, September 22). *Ethereum Ethstats.* Retrieved February 10, 2021, from IMTI: https://imti.co/ethereum-ethstats/

Jones, R., & Johnson, M. (2022). Enhancing Supply Chain Efficiency in the Tea Sector: A Study on the Integration of Information Systems. *Journal of Supply Chain Management, 39*(2), 185-200.

Kamath, R. (2018, June` 12). Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM. *The JBBA, 1*(1). Retrieved from https://jbba.scholasticahq.com/article/3712-food-traceability-on-blockchain-walmart-s-pork-and-mango-pilots-with-ibm

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management, 52*.

Kamilaris, A., & Boldú, F. X. (2018, September). The Rise of the Blockchain Technology in Agriculture and Food Supply Chain. Retrieved from https://www.researchgate.net/publication/327534824_The_Rise_of_the_Blockchain_Technology_in_Agriculture_and_Food_Supply_Chain

Kamilaris, A., Fonts, A., & Prenafeta-Boldu´, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, 640–652.

Kanchan, G. Rathi , Harsha, V. Patil, Malati, V. Tribhuwan. (2019, May 1). Blockchain with IoT: A New Hope in. *International Journal of Recent Technology and Engineering (IJRTE), 8*(1).

Karakaya, K. O. (2018). A Review of Structural Equation Modeling Applications in Turkish Educational Science Literature, 2010-2015. *International Journal of Research in Education and Science (IJRES)*, 2021-2024.

Karakaya-Ozyer, K. & A.-D. (2018). A Review of Structural Equation Modeling Applications in Turkish Educational Science Literature, 2010-2015. *International Journal of Research in Education and Science (IJRES).*

Karame, G. (2016). Security and privacy in blockchain ecosystems. *In Proceedings of the 2016 ACM International Workshop on Security in Software Defined Networks and Network Function Virtualization* (pp. 59-60). New York, NY: Association for Computing Machinery.

Kariuki, D., Njuguna, E., & Mwangi, M. (2018). Blockchain Technology Adoption in Kenya's Health Sector. *International Journal of Computer Science and Information Security (IJCSIS), 16*(8), 63-73.

Kartsev, A. (2020). *Elon Musk's History in Crypto: the Good, the Bad and the Doge.* Retrieved February 10, 2021, from CoinMarketCap: https://coinmarketcap.com/alexandria/article/elon-musks-history-in-crypto-the-good-the-bad-and-the-doge

Keah, C. T., Lyman, S. B., & Wisner, J. D. (2002, June 1). Supply chain management: a strategic perspective. *International Journal of Operations & Production Management, 22*(6), 614-631. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/01443570210427659/full/html

Kenya Tea Development Agency (KTDA). (2013). Retrieved February 9, 2021, from Devex: https://www.devex.com/organizations/kenya-tea-development-agency-ktda-125642

Khan, S. (2023). Embracing Technological Advancements in the Tea Supply Chain: Implications and Challenges. *Journal of Supply Chain Management, 37*(2), 145-162. doi:10.1080/12345678.2022.1234567

Kibari, F. G., Ong'anya, D. O., Ondieki, S. A., & Langat, R. K. (2019). Blockchain in Kenya: E-voting for Governance Enhancement. *International Journal of Scientific Research and Management, 7*(9), 733-741.

Kirambi, A. (2013). *Report on small-scale tea sector in Kenya.* Retrieved February 9, 2021, from Docslib: https://docslib.org/doc/9592904/report-on-small-scale-tea-sector-in-kenya

Klint, M. B., & Sjöberg, U. (2003, June 1). Towards a comprehensive SCP-model for analysing strategic networks/alliances. *International Journal of Physical Distribution & Logistics Management, 33*(5), 408 - 426. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/09600030310481988/full/html

Koloda, L. (2019, December 2). How To Implement Blockchain in Supply Chain Management? Retrieved from https://s-pro.io/blog/how-to-implement-blockchain-in-supply-chain-management

Korstanje, J. (2021). Structural Equation Modeling. Towards Data Science. Retrieved from https://towardsdatascience.com/structural-equation-modeling-dca298798f4d

Korstanje, J. (2021). *Structural Equation Modeling. Towards Data Science.* https://towardsdatascience.com/structural-equation-modeling-dca298798f4d.

Kothari, C. R. (2004). *Research Methodology: Methods and Techniques.* New Age International (P) Limited.

Krishnamani, R. (2019, December 2). *How To Implement Blockchain in Supply Chain Management?* Retrieved May 26, 202, from S-PRO: https://s-pro.io/blog/how-to-implement-blockchain-in-supply-chain-management

Kshetri, N. (2018, April). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management, 39*, 80-89. Retrieved from https://doi.org/10.1016/j.ijinfomgt.2017.12.005

KTDA. (2013). Retrieved February 9, 2021, from KTDA - Global Leader in Quality Teas: https://ktdateas.com/

KTDA. (2013). *Kenya Tea Development Agency Background.* Retrieved 2 9, 2021, from http://www.ktdateas.com

Kulmala, H. I., & uusi-Rauva, e. (2005, July). Network as a business environment: experiences from software industry. *Supply Chain Management, 10*(3), 169-178. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/13598540510606223/full/html

Kumar, R. (2011). *Research Methodology: A Step-by-Step Guide for Beginners.* SAGE Publications. Retrieved from https://rauterberg.employee.id.tue.nl/lecturenotes/DBB150/references/Kumar-2011%20Research%20Methodology-ed3.pdf

Kumar, S. U. (2017). Structure Equation Modeling Basic Assumptions and Concepts: A Novices Guide. *International Journal of Quantitative and Qualitative Research Methods,*, 5 (4), 10-16.

Kumar, S., & Singh, V. (2020, May 8). *Applications of blockchain technology in the food industry.* Retrieved May 26, 2021, from New Food magazine: https://www.newfoodmagazine.com/article/110116/blockchain/

Kumar, S., and Upadhaya, G. (2017). Structure Equation Modeling Basic Assumptions and Concepts: A Novices Guide. *International Journal of Quantitative and Qualitative Research Methods, 4*, 10-16.

Kummer, S., & Herold, D. M. (2020, March). A Systematic Review of Blockchain Literature in Logistics and Supply Chain Management: Identifying Research Questions and Future Directions. *Future Internet, 12*(3), 60. Retrieved from https://www.researchgate.net/publication/340104881_A_Systematic_Review_of_Blockchain_Literature_in_Logistics_and_Supply_Chain_Management_Identifying_Research_Questions_and_Future_Directions

Kunii, H. S., Jajodia, S., & Sølvberg, A. (2001). Conceptual Modeling - ER 2001. *20th International Conference on Conceptual Modeling*. Retrieved from https://link.springer.com/book/10.1007/3-540-45581-7

Laaper, S., Yeh, W., Fitzgerald, J., Basir, M and Quasney, E. (2019). *Using blockchain to drive supply chain transparency;Future trends in supply chain.* Retrieved 2 9, 2021, from Delloitte: https://www2.deloitte.com/ru/en/pages/operations/articles/blockchain-supply-chain-innovation.html.

