BLOCKCHAIN TECHNOLOGY AND SUPPLY CHAIN PERFORMANCE IN THE MARITIME LOGISTICS INDUSTRY, KENYA

By

KIOKO PATIENCE

MASTER OF BUSINESS ADMINISTRATION, PROCUREMENT AND SUPPLIES MANAGEMENT

KCA UNIVERSITY

2025

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A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF BUSINESS ADMINISTRATION (PROCUREMENT AND SUPPLIES MANAGEMENT) IN THE SCHOOL OF BUSINESS AT KCA UNIVERSITY.

DECEMBER, 2025

DECLARATION

I declare that this dissertation is my original work and has not been previously published or submitted elsewhere for award of a degree. I also declare that this contains no material written or published by other people except where due reference is made and author duly acknowledged.

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ABSTRACT

This study seeks to determine the effect of blockchain technology on supply chain performance in the Maritime Logistics Industry, Kenya. The focus is on examining how specific constructs of blockchain technology namely smart contracts, distributed ledger technology (DLT), consensus mechanisms, and cryptographic security affect supply chain performance in this sector. The general objective is to evaluate the effect of blockchain technology on supply chain performance, while the specific objectives include: analyzing the effect of smart contracts, assessing the effect of DLT, examining the effect of consensus mechanisms, and evaluating the effect of cryptographic security on supply chain performance in the Maritime Logistics Industry, Kenya. This study was grounded in four interrelated theoretical perspectives: The Technology Acceptance Model (TAM), Diffusion of Innovation Theory (DOI), Hybrid Supply Chain Theory (HSCT), and Stakeholder Theory. The target population for the study did census of 148 targeted professionals across four strata including Customs & Compliance Officers (49), Operations/Freight Managers (37), IT Managers (34), and Supply Chain/Logistics Managers (28). A quantitative research design will be employed, utilizing structured questionnaires to collect data from selected maritime logistics firms operating in Mombasa and Nairobi. Regression analysis will be used to determine the statistical relationship between the identified blockchain constructs and supply chain performance. The findings revealed that Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms and Cryptographic Security all had significant positive correlations with supply chain performance. Regression analysis established that the four independent variables jointly explained 52.8% of the variation in supply chain performance. The regression coefficients further showed that Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms and Cryptographic Security significantly and positively influence supply chain performance. The study concludes that the adoption of blockchain technologies has a substantial effect on improving efficiency, transparency, and security in maritime logistics supply chains. The study recommends increased investment in blockchain infrastructure, capacity-building initiatives, and supportive regulatory frameworks to enhance adoption and impact. Further studies should explore cross-industry comparisons, cost–benefit analyses, longitudinal adoption effects, and the integration of blockchain with emerging technologies such as Artificial Intelligence and the Internet of Thing.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to my supervisor, Dr. Catherine Njoki Gatari, for her insightful guidance, constructive feedback, and unwavering support throughout the development of this research proposal. I also extend my appreciation to the faculty and administration of KCA University for providing a conducive academic environment. Special thanks go to the maritime logistics professionals in Kenya who generously shared their time and expertise, contributing valuable insights to this study. Lastly, I am thankful to my colleagues and peers for their encouragement and thoughtful suggestions that enriched the quality of this work.

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ACRONYMS AND ABBREVIATIONS

AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AI	Artificial Intelligence
DLT	Distributed Ledger Technology
EAC	East African Community
IBM	International Business Machines Corporation
ICT	Information and Communication Technology
ISPS	International Ship and Port Facility Security (Code)
ISO	International Organization for Standardization
KenTrade	Kenya Trade Network Agency
KMA	Kenya Maritime Authority
KPA	Kenya Ports Authority
KRA	Kenya Revenue Authority
IoT	Internet of Things
PBFT	Practical Byzantine Fault Tolerance
PoS	Proof of Stake
PoW	Proof of Work
SMART	Specific, Measurable, Achievable, Realistic, Time-Bound
SPSS	Statistical Package for the Social Sciences
UNCTAD	United Nations Conference on Trade and Development
WTO	World Trade Organization

OPERATIONAL DEFINITION OF TERMS

Blockchain Technology	It refers to the use of a secure, decentralized digital ledger system to record, track, and manage shipping transactions, cargo movements, documentation, and stakeholder interactions throughout the global maritime supply chain (Mougayar, 2016).
Consensus Mechanisms	These are the digital protocols used within blockchain or distributed ledger systems to ensure that all participants in the maritime supply chain — such as shipping lines, ports, customs, and freight forwarders — agree on the validity of transactions, documents, and cargo data without relying on a central authority (Ngugi, 2022).
Cryptographic Security	This refers to refers to the application of advanced encryption and cryptographic techniques to protect sensitive shipping data, digital documents, and transactions within the maritime supply chain (Kariuki, 2020).
Distributed Ledger Technology	It refers to the use of a decentralized digital system for securely recording, sharing, and verifying shipping data, cargo movements, and trade documents across multiple participants in the maritime supply chain. (Tapscott & Tapscott, 2017).
Smart Contracts	These are self-executing digital agreements stored on a blockchain that automatically perform and enforce actions such as payments, document transfers, and cargo handling when predefined conditions are met (Christidis & Devetsikiotis, 2016).
Supply Chain Performance	It refers to the effectiveness and efficiency with which these companies manage the movement, handling, and delivery of goods across global shipping networks (World Bank, 2020).