Laura, S. (2015, June 24). *Nasdaq Selects Bitcoin Startup Chain To Run Pilot In Private Market Arm.* Retrieved May 25, 2021, from Forbes: https://www.forbes.com/sites/laurashin/2015/06/24/nasdaq-selects-bitcoin-startup-chain-to-run-pilot-in-private-market-arm/?sh=b07bd8683d58

Lee. (2018, July 16). *Combating Substandard and Counterfeit Medicines by Securing the Pharmaceutical Supply Chain: The Drug Supply Chain Security Act (DSCSA) of 2013.* Retrieved May 26, 2021, from NCBI: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6438546/

Leong C., Viskin T., Stewart R. (2018). Retrieved 7 17, 2022, from https://www.accenture.com/t20190115T192110Z__w__/us-en/_acnmedia/PDF-93/Accenture-Tracing-Supply-Chain-Blockchain-Study-PoV.pdf

Lepoint, T., Naessens, V., & Toussaint, C. (2018). A Survey of Blockchain Security Issues and Challenges. *In Proceedings of the 4th International Conference on Information Systems Security and Privacy*, *1*, pp. 706-713.

Lerdpornkulrat, T. P. (2017). Construct reliability and validity of the shortened version of the information-seeking behavior scale. *International Journal of Information and Communication Technology Education*, 13(2), 27–37.

Lerdpornkulrat, T., Poondej, C., & Koul, R. (2017). Construct reliability and validity of the shortened version of the information-seeking behavior scale. *International Journal of Information and Communication Technology Education, 2*, 27-37. Retrieved from https://doi.org/10.4018/IJICTE.2017040103

Lin, I. C., & Shih, H. (2017, June 10). FOOD TRACEABILITY SYSTEM USING BLOCKCHAIN. *Proceedings of the 79th IASTEM International Conference*. Retrieved from https://www.bing.com/ck/a?!&&p=3d21b89f8d79b23dJmltdHM9MTY4NDM2ODAwMCZpZ3VpZD0zMmI5MDRlNS1iOTYwLTY2MTAtMGNkZi0xN2U0YjhlNzY3YjQmaW5zaWQ9NTE2OQ&ptn=3&hsh=3&fclid=32b904e5-b960-6610-0cdf-17e4b8e767b4&psq=Food+traceability+system+using+blockchain.%2c%e2%80%9d+

Lo'ai Tawalbeh et al. (2020, June 15). IoT Privacy and Security: Challenges and Solutions. *Applied Sciences, 10*(12). doi:https://doi.org/10.3390/app10124102

Ludewig, J. (2003, March). Models in software engineering – an introduction. *Software and Systems Modeling, 2*, 5-14. Retrieved from https://link.springer.com/article/10.1007/s10270-003-0020-3

Luzzini, D., & Caniato, F. (2012, August 17). A transaction costs approach to purchasing portfolio management. *International Journal of Operations & Production Management, 32*(9).

Madhok, A. (2002, June). Reassessing the fundamentals and beyond: Ronald Coase, the transaction cost and resource-based theories of the firm and the institutional structure of production. *Strategic Management Journal, 23*(6), 535 - 550. Retrieved from https://onlinelibrary.wiley.com/doi/10.1002/smj.247

Maersk and IBM Unveil First Industry-Wide Cross-Border Supply Chain Solution on Blockchain. (2017, March 6). Retrieved February 10, 2021, from Financial IT: https://financialit.net/news/blockchain/maersk-and-ibm-unveil-first-industry-wide-cross-border-supply-chain-solution

Maersk and IBM Unveil First Industry-Wide Cross-Border Supply Chain Solution on Blockchain. (2017, March 5). Retrieved May 25, 2021, from PR Newswire: https://www.prnewswire.com/news-releases/maersk-and-ibm-unveil-first-industry-wide-cross-border-supply-chain-solution-on-blockchain-300418039.html

Mangla,et al. (2022, December). A conceptual framework for blockchain-based sustainable supply chain and evaluating implementation barriers: A case of the tea supply chain. *Business Strategy and the Environment, 31*(8), 3693-3716. Retrieved from https://onlinelibrary.wiley.com/doi/10.1002/bse.3027

Manuj, I., & Omar, A. (2013). The Quest for Competitive Advantage in Global Supply Chains: The Role of Interorganizational Learning. *Transportation Journal, 52*(4), 463-492. Retrieved from https://www.jstor.org/stable/10.5325/transportationj.52.4.0463

Maouchi, M. e., Ersoy, O., & Zekeriya, E. (2018, May). TRADE: A Transparent, Decentralized Traceability System for the Supply Chain. *Proceedings of 1st ERCIM Blockchain Workshop 2018*. Retrieved from https://www.researchgate.net/publication/325650820_TRADE_A_Transparent_Decentralized_Traceability_System_for_the_Supply_Chain

Maouchi, Mourad el; Ersoy, Oğuzhan; Zekeriya, Erkin. (2018, May). A Transparent, Decentralized Traceability System for the Supply Chain. Amsterdam, Netherlands. Retrieved from ResearchGate: http://dx.doi.org/10.18420/blockchain2018_01

Mbabazi, E. (2020, December 3). *Relief as Tea Bill is Passed by National Assembly.* Retrieved May 25, 2023, from Kenyan Wallstreet: https://kenyanwallstreet.com/national-assembly-passes-tea-bill/

Mearian, L. (2017, April 24). *FAQ: What is blockchain and how can it help business?* Retrieved May 25, 2021, from CSO Online: https://www.csoonline.com/article/3191619/faq-what-is-blockchain-and-how-can-it-help-business.html

Meijer, C. R. (2020, September 30). *Smart working with blockchain-based smart contracts.* Retrieved May 25, 2021, from Finextra Research: https://www.finextra.com/blogposting/19383/smart-working-with-blockchain-based-smart-contracts

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Journal of Business Logistics Journal of Business Logistics Full Access DEFINING SUPPLY CHAIN MANAGEMENT. *Journal of Business Logistics, 22*(2), 1-25. Retrieved from https://www.bing.com/ck/a?!&&p=f6bec23de590da5aJmltdHM9MTY4NDk3MjgwMCZpZ3VpZD0zMmI5MDRlNS1iOTYwLTY2MTAtMGNkZi0xN2U0YjhlNzY3YjQmaW5zaWQ9NTE3Nw&ptn=3&hsh=3&fclid=32b904e5-b960-6610-0cdf-17e4b8e767b4&psq=Mentzer+et+al%2c+%e2%80%9cDefining+Supply+Chain+Managem

Miemczyk, J., & Howard, M. (2016, June 13). Dynamic development and execution of closed-loop supply chains: a natural resource-based view. *Supply Chain Management, 21*(4). Retrieved from https://www.emerald.com/insight/content/doi/10.1108/SCM-12-2014-0405/full/html

Miller, J. W., & Saldanha, J. P. (2013, December). Combining Formal Controls to Improve Firm Performance. *Journal of Business Logistics, 34*(4). Retrieved from https://www.researchgate.net/publication/259552208_Combining_Formal_Controls_to_Improve_Firm_Performance

Mire, S. (2020). *"28 Startups Using Blockchain To Transform Supply Chain Management.* Retrieved February 9, 2021, from Disruptor Daily: http://www.disruptordaily.com/blockchain-market-

Misiko, M. A., Odihambo, B. O., & Byiringiro, J. C. (2019). Blockchain for Traceability in the Agricultural Supply Chain: A Case Study of Kenyan Tea. *International Journal of Computer Science and Information Security (IJCSIS), 17*(4), 51-57.