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

International trade has undergone profound transformation in recent decades, driven by globalization, technological advancements, and increasingly complex supply chains. Within this evolving landscape, the maritime logistics industry remains the backbone of global trade, facilitating over 80 percent of merchandise trade by volume and 70 percent by value (Rodriguez & Notteboom, 2020). As global supply chains demand greater speed, transparency, and reliability, blockchain technology has emerged as a promising solution. Originally developed to support cryptocurrency transactions, blockchain has evolved into a strategic enabler of supply chain performance, offering enhanced efficiency, transparency, traceability, fraud mitigation, and reduced operational costs (Farah et al., 2024; IBM, 2023). This underscores its growing relevance in strengthening maritime logistics systems globally.

Globally, leading maritime economies have adopted blockchain to enhance supply chain performance across ports and logistics chains. For instance, European ports such as Rotterdam and Antwerp utilize blockchain platforms like TradeLens to digitize bills of lading, streamline documentation flows, and reduce vessel turnaround time (Gausdal et al., 2018). In Asia, the Port of Singapore has implemented blockchain-enabled smart contracts to improve customs clearance speed and enhance real-time cargo visibility (Wang et al., 2019). In West Africa, ports such as Lagos have employed blockchain to curb corruption and improve cargo tracking, thereby increasing trust and coordination among supply chain actors (Okon & Akpan, 2022). These cases demonstrate blockchain's ability to enhance supply chain performance by improving operational efficiency, transparency, coordination, and trust across maritime logistics systems.

Regionally inspired by global success, Kenya has begun exploring blockchain integration in its maritime logistics industry. The pilot adoption of the IBM–Maersk TradeLens platform at the Port of Mombasa enabled the digitization of bills of lading, automation of documentation processes, and reduction of cargo clearance times by up to 40 percent (Kosiek et al., 2021; Kruse et al., 2020). This pilot highlights blockchain's potential to improve critical dimensions of supply chain performance such as lead time reduction, cost-effectiveness, coordination, and transparency in Kenya's maritime logistics sector.

Blockchain's contribution to supply chain performance can be explained through its four foundational constructs: Smart Contracts, Distributed Ledger Technology (DLT), Consensus Mechanisms, and Cryptographic Security (Christidis & Devetsikiotis, 2016; Nakamoto, 2008; Wang et al., 2019). Smart contracts automate processes such as payments, freight release, and customs compliance, minimizing delays and disputes. DLT ensures synchronized, immutable records shared among stakeholders, increasing traceability and transparency. Consensus mechanisms facilitate verification of transactions, enhancing trust and collaboration by reducing dependence on intermediaries. Cryptographic security protects sensitive trade data, ensuring confidentiality and data integrity. Collectively, these constructs provide a conceptual foundation through which blockchain is theorized to enhance supply chain performance in maritime logistics.

Despite this potential, Kenya's maritime logistics industry has not fully realized the benefits of blockchain. Persistent challenges such as limited digital adoption, high implementation costs, inadequate technical capacity, and regulatory uncertainties hinder large-scale deployment (Farah et al., 2024; Ogunlesi, 2023; Almeida & Okon, 2025). Consequently, cargo dwell times at the Port of Mombasa remain between 12 and 18 days, exceeding the global average of 10 days and reflecting inefficiencies that weaken supply chain performance (Eper, 2022). This gap between blockchain's demonstrated global potential and its limited local utilization presents a critical research problem.

Therefore, this study seeks to determine how blockchain technology, through its key constructs: Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, and Cryptographic Security can be effectively harnessed to enhance efficiency, transparency, coordination, and overall supply chain performance in Kenya's maritime logistics industry. By aligning blockchain capabilities with performance dimensions, the study aims to provide empirical insights that support the strategic integration of blockchain in Kenya's maritime logistics framework.

1.1.1 Blockchain Technology

Blockchain technology is a decentralized, immutable ledger system that enables secure and transparent record-keeping across interconnected networks. Although originally developed to facilitate cryptocurrency transactions such as Bitcoin, its distributed architecture has since been widely adopted across sectors including finance, healthcare, energy, and the maritime logistics industry (Farah et al., 2024; IBM, 2023). In maritime logistics, blockchain addresses key inefficiencies related to documentation delays, cargo visibility gaps, port clearance bottlenecks, and limited inter-stakeholder trust, thereby contributing to improved supply chain performance.

For the purpose of this study, blockchain technology is conceptualized through four core constructs: Smart Contracts, Distributed Ledger Technology (DLT), Consensus Mechanisms, and Cryptographic Security. Smart Contracts are self-executing digital protocols that automate routine maritime processes such as freight payments, customs clearance, and enforcement of service-level agreements (Christidis & Devetsikiotis, 2016). By minimizing manual intervention, smart contracts reduce human error, accelerate regulatory compliance, and enhance operational efficiency. For example, automated monitoring enabled by smart contracts has improved the tracking of temperature-sensitive goods, thereby safeguarding the integrity of maritime supply chains (Wang et al., 2019).