Mittal, S., Singla, A., & Sharma, S. (2021). Blockchain and its applications: A systematic literature review. *Journal of Information Science, 47*(6), 881-913.

Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Shahbaz Khan, Rajiv Suman. (2021). Blockchain technology applications for Industry 4.0: A literature-based review. *Blockchain: Research and Applications, 2*(4). doi:https://doi.org/10.1016/j.bcra.2021.100027

Mohd Javaid; Abid Haleem; Ravi Pratap Singh; Shahbaz Khan; Rajiv Suman. (2021). Blockchain technology applications for Industry 4.0: A literature-based review,. *International Journal of Advanced Science and Technology, 30*(8), 407-420. Retrieved from https://doi.org/10.1016/j.bcra.2021.100027

Mucheru, P., Weru, J., & Kariuki, S. (2021). Blockchain Technology for Enhancing Drug Traceability: A Kenyan Pharmaceutical Industry Perspective. *International Journal of Advances in Scientific Research and Engineering, 7*(4), 32-40.

Narayanan, V. G., & Singh, J. (2005, January). Agency Costs in a Supply Chain with Demand Uncertainty and Price Competition. *Management Science, 51*(1), 120-132. Retrieved from https://www.researchgate.net/publication/220534471_Agency_Costs_in_a_Supply_Chain_with_Demand_Uncertainty_and_Price_Competition

Ngatia, C. W. (2013). Supply chain management practices and performance of Kenya tea development agency managed factories. *UoN Digital Repository*. Retrieved from http://erepository.uonbi.ac.ke/handle/11295/59159http://erepository.uonbi.ac.ke/handle/11295/59159http://erepository.uonbi.ac.ke/handle/11295/59159http://erepository.uonbi.ac.ke/handle/11295/59159http://erepository.uonbi.ac.ke/handle/11295/59159

Niforos, M. (2017b). Blockchain in finance. In The Global Fintech Landscape: Shaping the Future of Financial Services. World Scientific Publishing.

O'Byrne, Rob. (2018). *Supply Chains and Blockchain Part 2.* Retrieved February 9, 2021, from Logistics Bureau: https://www.logisticsbureau.com/supply-chains-blockchain-part-2-making-it- work

Obonyo, D. O., Ondieki, S. A., Ogot, S. K., & Kibari, F. G. (2020). Leveraging Blockchain Technology for Enhanced Government Operations and Public Service Delivery: A Kenyan Perspective. *International Journal of Scientific Research and Management, 8*(1), 111-122.

Ochieng, C., Njihia, J., & Ogalo, E. (2021). A Framework for Implementing Blockchain Technology in Secure Land Title Management in Kenya. *International Journal of Scientific and Technology Research, 10*(3), 384-392.

Oduor, J., Ondieki, S., & Chweya, D. (2020). Decentralized Finance (DeFi): An Exploration of its Application and Potential in Kenya's Financial Ecosystem. *International Journal of Advances in Scientific Research and Engineering, 6*(10), 42-52.

Ometoruwa, T. (2020). *Solving the Blockchain Trilemma: Decentralization, Security & Scalability - Coin Bureau.* Retrieved April 8, 2021, from The Coin Bureau: https://www.coinbureau.com/analysis/solving-blockchain-trilemma/

Ondieki, S., & Waiganjo, E. (2019). Cryptocurrency Adoption and the Financial Inclusion Agenda: A Review of Cryptocurrency Adoption in Kenya. *International Journal of Innovation and Economic Development, 5*(5), 17-27.

Ouma, G., Aswani, J., & Ogutu, M. (2020). Towards a Blockchain-Based Supply Chain Management Framework in Kenya. *Journal of Innovation and Entrepreneurship, 9*(1), 1-22.

Pandey, V., Pant, M., & Snasel, V. (2022, May). Blockchain technology in food supply chains: Review and bibliometric analysis. *Technology in Society, 69*. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0160791X22000951?via%3Dihub

Pant, R. R., & Prakash, G. (2015, May 15). A Framework for Traceability and Transparency in the Dairy Supply Chain Networks. *Procedia - Social and Behavioral Sciences, 189*, 385-394. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042815020285

Pant, R. R.; Prakash, Gyan; Farooquie, Jamal A. (2015). A Framework for Traceability and Transparency in the Dairy Supply Chain Networks. *Procedia - Social and Behavioral Sciences, 189*, 385-394. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042815020285?via%3Dihub

Pearson, S., & May, D. (2019, March). Are Distributed Ledger Technologies the panacea for food traceability? *Global Food Security, 20*. Retrieved from https://doi.org/10.1016/j.gfs.2019.02.002

Perboli, G., & Musso, S. (2018, October 16). Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases. *IEEE Access, 6*, 62018-62028. Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8493157

Perboli, G., Musso, S., & Rosano, M. (2018). Blockchain in logistics and supply chain: A lean approach for designing real-world use cases. *IEEE Access*, 62018–62028.

Petrovic-Lazarevic, S. Y., Sohal, A. S., & Baihaqi, I. (2007). Supply chain management practices and supply chain performance in the Australian manufacturing industry. *Proceedings of the International Scientific Conference: Contemporary Challenges of Economic Theory and Practice.*, 277 - 288. Retrieved from https://research.monash.edu/en/publications/supply-chain-management-practices-and-supply-chain-performance-in

Poirier, C. C. (1999). *Advanced Supply Chain Management: How to Build a Sustained Competitive Advantage.* Berrett-Koehler Publishers. Retrieved from https://www.biblio.com/9781576750520

Porter, M. E. (1980). *Competitive Strategy: Techniques for Analyzing Industries and Competitors.* New York: Free Press. Retrieved from http://www.hbs.edu/faculty/product/195

Rambim, D. A., & Awuor, F. M. (2020, May 1). Blockchain based Milk Delivery Platform for Stallholder Dairy Farmers in Kenya: Enforcing Transparency and Fair Payment. *2020 IST-Africa Conference (IST-Africa)*, 1-6. Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9144071

Rizzo,2015; Caffyn,2015 & Cuthbertson, 2015. (n.d.). *Why Visa Europe is Testing Remittances on the Blockchain.* Retrieved May 25, 2021, from CoinDesk: https://www.coindesk.com/markets/2015/11/25/why-visa-europe-is-testing-remittances-on-the-bitcoin-blockchain/

Saberi, S., Cruz, J. M., Sarkis, J., & Nagurney, A. (2018). Blockchain technology: innovations and implications. Transportation Research Part E. *Logistics and Transportation Review, 112*, 389-403.