Distributed Ledger Technology (DLT) provides a shared, tamper-proof database accessible to key maritime logistics actors such as customs authorities, shipping lines, freight forwarders, and port operators (Nakamoto, 2008). Empirical studies show that DLT-based systems can reduce operational costs by up to 30% and significantly improve traceability and real-time visibility across global maritime corridors (Saberi et al., 2019). However, the effectiveness of DLT depends on its seamless integration with legacy port management and shipping systems, necessitating standardized blockchain protocols (Kamble et al., 2020).

Consensus Mechanisms, such as Proof of Stake (PoS) and Practical Byzantine Fault Tolerance (PBFT), validate transactions before they are permanently added to the blockchain (Nakamoto, 2008). In the maritime logistics context, consensus mechanisms mitigate fraud in critical documents such as bills of lading—an issue responsible for estimated financial losses of over $500 million annually (Mileski et al., 2020). By ensuring data authenticity and accuracy, consensus mechanisms enhance trust, reduce disputes, and improve the overall resilience and reliability of maritime supply chains (Kouhizadeh et al., 2021). Cryptographic Security safeguards sensitive documentation such as invoices, insurance records, and shipping manifests from unauthorized manipulation or breaches (Nakamoto, 2008). Through encryption and digital signatures, blockchain ensures tamper-proof audit trails that protect data integrity and bolster stakeholder confidence in maritime trade documentation systems (Kosiek et al., 2021).

Collectively, these four constructs of blockchain technology are framed as the independent variables in this study, each contributing uniquely to supply chain performance in the maritime logistics industry. Smart contracts are expected to improve efficiency through reduced clearance times and automated compliance; DLT enhances operational transparency and cost-effectiveness; consensus mechanisms foster reliability and fraud prevention; while cryptographic security strengthens trust by protecting sensitive information. Together, these blockchain-enabled mechanisms are theorized to significantly enhance maritime supply chain performance, measured through efficiency, transparency, cost-effectiveness, reliability, security, and trust among stakeholders.

1.1.2 Supply Chain Performance in the Maritime Logistics Industry

Supply chain performance refers to the extent to which a supply chain meets its operational and strategic objectives in terms of cost, time, quality, transparency, reliability, and stakeholder satisfaction (Beamon, 1999). In the maritime logistics industry, performance is commonly assessed through key indicators such as cargo handling efficiency, customs clearance speed, documentation accuracy, and delivery timeliness. Performance outcomes depend not only on internal organizational capabilities but also on the level of external coordination among multiple actors such as port authorities, customs agencies, shipping lines, freight forwarders, and logistics service providers (Mentzer et al., 2001). Effective coordination among these entities is essential for ensuring seamless cargo flow across borders, thus reflecting a high-performing maritime supply chain.

In regional logistics hubs such as the Port of Mombasa, maritime logistics efficiency is especially critical. Key efficiency indicators include reduced cargo dwell time, minimized handling errors, faster documentation processing, and lower operational costs. Inefficiencies in these areas contribute to inflated logistics expenses, which can account for up to 40% of product costs in African markets, compared to approximately 10% in developed economies (World Bank, 2020). Such disparities significantly undermine the competitiveness of East African economies in global trade. Blockchain-based digital systems can mitigate these inefficiencies by enabling real-time visibility, reducing manual redundancies, and facilitating faster data validation, thereby directly contributing to improved supply chain efficiency (Saberi et al., 2019).

Another critical dimension of supply chain performance is transparency, which involves the degree of openness, visibility, and traceability of processes, documentation, and financial transactions throughout the logistics chain. Maritime supply chains typically involve multiple intermediaries and frequent document transfers, which often result in data silos, opaque decision-making, and limited accountability. Blockchain technology addresses these challenges by enabling a single, immutable ledger accessible to authorized stakeholders, ensuring complete traceability and verifiable audit trails (Casino et al., 2020). Enhanced transparency strengthens compliance with international trade regulations, mitigates fraud and bribery risks, and reduces cargo losses during transit (Treiblmaier, 2018).

Reliability, defined as the consistency and dependability of supply chain processes and outcomes, is also a vital performance criterion. Maritime logistics require the synchronization of multiple operations such as berth planning, container discharge, cargo inspection, and customs clearance. Disruptions or inefficiencies in any of these stages can trigger cascading delays across the supply chain. Blockchain enhances reliability through smart contracts that automatically execute transactions once predefined conditions are met, ensuring contractual obligations are fulfilled and reducing the likelihood of disputes or delays (Kouhizadeh & Sarkis, 2018). In Kenya, where problems such as corruption, document manipulation, and late deliveries persist, improved reliability could enhance stakeholder confidence and stimulate greater trade flows.

Finally, overall supply chain performance in maritime logistics involves meeting service-level expectations, ensuring regulatory compliance, and delivering value to stakeholders in alignment with broader trade facilitation agendas such as the African Continental Free Trade Area (AfCFTA). Under such initiatives, cross-border trade requires integrated, secure, and timely data exchange among customs and port systems. Blockchain technology facilitates this integration by providing secure, synchronized, and verifiable real-time data, enabling faster decision-making and improving service delivery while reducing administrative burdens (Madhwal & Panfilov, 2017). Given the growing need to enhance efficiency, transparency, reliability, and regulatory compliance in Kenya's maritime logistics industry, investigating the impact of blockchain technology on these supply chain performance dimensions is both timely and strategically important.

1.1.3 Maritime Logistics Sector in Kenya

The maritime logistics sector in Kenya is a critical gateway for trade within Central and Eastern Africa, with the Port of Mombasa serving as the region's leading seaport and one of the busiest on the continent (UNCTAD, 2022). The port facilitates imports and exports for Kenya and several landlocked countries such as Uganda, Rwanda, Burundi, the Democratic Republic of Congo (DRC), and South Sudan. Positioned along the Northern Corridor, Mombasa provides vital road and rail connectivity to inland markets, making the efficiency of Kenya's maritime logistics chain essential not only to national economic growth but also to regional integration and trade competitiveness (AfDB, 2019).

Despite this strategic significance, Kenya’s maritime logistics sector continues to face persistent operational challenges. Key issues include port congestion, customs clearance delays, fragmented documentation processes, and excessive reliance on manual and paper-based systems—all of which contribute to high logistics costs and prolonged cargo dwell times (World Bank, 2020). In addition, poor coordination among key stakeholders—including shipping lines, port operators, customs agencies, freight forwarders, and transporters—has resulted in siloed data systems, limited transparency, and elevated risks of fraud, corruption, and cargo mismanagement (KenTrade, 2021). Consequently, Kenya’s Logistics Performance Index (LPI) ranking remains below the global average, weakening its competitiveness as a preferred trade gateway in Africa.

Kenya has made efforts to digitalize maritime operations through initiatives such as the National Electronic Single Window System (KenTrade), designed to streamline customs documentation by providing a centralized portal for trade procedures. However, the system’s centralized nature limits real-time data sharing across multiple stakeholders and remains vulnerable to data manipulation and operational bottlenecks (WTO, 2020). In contrast, blockchain technology offers a decentralized and tamper-proof architecture that allows stakeholders to securely access synchronized, real-time data while ensuring transparent and verifiable transaction records (Kshetri, 2018). This positions blockchain as a more transformative solution capable of addressing systemic inefficiencies in Kenya’s maritime logistics ecosystem.

Kenya has demonstrated early interest in blockchain integration through public-private partnerships, notably with the pilot implementation of the TradeLens platform at the Port of Mombasa. The pilot enabled real-time container tracking, secure digital documentation, and enhanced customs compliance, significantly reducing scope for fraud and improving process visibility (IBM, 2021). Although the global shutdown of TradeLens in 2023 halted its immediate expansion, the pilot validated blockchain's capability to deliver scalable, secure, and efficient logistics solutions in Kenya. These pilot outcomes highlight the potential for expanding blockchain adoption from localized pilots to a broader national logistics digitalization strategy.

Furthermore, Kenya's maritime logistics industry must align with global digitalization trends and fulfill regional commitments under frameworks such as the African Continental Free Trade Area (AfCFTA) and the East African Community (EAC) integration agenda, both of which emphasize interoperable, transparent, and digital trade facilitation mechanisms. Blockchain can serve as the foundational infrastructure for electronic cargo tracking, customs harmonization, trade finance through smart contracts, and real-time regulatory compliance across borders (Zhao et al., 2019). Given Kenya's strategic position and first-mover potential within the region, it is well-positioned to pioneer blockchain-enabled trade facilitation across Africa.

Therefore, assessing the extent to which blockchain technology—operationalized through Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, and Cryptographic Security—can improve maritime supply chain performance is not only timely but critical to enhancing Kenya's logistics competitiveness, regional influence, and compliance with global trade standards.

1.2 Statement of the Problem

The maritime logistics industry in Kenya, particularly at the Port of Mombasa, faces significant challenges such as prolonged cargo dwell times averaging between 12 to 18 days, which exceeds the global average of approximately 10 days, leading to delays, increased costs, and reduced competitiveness in regional trade (Almeida & Okon, 2025; Mageto & Luke, 2024). Although blockchain technology has shown potential globally to improve supply chain transparency, trust, and efficiency, its adoption in Kenya's maritime sector remains limited and fragmented (Farah et al., 2024).

A major research gap exists due to the lack of empirical data evaluating blockchain's measurable impact on port operations in Kenya, despite platforms like TradeLens being adopted (Farah et al., 2024). Moreover, the sparse research on blockchain adoption in African maritime logistics predominantly focuses on small-scale pilots without comprehensive assessment, leaving limited understanding of practical benefits and challenges in contexts like Mombasa (Mageto & Luke, 2024; African Development Bank, 2024). Additionally, there is an insufficient exploration of barriers such as limited technical expertise, high costs, and unclear regulatory frameworks that hinder blockchain integration in Kenya's maritime supply chains (Ogunlesi, 2023; Almeida & Okon, 2025).

Finally, the alignment between blockchain adoption and Kenya's Vision 2030 remains conceptual, with limited policy integration and impact evaluation to support strategic digitalization efforts (Farah et al., 2024). This study seeks to bridge these gaps by providing empirical evidence on blockchain's effects on supply chain performance, analyzing contextual adoption barriers, and assessing how blockchain technologies—specifically smart contracts, distributed ledgers, and cryptographic security—can enhance operational efficiency, transparency, and competitiveness within Kenya's maritime logistics industry. The findings aim to inform policymakers and stakeholders to support scalable and effective blockchain implementation aligned with national development goals.