Sachin Chauhan; Rohit Bansal; Ram Singh. (June 2022). Blockchain adoption in supply chain management: A systematic literature review and future research directions. *Journal of Cleaner Production, 335*.

Salcedo, S., & Grackin, A. (2000). The e-value Chain.

Santander's InnoVentures Distributed Ledger Challenge. (n.d.). Retrieved May 25, 2021, from Santanders: https://santanders.splashthat.com/

Schmidt, C. G., & Wagner, S. M. (2019). Blockchain and supply chain relations: A transaction cost theory perspective. *Journal of Purchasing and Supply Management, 25*(4). Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S1478409218301298?via%3Dihub

Shi, P., & Yan, B. (2016). Factors affecting RFID adoption in the agricultural product distribution industry: Empirical evidence from China. *SpringerPlus, 5*(1).

Shin, L. (2015, June 24). *Nasdaq Selects Bitcoin Startup Chain To Run Pilot In Private Market Arm.* Retrieved February 9, 2021, from Forbes: https://www.forbes.com/sites/laurashin/2015/06/24/nasdaq-selects-bitcoin-startup-chain-to-run-pilot-in-private-market-arm/

Skjoett-Larsen, T. (1999, July 1). Supply Chain Management: A New Challenge for Researchers and Managers in Logistics. *The International Journal of Logistics Management, 10*(2), 41-54. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/09574099910805987/full/html

Skuchain. (2020). *SkuChain | World Economic Forum.* Retrieved February 10, 2021, from The World Economic Forum: https://www.weforum.org/organizations/skuchain

Smith, J., Brown, A., Davis, L., & Wilson, R. (2022). Addressing Transparency and Traceability Challenges in the Tea Supply Chain: The Role of Blockchain Technology. *International Journal of Logistics Management, 34*(4), 567-584.

Snell, T. (2018). The use of blockchain in supply chain management: A systematic literature review. *Supply Chain Forum: An International Journal, 19*(1), 20-41. doi:10.1080/16258312.2018.1434284

Stank, T. P., & Pellathy, D. A. (2017, March). New Frontiers in Logistics Research: Theorizing at the Middle Range. *Journal of Business Logistics, 38*(1), 6-17. Retrieved from https://onlinelibrary.wiley.com/doi/10.1111/jbl.12151

Stimson, N. F. (2007, December). Library Change as a Branding Opportunity: Connect, Reflect, Research, Discover. *College and Research Libraries News, 68*(11). Retrieved from https://www.researchgate.net/publication/39728293_Library_Change_as_a_Branding_Opportunity_Connect_Reflect_Research_Discover

Stranieri, S., & Orsi, L. (2017, March 13). Traceability and risks: an extended transaction cost perspective. *Supply Chain Management, 22*(2), 145-159. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/SCM-07-2016-0268/full/html

Sujati, H. (2020). Testing the Construct Validity and Reliability of Curiosity Scale Using Confirmatory Factor Analysis. *Journal of Educational and Social Research*.

Taherdoost, H. (2023). The Impact of E-commerce on Supply Chain Management: Empirical Evidence from the Tea Industry. *International Journal of Engineering Business Management, 15*. doi:https://doi.org/10.1177/1847973X23698712

Tapscott, A., & Tapscott, D. (2016). *Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money, Business, and the World.* Portfolio / Penguin. Retrieved from https://searchworks.stanford.edu/view/11815474

Tarasenko, A. (2020). Blockchain technology implementation: Theoretical aspects and practical applications. *Technology audit and production reserves, 2*(3), 53-59.

Tate, W. L., & Dooley, K. J. (2011, March 1). Transaction Cost and Institutional Drivers of Supplier Adoption of Environmental Practices. *Journal of Business Logistics, 32*, 6-16. Retrieved from https://www.semanticscholar.org/paper/Transaction-Cost-and-Institutional-Drivers-of-of-Tate-Dooley/11ff5e25cc0eef84fe5a4c41db82c53b836a215e

Tentama, F., & Anindita, W. D. (2020). Employability scale: Construct validity and reliability. *International Journal of Scientific and Technology Research, 9*(4), 3166–3170.

The great chain of being sure about things. (2015, October 31). Retrieved May 25, 2023, from The Economist: https://www.economist.com/briefing/2015/10/31/the-great-chain-of-being-sure-about-things

Tian, F. (2017, June). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. *IEEE Xplore*, 1-6. Retrieved from http://dx.doi.org/10.1109/ICSSSM.2017.7996119

Torresen, J. (2020, February 4). *Blockchain Technology for Agriculture: Applications and Rationale.* Retrieved May 26, 2021, from Frontiers: https://www.frontiersin.org/articles/10.3389/fbloc.2020.00007/full

Transparent yet Private Digital Currency. (2018, January 9). Retrieved February 10, 2021, from Sweetbridge: https://blog.sweetbridge.com/archive/2018/01

TransVoyant. (2018). Blockchain the Newest Technology in Supply Chain Part 1. Retrieved February 9, 2021, from https://transvoyant.com/blockchain-newest-technology-supply-chain-part-1

Treiblmaier, H. (2018, November 13). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management, 23*(6), 545 - 559. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/SCM-01-2018-0029/full/html

Treiblmaier, H. (2018, August). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *23*(15). Retrieved from https://www.researchgate.net/publication/326734817_The_Impact_of_the_Blo ckchain_on_the_Supply_Chain_A_Theory-Based_Research_Framework_and_a_Call_for_Action

Tse, D., & Zhang, B. (2017, December). Blockchain Application in Food Supply Information Security. *2017 IEEE International Conference on Industrial Engineering and Engineering Management, IEEM 2017*, 1357-1361. Retrieved from https://doi.org/10.1109/IEEM.2017.8290114

Tse, D.; Zhang, B.; Yang, Y.; Cheng, C.; My, H. (2017). Blockchain application in food supply information security. *Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management (IEEM 2017)*, (pp. 1357–1361). Singapore.

Tyndall, G. R. (1998). *Supercharging Supply Chains: New Ways to Increase Value Through Global Operational Excellence.* Wiley. Retrieved from https://books.google.co.ke/books/about/Supercharging_Supply_Chains.html?id=2gppQgAACAAJ&redir_esc=y

Unnu, K., Kieckhafer, K., Mello, M., & Jorgensen, K. (2019). Decision framework for blockchain technology adoption. *In Proceedings of the 52nd Hawaii International Conference on System Sciences.*

Using Blockchain to Drive Supply Chain Transparency and Innovation. (2019). Retrieved February 9, 2021, from Deloitte: https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html

Verhoeven, P., & Sinn, F. (2018, September 11). Examples from Blockchain Implementations in Logistics and Supply Chain Management: Exploring the Mindful Use of a New Technology. *logistics*. Retrieved from https://www.bing.com/ck/a?!&&p=7f9c95156305fb40JmltdHM9MTY4NDM2ODAwMCZpZ3VpZD0zMmI5MDRlNS1iOTYwLTY2MTAtMGNkZi0xN2U0YjhlNzY3YjQmaW5zaWQ9NTE3Mw&ptn=3&hsh=3&fclid=32b904e5-b960-6610-0cdf-17e4b8e767b4&psq=T.+.+Verhoeven%2c+P.%3b+Sinn%2c+F.%3b+Herden%2c+%e2%80%

Vu, Kim. (2018, April 16). *bext360 and Coda Coffee Release The World's First.* Retrieved May 26, 2021, from GlobeNewswire: https://www.globenewswire.com/news-release/2018/04/16/1472230/0/en/bext360-and-Coda-Coffee-Release-The-World-s-First-Blockchain-traced-Coffee-from-Bean-to-Cup.html

Wacker, J. G., & Yang, C. (2016, November 7). A transaction cost economics model for estimating performance effectiveness of relational and contractual governance: Theory and statistical results. *International Journal of Operations & Production Management, 36*(11), 1551 - 1575. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/IJOPM-10-2013-0470/full/html

Wang, M., Asian, S., Wood, L. C., & Wang, B. (2020). Logistics innovation capability and its impacts on the supply chain risks in the industry 4.0 era. *Modern Supply Chain Research and Applications, 2*(2), 83–98.

Wang, Y., & Singgih, M. (2019). The impact of blockchain technology on trust and business model innovation. *International Journal of Innovation Management, 23*(06).

Werbach, K. (2017, August 1). Trust, But Verify: Why the Blockchain Needs the Law. *Cyberspace Law eJournal*. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2844409

Wernerfelt, B. (1984, April-June). A Resource-Based View of the Firm. *Strategic Management Journal, 5*(2), 171-180. Retrieved from https://www.jstor.org/stable/2486175

West, S. G., Flinch, J. F., & Curran, P. J. (1996). Structural equation models with nonnormal variables: problems and remedies. *Structural equation modeling: Concepts, issues and applications*, 56-75.

Whipple, J. M., & Roh, J. (2010, August). Agency theory and quality fade in buyer-supplier relationships. *Agency theory and quality fade in buyer-supplier relationships, 21*(3), 338-352. Retrieved from https://www.researchgate.net/publication/235291738_Agency_theory_and_quality_fade_in_buyer-supplier_relationships

White, G. R., Afolayan, A., & Plant, E. (2014). Challenges to the Adoption of E-commerce Technology for Supply Chain Management in a Developing Economy: A Focus on Nigerian SMEs. In *E-commerce Platform Acceptance: Suppliers, Retailers, and Consumers* (pp. 23–39). Springer International Publishing. Retrieved from https://link.springer.com/chapter/10.1007/978-3-319-06121-4_2

Whitfield, D. P., & Ruddock, M. (2008, November). Expert opinion as a tool for quantifying bird tolerance to human disturbance. *Biological Conservation, 141*(11), 2708-2717. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0006320708003005

Wichmann, B. K., & Carter, C. R. (2015, March). How to Become Central in an Informal Social Network: An Investigation of the Antecedents to Network Centrality in an Environmental SCM Initiative. *Journal of Business Logistics, 36*(1), 102-119. Retrieved from https://onlinelibrary.wiley.com/doi/10.1111/jbl.12079

Williamson, O. E. (1987, December). Transaction cost economics: The comparative contracting perspective. *Transaction cost economics: The comparative contracting perspective, 8*(4), Transaction cost economics: The comparative contracting perspective. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/0167268187900382

Willson, K. C. (1999). *Coffee, Cocoa and Tea.* CAB International. Retrieved from https://www.cabidigitallibrary.org/doi/book/10.1079/9780851989198.0000

Wong, L. W., Leong, L. Y., Hew, J. J., Tan, G. W. H., & Ooi, K. B. (2020a). Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. *International Journal of Information Management, 52*.

Wong, L. W., Tan, G. W. H., Lee, V. H., Ooi, K. B., & Sohal, A. (2020b). Unearthing the determinants of Blockchain adoption in supply chain management. *International Journal of Production Research, 58*(7), 2100–2123.

Xu et al. (2016). The blockchain as a software connector. *In Proceedings of the 2016 13th Working IEEE/IFIP Conference on Software Architecture (WICSA),* (pp. 182-191). Piscataway,NJ: Institute of Electrical and Electronics Engineers.

Xu, L. (2022). Digital Platforms and Supply Chain Integration: A Review. *International Journal of Operations and Production Management, 42*(1), 31-52. doi:10.1108/IJOPM-11-2020-0773

Yadav, S., & Singh, S. P. (2020b). An integrated fuzzy-ANP and fuzzy-ISM approach using blockchain for sustainable supply chain. *Journal of Enterprise Information Management, 34*(1), 54–78.

Yang, C.-S., & Lirn, T.-c. (2017, October 2). Revisiting the resource-based view on logistics performance in the shipping industry. *International Journal of Physical Distribution \& Logistics Management, 47*(9), 884-905. Retrieved from https://doi.org/10.1108/IJPDLM-05-2017-0184

Yiannas, F. (2018). A New Era of Food Transparency Powered by Blockchain. *Innovations: Technology, Governance, Globalization, 12*(1-2), 46-56. Retrieved from https://direct.mit.edu/itgg/article/12/1-2/46/9839/A-New-Era-of-Food-Transparency-Powered-by

Yigitbasioglu, O. (2010, August). Information sharing with key suppliers: A transaction cost theory perspective. *Information sharing with key suppliers: A transaction cost theory perspective, 40*(7), 550-578. Retrieved from https://www.researchgate.net/publication/235304539_Information_sharing_with_key_suppliers_A_transaction_cost_theory_perspective

Yin, R. K. (2003). *Case Study Research: Design and Methods.* SAGE Publications. Retrieved from https://books.google.co.ke/books/about/Case_Study_Research.html?id=BWea_9ZGQMwC&redir_esc=y

Zhang, J. (2020). *Computer Security Threats.* IntechOpen. Retrieved from http://dx.doi.org/10.5772/intechopen.86530

Zhang, Jian. (2019). Blockchain consensus protocols: An overview. *International Journal of Big Data Intelligence, 6*(1), 4-14.

Zhao, G., & Liu, S. (2019, August). Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions. *Computers in Industry, 109*, 83-99. Retrieved from https://doi.org/10.1016/j.compind.2019.04.002

Zsidisin, G., & Ellram, L. M. (2003, June). An Agency Theory Investigation of Supply Risk Managemen. *Journal of Supply Chain Management, 39*(3), 15-27. Retrieved from https://www.researchgate.net/publication/227548287_An_Agency_Theory_Investigation_of_Supply_Risk_M_anagement

Zu, X., & Kaynak, H. (2012, March). An agency theory perspective on supply chain quality management. *International Journal of Operations & Production Management, 32*(4), International Journal of Operations & Production Management. Retrieved from https://www.researchgate.net/publication/241700523_An_agency_theory_perspective_on_supply_chain_quality_management

KTDA (2017) Kenya Tea Development Agency Background. Available at: http://www.ktdateas.com accessed on 16/07/2023

Charles, K. (2012). Challenges of entering new international markets by exporters of Kenyan tea; a case study of selected tea exporters. Unpublished master's thesis, Juja: JKUAT-Kenya.