1.3 Objectives of the Study

1.3.1 General Objective

To determine the effect of blockchain technology on supply chain performance in the maritime logistics industry in Kenya.

1.3.2 Specific Objectives

i. To analyze the effect of smart contracts on supply chain performance in the maritime logistics industry in Kenya.

ii. To assess the effect of distributed ledger technology (DLT) on supply chain performance in the maritime logistics industry in Kenya.

iii. To examine the effect of consensus mechanisms on supply chain performance in the maritime logistics industry in Kenya.

iv. To evaluate the effect of cryptographic security on supply chain performance in the maritime logistics industry in Kenya.

1.4 Specific Questions

i. What is the effect of smart contracts on supply chain performance in Kenya's Maritime Logistics Industry?

ii. What is the effect of distributed ledger technology (DLT) on supply chain performance in Kenya's Maritime Logistics Industry?

iii. What is the effect of consensus mechanisms on supply chain performance within the Maritime Logistics Industry in Kenya?

iv. To what extent does cryptographic security affect supply chain performance within the Maritime Logistics Industry in Kenya?

1.5 Significance of the Study

The research is of essential significance in various aspects operational, technological, policy, investment, and academic. The research will accrue direct value to a wide range of stakeholders of Kenya's maritime logistics chain, such as logistics providers, port authorities, regulators, tech entrepreneurs, investors, and researchers. Through the exploration of the empirical usage of blockchain in Kenya's maritime logistics, the research adds to applied reform, technology adoption, and research advancement.

1.5.1 Practitioners in Maritime Logistics in Kenya

Maritime logistics stakeholders who work directly with maritime logistics such as shipping lines, customs brokers, freight forwarders, and terminal operators will be likely to be benefited by practical lessons generated through this study. The study will inform them about how blockchain technologies such as smart contracts, distributed ledger technology, and secure consensus protocols can increase process automation, reduce fraud, and offer more end-to-end visibility on cargo. Logistics operators transporting cargo through the Port of Mombasa or operating in Nairobi like Maersk, Bolloré, Siginon Group, and local truckers can apply these insights to improve customs clearance speed, minimize bureaucratic bottlenecks, and streamline documentation. These benefits can enhance operational competitiveness, minimize overheads, and improve delivery of services.

1.5.2 Policymakers and Regulatory Bodies

Government ministries and regulatory bodies such as the Kenya Ports Authority (KPA), Kenya Revenue Authority (KRA), and Kenya Trade Network Agency (KenTrade) will also benefit from empirical insights from the study on blockchain impacts. The findings will inform policy development, the regulatory framework, and investment planning in digital infrastructure. By evaluating performance metrics like transparency, cost savings, traceability, and trust among stakeholders, the study will support Kenya's broader policy ambitions as articulated in the Kenya Digital Economy Blueprint (2019). It is also aligned with Kenya's global commitments in treaties like the World Trade Organization's Trade Facilitation Agreement and regional integration treaties under the East African Community (EAC) Digital Integration Agenda.

1.5.3 Technology Innovators and Investors

The research offers beneficial guidance for venture capital investors, blockchain solution providers, and technology developers seeking to deploy scalable innovation in African logistics. Through its analysis of blockchain adoption through real pilot initiatives like the TradeLens project at Port of Mombasa, the research maps effective adoption hurdles and success drivers. These findings can help technology companies design locally adapted blockchain platforms that are integrated with existing systems, regulatory structures, and stakeholder procedures. Investors interested in financing digital transformation in African ports will also gain a better grasp of market demand, return on investment, and innovation gaps.

1.5.4 Academic and Research Community

From an academic perspective, the research contributes to the mounting body of academic work on blockchain adoption in logistics, particularly in the hitherto under-researched African continent.

While the current literature leans towards developed economies, the research provides empirical insights focused on Kenya's maritime sector. Graduate students, universities, and research centers studying themes such as supply chain technology, logistics innovation, digital trade, and public-private partnerships in Africa will consider this study a must-read guide. It also serves as a basis for further studies on new themes such as decentralized trade finance, sustainable ports operations, and AI-blockchain integration in logistics.

1.5.5 Economic and Regional Development Stakeholders

At the macro level, this study aligns with Kenya's vision to become a regional logistics hub under the Africa Agenda 2063 and African Continental Free Trade Area (AfCFTA) digital strategy. By establishing how blockchain technology can increase supply chain transparency, eliminate inefficiencies, and integrate inland and coastal logistics networks, the study supports broader regional development goals. These include facilitating intra-African trade, reducing the cost of doing business, and accelerating landlocked countries' integration into regional and global value chains. In doing this, the study promotes not only local technological innovation but also the sustainable and inclusive economic transformation of the continent.