Chege, P., Ngugi, P., & Ngugi, J. (2017). Influence of internal business value chain practices on the supply chain performance of large manufacturing firms in Kenya. Unpublished PhD Thesis. Juja, Nairobi: JKUAT Kenya.

Diannah, M., & Joseph, M. (2012). Firm efficiency differences and distribution in the Kenyan manufacturing sector. African Development Review, 24(1), 52-66

EATTA, (2020). Mombasa Average Tea Auction Process Statistics. Mombasa: East Africa Tea Trade Association Publications.

KTDA, (2022). Kenya Tea Development Agency Report on tea production. Nairobi: Kenya Tea Development Agency Publications.

APPENDICES

APPENDIX 1: LETTER OF INTRODUCTION

Dear respondent,

RE: **Ph.D. IN INFORMATION TECHNOLOGY RESEARCH QUESTIONNAIRE**

My name is Ronoh Hillan, a student pursuing PhD degree in information technology in the department of Information Technology-School of Computing and Informatics at Masinde Muliro University of Science and Technology. My research topic is **'Blockchain-Based Model using Smart Contracts for Tea Supply Chain Management, Kenya.'**

The purpose of this letter is to kindly request you to fill the attached questionnaire to the best of your knowledge to help me complete this academic endeavor. The information you provide will be treated with utmost confidentiality and shall be used for academic purposes only.

Your assistance is highly appreciated, thank you. Yours faithfully,

……………………………

RONOH.K. HILLAN

SIT/H/01-53146/2018

SCHOOL OF COMPUTING AND INFORMATICS.

APPENDIX 2: FARMERS SELF ADMINISTRERED QUESTIONNAIRE

INSTRUCTIONS:

i. Please answer this questionnaire carefully, taking into account each question.
ii. The information you provide will be kept completely private, and the study's findings will only be shared in aggregate form.
iii. Please continue to provide frank and impartial comments in order to achieve the desired outcome.
iv. Every piece of data will solely be utilized for this research.

SECTION A. BACKGROUND INFORMATION

1. Please indicate your Gender

Female [ ] Male [ ]

2. Kindly indicate your age bracket (Years)

Below 30 [ ] 31-40 [ ] 41-50 [ ] 51-60 [ ] Above 60 [ ]

3. Indicate your Level of Education.

Ph.D. [ ] Masters [ ] Degree [ ] Diploma [ ] Others

Specify……………………………

4. Name of your tea Buying center:

____

5. Name of Factory:

____

6. How many Acres have you planted tea? ___________________ (Please Specify in acres)

SECTION B: ICT INFRASTRUCTURE READINESS (Objective 1 → H1)

Each statement will be answered on a 5-point Likert scale:

1 = Strongly Disagree

2 = Disagree

3 = Neutral / Not Sure

4 = Agree

5 = Strongly Agree

a) The tea buying center has reliable network or internet connections.

b) We are able to process transactions (weighing, recording deliveries, payments) without frequent delays.

c) The systems used at the buying center/factory are well organized and can handle large amounts of farmer data.

d) Records stored by the factory or buying center are secure and not easily lost.

e) The current systems can be improved to support new digital technologies in future.

SECTION C: DATA INTEGRATION & AUTOMATION (Objective 2 → H2)

i. Information about my tea deliveries is shared quickly between the buying center and the factory.

ii. Records from the buying center match with those at the factory.

iii. The process from tea delivery to payment is mostly automatic (with little paperwork).

iv. Delays and mismatches in records are common because of too much manual work.

v. If the process was automated, errors in my records would reduce.

SECTION D: COLLABORATION, LEGAL & POLICY FRAMEWORKS

(Objective 3 → H3)

a) The rules on how farmer data is used and shared are clear.
b) Farmers are consulted or involved in decisions about the buying center/factory management.
c) Stakeholders (farmers, clerks, factory, KTDA) work well together to solve problems.
d) There are clear guidelines/standards on record keeping and payments.
e) Government or KTDA support has made the system more transparent.

SECTION E: SECURITY & PRIVACY (Objective 4 → H4)

i. My tea delivery records are kept safe from tampering.
ii. Only authorized people (clerks, factory staff) can access farmer records.
iii. Payment details are handled in a safe and confidential way.
iv. I trust that records cannot be changed once they are confirmed.
v. Farmers are protected from fraud and loss of records.

SECTION F: ADOPTION OF BLOCKCHAIN PLATFORM IN TEA SUPPLY CHAIN (Objective 3)

This section helps you describe to what extent do you agree or disagree with the following statements about supply chain management (shared responsibility in governing the recording, exchange of data and management of the data to enhance transparency). Please answer all items by using a tick sign in the appropriate response. Use the key: Strongly Agree: 5, Agree: 4, Neutral: 3, Disagree: 2, Strongly Disagree: 1.

BCP26	There should be a blockchain based transparency model using smart contracts in the tea supply chain management	1	2	3	4	5
BCP27	Blockchain based transparency model will improve trust and verification					
BCP28	Use of ICT Technologies plays a vital role in the supply chain management that data is being shared					
BCP29	Overall accuracy of supply chain management will improve once the smart contract blockchain based model is implemented.					
BCP30	There is duplication during generation and recording of data					
BCP31	There is need of adopting a common data identifier during recording of the farmers data					

SECTION G: FACTORS INFLUENCING ADOPTION OF BLOCKCHAIN PLATFORM IN TEA SUPPLY CHAIN MANAGEMENT

If there was adoption of blockchain technology in the tea supply chain management rate in terms of challenge the factors that will hinder. Rate in terms of: Strongly agree (SA), Agree (A), Not Sure (NS), Disagree (D), Strongly Disagree (SD)

Statement	**SA**	**A**	**NS**	**D**	**SD**
ICT infrastructure					
Data and information integration					
Security and privacy					
Automation of end-to-end processes (business process re-engineering)					
Collaborative(Top management support, policies)					
Standards					

H. Recommendations

39. What other service improvements will you recommend to be implemented on the following:

a. Delivery of tea to Buying centres:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………

b. Processing of tea at factory.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………

Thank you so much for taking your time to assist the researcher to gather this vital information

APPENDIX 3: : FACTORY MANAGEMENT INFORMATION QUESTIONNAIRE

INSTRUCTIONS

i. Please complete this questionnaire considering each question thoughtfully.
ii. Your response will be strictly confidential and data from this research will be reported only in the aggregate.
iii. Kindly maintain honest and objective feedback so as to meet the intended purpose.
iv. All information will be used only for the purpose of this study.

SECTION A. BACKGROUND INFORMATION

1. Please indicate your Gender

Female [ ]   Male [ ]

2. Kindly indicate your age bracket (Years)

Below 30 [ ]   31-40 [ ]   41-50 [ ]   51-60 [ ]   Above 60 [ ]

3. Indicate your Level of Education.

Ph.D. [ ] Masters [ ] Degree [ ] Diploma [ ] Others

Specify……………………………

4. Officer title:

Factory Manager [ ] Factory Accountant [ ] Sales Representative-Auction [ ] ICT Officer [ ]

Others Specify: ____

5. Factory Name:

____

SECTION B. GENERAL INFORMATION

6. What is the total number of Farmers in your factory? _______ (Please Specify Number)

7. How many tea buying centers do you control? __________________ (Please Specify)

8. How often do you update your farmers on factory performance? (Please tick as appropriate)

□ Once a year,

□ Twice a year

□ Quarterly

□ Monthly

□ weekly

□ Not defined.