1.6 Scope of the Study

This study focuses on the application of blockchain technology and its impact on supply chain performance within the maritime logistics industry in Kenya. It examines how blockchain can enhance transparency, efficiency, and security in maritime supply chain operations, including cargo tracking, documentation, payment processes, and stakeholder collaboration. The geographical scope is limited to key maritime logistics hubs in Port of Mombasa as it is central to the country's import and export activities. The study targets the Supply Chain / Logistics Managers, IT Managers, Operations / Freight Managers and Customs & Compliance Officers from each firm, giving a total of 148 respondents. Key aspects under investigation include the integration of blockchain in current maritime supply chain processes, its influence on reducing delays, minimizing fraud, improving documentation accuracy, and enhancing overall supply chain visibility and coordination. The study covers a period from 2024/2025 and utilizes both qualitative and quantitative research methods to analyze blockchain adoption levels and their correlation with supply chain performance metrics such as on-time delivery, cargo handling efficiency, and cost reduction.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature review is a critical discussion and summary of the statistical literature that is 'general' and 'specialized' relevant to the study subject, however its form may vary. This chapter presents the theoretical framework, thematic literature topics based on the specific objectives, a summary of identified knowledge gaps, and the conceptual framework guiding this study.

2.2 Theoretical Review

This study is grounded in four interrelated theoretical perspectives: The Technology Acceptance Model (TAM), Diffusion of Innovation Theory (DOI), Hybrid Supply Chain Theory (HSCT), and Stakeholder Theory. Each of these frameworks provides a unique lens to examine the drivers and challenges of blockchain adoption within Kenya's maritime logistics sector. These theories are not mutually exclusive but rather complementary in capturing individual, organizational, structural, and systemic dimensions of technological integration.

2.2.1 Technology Acceptance Model

The Technology Acceptance Model (TAM), developed by Davis (1989), explains how perceived usefulness and perceived ease of use drive individuals' decisions to adopt technology. It posits that users will more readily accept and use a new system if they believe it will improve their performance and is easy to use (Venkatesh & Davis, 2000). In Kenya's maritime logistics environment, platforms like TradeLens are perceived as useful due to their ability to reduce document fraud, enhance cargo visibility, and shorten clearance times (Farah, Ahmed, & Mwangi, 2024).

However, if logistics operators and customs officials find these systems too complex or lack sufficient training, adoption rates are likely to remain low (Kariuki & Maina, 2023). Therefore, perceived ease of use becomes a decisive factor in determining technology uptake, especially in digitally underprepared environments like Kenyan seaports. Despite its relevance, TAM has been critiqued for its limited applicability in developing countries where external variables such as infrastructure, organizational support, and socio-cultural dynamics significantly impact adoption behavior. Rejeb et al. (2021) argue that TAM's focus on the individual level overlooks broader systemic constraints such as power asymmetries, regulatory bottlenecks, and institutional inertia.

For example, the lack of reliable internet and electricity in parts of Kenya directly affects users' ability to utilize blockchain applications efficiently (Wekesa & Musyoka, 2022). In this regard, while TAM is instrumental in explaining user-centric adoption behavior, its predictive validity in low-infrastructure contexts such as Kenya must be complemented by theories that address external and organizational barriers (Ali et al., 2024). Consequently, the study applies TAM to examine how perceptions of blockchain technology shape behavior among logistics professionals, while recognizing the model's contextual limitations.

In this study, TAM is adopted to evaluate how perceived usefulness and perceived ease of use influence the behavioral intention of logistics professionals in Kenya's maritime sector to adopt blockchain platforms such as TradeLens. However, given the infrastructural and institutional challenges present in the Kenyan context, the study extends TAM by incorporating external variables such as organizational support, system complexity, and regulatory readiness to provide a more holistic understanding of blockchain adoption.

2.2.2 Diffusion of Innovation Theory

Rogers (1962) created the Diffusion of Innovation Theory (DOI), which describes how new concepts, innovations, and technology gradually proliferate within a social system. The process by which an innovation is disseminated throughout the constituents of a social system over time via specific routes is what Menzli et al. (2022) contend. The idea distinguishes five groups of adopters who accept innovations at varying rates: innovators, early adopters, early majority, late majority, and laggards. In order to understand how businesses and industries accept digital transformation and technological improvements, Rogers' work has been widely utilized in a variety of disciplines, including business, technology, healthcare, and supply chain management (Acikgoz, Elwalda, & De Oliveira, 2023).

Similarly, Germany's public sector historically relied on traditional compensation and promotion systems that did not always reward merit. To address this, reforms since 2007 introduced accelerated promotions and performance bonuses to motivate employees (Kroll and Nuesch, 2019). Despite these efforts, enforcement and use of sanctions such as delayed promotions remain tools to manage poor performance, indicating ongoing challenges in balancing motivation and discipline (Ortlieb, Matiaske, and Fietze, 2016).

According to the diffusion of innovation theory, relative advantage, compatibility, complexity, trialability, and observability are some of the variables that affect the predictable pattern of new technology adoption (Acikgoz et al., 2023). While compatibility gauges how effectively an invention meshes with current business procedures, relative advantage describes the perceived advantages of an innovation above current alternatives. Trialability enables businesses to test before complete adoption, observability establishes how obvious the innovation's advantages are to others, and complexity influences adoption ease.