9. What mode of communication do you apply? (Please tick all that apply)

□ Radio

□ Print Media

□ Posters

□ Mobile

□ Word of Mouth

□ Meetings (Barazas)

□ Not defined.

10. How do you validating accuracy of all stock details whether the stock is in transit, warehouse and the factory? __________________ (Please Specify)

Receiving of Tea from Farmers

11. How do you record daily tea received from each Buying center? (Please tick all that apply)

□ Recorded Manually.

□ Recorded manually and immediately entered in computer

□ Entered in computer at source

□ Other recording Please indicate: ___________________________________

12. Do you compare with the total weights as recorded by the tea Buying clerk against factory records? (Please tick as appropriate)

□ Yes

□ No

13. If there are any differences, what is the average difference? ____ (Please specify weight
in Kilograms negative to indicate deficit positive to indicate gain)

14. How do you handle the excess / deficit daily weight when calculating payment? (Please tick all that apply)

□ Use only Factory weight

□ Use Buying center weight.

□ Surcharge tea Buying clerk on the deficit difference (if deficit).

□ Use the end product weight

15. Do you have a system to check daily tea collection per each Buying center? (Please tick as appropriate)

□ Yes

□ No

16. Do you have a system in place that can show the amount of tea held in a Tea Buying centre at any given time? (Please tick as appropriate)

□ Yes

□ No

17. How do you schedule tea collection from tea Buying centers? (Please tick as appropriate)

□ Assign vehicles to particular Buying centers

□ Assign vehicle according to amount of tea in Buying centers

□ Ad-hoc assignment

□ Other Assignment Please indicate:

____

Processing of Tea

18. Do you have a system in place that checks the weight of tea leaves in different stages of processing? (Please tick as appropriate)

□ Yes

□ No

19. Having poor quality / low yield is attributed to either, poor harvest, poor handling or tea overstaying at buying center before it is brought for processing among others. How do you Communicate about Tea quality to farmers: (Please tick all that apply)

□ Tea Buying clerks

□ Posters

□ Meetings

□ Radio

□ Mobile phones

□ Put on Payslip

□ No defined method

20. How do you check and record the quality of tea at:

a. Tea Buying centre? (Please indicate)

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………

b. The Factory.

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………

Dispatching of processed Tea

21. Do you have a system recording dispatch of final tea product from the factory? (Please tick as appropriate)

□ Yes

□ No

22. If yes, how is the system linked to payment system? (Please tick all that apply)

□ Systems fully integrated.

□ Data downloaded to another system.

□ System produces payment slips.

□ Data is manually transferred.

□ No linkage

□ Other State: ____

23. How do you treat the operational costs before coming up with the final payments (Especially for Bonus payments)? (Please tick as appropriate)

□ Remove all operational costs before declaring Bonus.

□ Have a standard amount deducted per Kilogram.

□ Treated differently as per situation

□ No specific method used.

Type of ICT Systems on board

24. Do you have any automated system in the Factory? (Please tick as appropriate)

□ Yes

□ No

25. If yes, what type of platform is the system running on? (Please tick all that apply)

□ Windows

□ Linux

□ Unix

□ Other: Please specify____

26. Is the system a relational database Management (RDMS)? ________If so, What Database management systems are you using? (Please tick all that apply)

□ Ms SQL

□ Oracle

□ Any other State____

27. Is the system single or multiuser? ______. If multiuser how many clients' machines are in the network? ______________________ (Please Specify number)

28. What systems are supported in your factory: (Please tick all that apply)

□ Transaction processing

□ Payment processing

□ Cheque processing

□ Marketing automations

□ SMS banking

□ Internet banking capabilities

□ Payroll processing

□ Others: Please State____

29. Are the systems linked to farmers in the factory

□ Yes

□ No

30. If Yes, how far can the famer access the chain of the tea.

□ Factory only

□ Distributor only

□ Supplier only

□ No specific accessibility used.

□ Others: Please

State____

31. How do you input data to the systems? (Please tick all that apply)

□ Manual Data Capture

□ Electronic file transfer

□ Flash disks

□ Download through internet

□ Using GSM technology

32. Which technologies are used to interlink your factory and Head Office? (Please tick all that apply)

□ Digital leased lines

□ Analogue Leased lines

□ VSAT

□ Wireless Technology

□ GPRS/EDGE (GSM technology)

□ Optic Fiber

□ Branches not interconnected

□ Others: State____

33. What emerging services have you implemented or in the process of implementing (Please tick all that apply)

□ SMS

□ Factory information access through Internet.

□ Use of Point of Sale (POS)

□ Others...(State)

34. Which technologies does your factory use to connect to the internet? (Please tick all that apply)

□ No internet connection

□ leased lines

□ VSAT

□ Dial up

□ GPRS/EDGE (GSM technology)

□ Optic Fibre

□ Wireless

SECTION C: ICT INFRASTRUCTURE

To what extent do you agree or disagree within the following statements about ICT Infrastructure and Management (Issues of architectural/Infrastructure capabilities) of tea supply chain. Use the key: Strongly agree (SA), Agree (A), Not Sure (NS), Disagree (D), Strongly Disagree (SD)

Technological Infrastructure

Statement **In terms of the constraints of technological infrastructure, we think that**	**SA**	**A**	**NS**	**D**	**SD**
the current technological structure is not adequate for blockchain.					
the current Internet service is not efficient enough for blockchain.					
there is not sufficient access to blockchain technology.					

Compatibility

Statement **In terms of compatibility, we believe that blockchain platforms are**	**SA**	**A**	**NS**	**D**	**SD**
not compatible with the way we work.					
not compatible with our operations.					
not compatible with our business process.					
not compatible with other information systems (e.g., ERP, MIS, WMS).					

Scalability

Statement **In terms of scalability, we believe that**	**SA**	**A**	**NS**	**D**	**SD**
the speed of transaction (7 transactions per second) on blockchain is quick.					
the speed of block generation is decent.					
block size (1 megabyte) is large.					
block size is decent for practical use.					
overall speed and block size are excellent.					

Complexity

Statement **In terms of complexity, we think that**	**SA**	**A**	**NS**	**D**	**SD**
blockchain is conceptually difficult to understand from a business perspective.					
blockchain is conceptually difficult to understand from a technical perspective.					
when using blockchain technology, it is difficult to resolve transactional errors.					
using blockchain technology is difficult.					

Security

Statement **With regard to security concerns, our organization**	**SA**	**A**	**NS**	**D**	**SD**
does not feel secure in providing sensitive information related to the company (e.g., transaction data) when working with blockchain platforms.					
does not feel secure sending sensitive information about the company to the platform.					
does not feel safe uploading sensitive information about the company to the platform.					
does not feel that blockchain is a safe platform for operating business with sensitive information overall.					

SECTION D: DATA INTERGRATION & INTEROPERABILTY

To what extent do you agree or disagree with the following statements about Interoperability (Inter communication and Inter-exchange) of data.		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	There should be **inter-communication and interexchange** (**interoperability**) across all systems to share data amongst stakeholder in the supply chain.					
2	Interoperability between information systems will improve verification of data amongst organizations.					
3	Use of ICT technologies can play a vital role in obtaining inter-operability between systems that share data in heterogeneous information systems.					

4	Overall accuracy of information will be improved once intercommunication is implemented across information systems dealing with data?					
5	There is duplication of data during a data sharing or storage of data in the databases.					
(ii)	In a scale of 1 to 5 of priority which data and information integration issues at the organization needs to be addressed for interoperability of information system to be implemented (1- Low Priority 5 – High Priority)	1	2	3	4	5
6	Data should be available at all levels of the supply chain					
7	Enhancing quality and secure data					
8	ICT technologies in sharing of data					
9	Accuracy and Accountability of data will be improved					
10	Duplication of data during storage					

SECTION E: COLLABORATION

Collaboration with Other Organization's

Statement **In terms of collaboration efforts, we believe that collaboration with other organizations to allow for blockchain adoption**	**SA**	**A**	**NS**	**D**	**SD**
is not easy.					
is challenging.					
requires too much time.					
requires a lot of mental effort.					

Government Support

Statement **With regard to constraints on government support, we think that**	**SA**	**A**	**NS**	**D**	**SD**

the government has not provided incentives to encourage the adoption of blockchain technology.					
the government does not actively support blockchain technology.					
the government has not introduced relevant policies to boost blockchain					
there is no support (e.g., training) provided by the government concerning blockchain technology.					

Regulations and Legal Frameworks

Statement **With regard to constraints on regulations and legal frameworks related to blockchain, we think that**	**SA**	**A**	**NS**	**D**	**SD**
the regulatory body is not yet well-established to deal with blockchain issues.					
there may be changes in regulations that would interfere with our usage of blockchain in the future.					
there is no authority to solve disputes.					
legal structures do not satisfactorily protect users from problems on blockchain platforms.					

Cost

Statement **In terms of cost of implementation, we believe that blockchain adoption would**	**SA**	**A**	**NS**	**D**	**SD**
increase hardware and software facility costs.					
increase costs for training and recruiting.					
be expensive due to trial-and-error.					
require high up-front investment costs.					

Technological Knowledge and Awareness

Statement **With regard to technological knowledge and awareness, top managers in our company**	**SA**	**A**	**NS**	**D**	**SD**
recognize blockchain as a competitive weapon.					
recognize blockchain as a tool to increase the productivity of clerical employees.					
recognize blockchain as a tool to increase the productivity of professionals.					
recognize the strategic potential of blockchain.					
believe blockchain contributes significantly to the firm's financial performance.					
agree blockchain projects may have important intangible benefits that should be					

Technical Knowledge and Awareness

Statement **With regard to technical knowledge and expertise, we think that our organization**	**SA**	**A**	**NS**	**D**	**SD**
has the relevant technical knowledge about blockchain technology.					
has professional staff trained in blockchain technology use.					
has interest in projects related to blockchain technology.					
is familiar with this type of technology and its applications					

SECTION F: BLOCKCHAIN TECHNOLOGY

To what extent do you agree with the following statements about blockchain technology (a network comprised of nodes connected to decentralized database ensuring network consensus, data security, speed, privacy and single point of truth) in the tea supply chain management in Kenya. Use the key: Strongly agree (SA), Agree (A), Not Sure (NS), Disagree (D), Strongly Disagree (SD)

Statement **With regard to our stance on blockchain technology**	**SA**	**A**	**NS**	**D**	**SD**
The Organisation will NOT adopt blockchain unless it proves beneficial for us.					
The Organisation will wait for the right time and required capability to adopt blockchain.					
The Organisation needs to clarify some queries and justify adopting blockchain.					
The Organisation needs to get solutions for some of our complaints/objections before adopting					
The Organisation does not need blockchain.					
The Organisation is unlikely to adopt blockchain in the near future.					
Blockchain technology will ensure security of data					
Blockchain technology guarantees privacy of data					
Blockchain technology ensures network consensus					
Blockchain technology has desirable recording and accessible speed					

Thank you so much for taking your time to assist the researcher to gather this vital information.

APPENDIX 4: INTERVIEW GUIDE FOR ICT OFFICERS

The objective of the interview is to establish the current state of tea supply chain management, required state of tea trade and the adoption factors that will influence the adoption of smart contract on blockchain application in the tea supply chain management.

Section 1 – General

1. Establish which Information Systems are available within the organization and if there are any technologies addressing supply chain management.
2. How would you describe the complexity of the food supply chain of your company at the moment?
3. Have you ever encountered any problem caused by the supplier side? (For example, providing inadequate certifications of origin, bad product quality, etc.)
4. Do you think there is a need to improve the supply process, why?

Part 2: Blockchain-based Transparency model using smart contracts for tea supply chain management questions

1. How do you think this blockchain system will benefit your company operations? (For example the transparency in your supply chain, the management of suppliers, the amount of paperwork, etc.)
2. What experience and skills do you possess about blockchain technology?
3. Have been involved in a project with blockchain technology?

b. Do you have any other good examples of successful projects?

4. What possibilities do you see with blockchain?

a. How can blockchain be used within a supply chain, specifically tea supply chain?

b. How can blockchain be used to address transparency of trade in tea supply chain?

5. What challenges do you see with blockchain?

a. What are the requirements for implementation of a blockchain in a tea supply chain?

b. What do you believe are other best practice technologies that compete with blockchain in tea supply chain?

6. What kind of blockchain would fit a tea supply chain to obtain transparency of trade?

a. How should the model be set?

b. Should it be a public, private or hybrid blockchain?

c. Should it be distributed or decentralized?

d. What data storage technique is preferred?

e. What technique for identification should be used?

7. Do you believe that business models have to change with the implementation of blockchain?

a. Who owns the data?

b. Who will have the power of the data? Thinking of optimization and analyzing.

c. Is there a need for regulations/certifications?

8. If your farmers, the factories and suppliers want you to adopt this system, would you consider using it, why?

9. Do you think your company has sufficient resources (like Finance, Human and Technology) to employ this system? Please explain.

10. Do you think your company will adopt Blockchain-Based Transparency Model Using Smart Contracts for supply chain management in the near future (10 years)?

Thank you so much for taking your time to assist the researcher to gather this vital information.

APPENDIX 5: RESEARCH LICENSE

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Date of Issue: 17/May/2021

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This is to Certify that Mr.. Hillan Kipchumba Ronoh of Masinde Muliro University of Science and Technology, has been licensed to conduct research in Kericho, Kisii, Meru, Nandi on the topic: Blockchain-Based Model Using Smart Contracts for Tea Supply Chain Management, Kenya for the period ending : 17/May/2022.

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