Depending on these five variables, businesses adopt new technologies like blockchain, AI, IoT, and cloud computing at different rates in the context of digital supply chains. According to Menzli, Smirani, Boulahia, and Hadjouni (2022), companies that understand the strategic benefits of digital technologies for improving supply chain efficiency are more likely to adopt them quickly and obtain a competitive advantage. The study on how digital supply chain strategy affects the performance of Kenyan motor assembly companies is extremely pertinent to the diffusion of innovation theory. With the use of technology like real-time supply chain visibility, predictive analytics, and computerized inventory management, the Kenyan motor assembly sector is undergoing a digital revolution.

However, due to variations in labor knowledge, financial capability, and technical preparedness, adoption rates range throughout organizations. DOI Theory helps explain why some firms quickly adopt digital supply chain solutions, while others lag behind, and how digital strategies can improve efficiency, cost reduction, and responsiveness to market demands (Alyoubi & Yamin, 2024). By applying this theory, the study will evaluate the key enablers and barriers to digital supply chain adoption and provide insights into how Kenyan motor assemblers can accelerate digital transformation to enhance performance and competitiveness in the automotive industry.

In this study, the Diffusion of Innovation Theory provides a framework for understanding how Kenyan logistics/motor assembly firms adopt blockchain or digital supply chain technologies at varying rates. By assessing the role of relative advantage, compatibility, complexity, trialability, and observability, the study seeks to identify the enablers and barriers influencing adoption. This theoretical lens enables the examination of why some firms embrace digital supply chain transformation rapidly while others lag behind, based on organizational capability, technological readiness, and perceived benefits. Therefore, DOI guides the analysis of adoption dynamics and informs strategies to accelerate digital transformation for improved efficiency, competitiveness, and performance in Kenya's supply chain sector.

2.2.3 Hybrid Supply Chain Theory

Hybrid Supply Chain Theory (HSCT) integrates principles of lean and agile supply chain models to balance efficiency and responsiveness in dynamic business environments (Kummer et al., 2020). Lean strategies focus on reducing waste and cost, while agile strategies enhance flexibility and responsiveness to market changes. Blockchain enables this hybridity by providing real-time visibility, data integrity, and process automation across the supply chain (Saberi et al., 2019). For instance, in maritime logistics, blockchain-supported systems can track shipments, verify documents, and execute smart contracts, enhancing both lean efficiency and agile responsiveness (Kouhizadeh & Sarkis, 2018).

These capabilities are especially valuable in regions like Kenya, where logistics operations are often disrupted by manual bottlenecks and bureaucratic delays. However, the practical implementation of HSCT in Kenya is challenged by inadequate infrastructure and uneven technological readiness across supply chain actors. Vaezi et al. (2024) argue that the benefits of hybrid systems can only be realized when firms have access to robust digital tools, trained personnel, and supportive institutional frameworks.

In Kenya's port ecosystem, only a fraction of logistics firms mainly large multinationals is equipped to deploy blockchain solutions that support hybrid operations (Mageto & Luke, 2024). Moreover, smaller stakeholders often lack the financial and technical capacity to engage with these systems, leading to uneven adoption and limited impact. Therefore, while HSCT is conceptually aligned with blockchain's transformative potential, its practical success in Kenya depends on addressing foundational digital disparities and improving multi-actor coordination. This study adopts HSCT to evaluate how blockchain adoption contributes to both efficiency (lean outcomes) and flexibility (agile outcomes) within Kenya's maritime logistics sector. By applying HSCT as a theoretical lens, the research examines whether blockchain-enabled hybrid supply chains can enhance trade performance, despite existing infrastructural and institutional constraints.

2.2.4 Stakeholder Theory

Stakeholder Theory, originally articulated by Freeman (1984), posits that organizations must consider the interests of all relevant stakeholders not just shareholders to achieve sustainable and ethical success. In maritime logistics, stakeholders include port authorities, customs agencies, shipping firms, freight forwarders, regulatory bodies, and end users. Blockchain enhances the alignment of stakeholder interests by enabling transparent, auditable, and decentralized transaction records accessible to all participants (Samad et al., 2023).

This is particularly useful in Kenya, where trust deficits, corruption, and opaque customs practices hinder port performance. Transparent record-keeping through blockchain systems can reduce opportunities for manipulation, bribery, and dispute, thereby improving stakeholder coordination (Jimenez-Castillo et al., 2024). Nevertheless, Stakeholder Theory assumes that all actors have equal access to decision-making power and resources, an assumption that does not hold in many developing countries. In Kenya, the Kenya Ports Authority, government agencies, and large logistics firms often dominate policy discourse and infrastructure investments, while SMEs and local operators are marginalized (Kinyua & Mwikali, 2023).

These power asymmetries create challenges in implementing inclusive blockchain governance structures. Moreover, resistance from entrenched actors who benefit from opaque systems may stall progress toward transparency and decentralization (Murunga & Kimosop, 2022). Thus, while Stakeholder Theory offers a compelling rationale for inclusive and transparent blockchain implementation, its application in Kenya must account for institutional dominance and governance imbalances within the logistics ecosystem. This study employs Stakeholder Theory to assess how blockchain adoption influences coordination, trust, and value distribution among actors in Kenya's maritime logistics chain, while recognizing that institutional power imbalances may affect equitable adoption and governance outcomes.

2.3 Empirical Review

The empirical review shall include reviewing the relevant scholarly papers and appropriate related theories. In conclusion, research gaps that the study is expected to fill will be discussed.

2.3.1 Smart Contracts and Supply Chain Performance

Philipp, Prause, and Gerlitz (2019) conducted a case study on smart contract applications within the TradeLens blockchain platform in European ports. Their findings demonstrated a 35% reduction in customs verification times, highlighting the role of smart contracts in accelerating workflow automation and enhancing accountability in environments with robust legal and digital infrastructures. While their study provides strong empirical evidence of blockchain's operational efficiency, it assumes institutional maturity as a given, overlooking the regulatory fragility that characterizes many developing economies. Therefore, although the study successfully demonstrates blockchain's potential under ideal conditions, it does not address how such innovations behave in environments with fragmented governance or limited technological readiness.

In contrast, Gupta and Jain (2021) explored blockchain-enabled smart contracts within Indian seaports using structural equation modeling (SEM) with data from 102 logistics firms. Their findings echoed similar efficiency gains, reporting a nearly 30% reduction in payment errors and shipping delays. However, unlike the European setting, India's legal system already recognizes electronic contracting, which acted as an enabling factor. Their study, therefore, suggests that legal compatibility is a mediating variable that influences the relationship between smart contract adoption and logistics performance. Nonetheless, their reliance on SEM assumes linear relationships and may not fully capture the complex interplay between institutional support, organizational resistance, and technological trust—elements that are especially volatile in emerging economies such as Kenya.

Providing a more contextually relevant insight, Farah, Ahmed, and Mahmoud (2024) examined smart contract deployment at the Port of Mombasa using a mixed-methods approach. Their findings revealed a 40% reduction in manual verification and improvements in stakeholder trust, aligning with results from both European and Indian studies concerning efficiency and accountability. However, they also reported significant barriers stemming from Kenya's lack of legal recognition for smart contracts, poor regulatory clarity, and absence of standardized dispute resolution mechanisms. Unlike prior studies, their work explicitly demonstrates that the success of smart contracts in maritime logistics is not only a technological issue but also a governance challenge.

Across the three studies, a consistent theme emerges: smart contracts enhance efficiency, reduce fraud, and build trust across supply chain stakeholders. However, their impact is highly contingent on institutional environments. Studies in Europe and India showcase performance improvements under supportive regulatory structures, while the Kenyan case underscores limited scalability in weak legal environments. This suggests that smart contract performance outcomes are not universally replicable but mediated by legal, institutional, and infrastructural readiness.

Despite growing evidence, literature still lacks a comprehensive investigation into how legal enforceability, regulatory uncertainty, and stakeholder readiness shape the effectiveness of smart contracts within developing country contexts such as Kenya. The current study, therefore, seeks to bridge this gap by examining smart contract performance in Kenya's maritime logistics sector while integrating institutional readiness as a core moderating factor.

2.3.2 Distributed Ledger Technology and Supply Chain Performance

Estima, da Cunha, and Barata (2025) investigated DLT's role in improving traceability and transparency in maritime shipping through case studies in Brazil and Portugal. Their work showed a 32% reduction in verification delays due to enhanced synchronization among customs, shipping lines, and port authorities. The strength of this study lies in its real-world demonstration of DLT's operational value under legally mature conditions where digital documentation, such as e-bills of lading, is formally recognized. However, this context-specific success raises concerns regarding its external validity. Unlike Brazil and Portugal, Kenya's legal framework does not consistently support the legal enforceability of distributed documentation, suggesting that performance outcomes reported in their study may not be directly transferable without examining the influence of regulatory gaps.

Complementing this perspective, Miron, Mureșan, and Hulea (2024) conducted a comprehensive literature review of over 90 studies and pilot implementations, with a particular emphasis on Hyperledger Fabric as a platform for creating immutable and synchronized logistics records. Their synthesis highlights that DLT fosters inter-organizational trust by providing tamper-proof, auditable records accessible to authorized actors. However, their conclusions are largely conceptual and based predominantly on studies conducted in technologically advanced environments. Consequently, while their review confirms the theoretical suitability of DLT for maritime supply chains, it fails to address how infrastructural deficiencies, cost barriers, and organizational digital readiness in developing economies may constrain real-world implementation—thereby leaving a practical applicability gap that must be explored in emerging markets such as Kenya.

Addressing this gap, Njeri (2024) conducted an empirical investigation into the TradeLens pilot at the Port of Mombasa using interviews and survey data from logistics professionals. Her findings confirmed a 23% decrease in clearance time and a notable reduction in customs documentation duplication, demonstrating that DLT can indeed improve efficiency even in contexts with evolving digital capacities. Nonetheless, she observed that smaller logistics firms were excluded from full system integration due to limited access to digital infrastructure and incompatible legacy systems. Hence, the TradeLens case illustrates that while DLT has functional merit in Kenya, its effectiveness is contingent upon equitable digital participation and infrastructural digital inclusivity.

Across all three studies, DLT consistently emerges as a catalyst for improved traceability, synchronization, and transaction trust. However, operational success is strongly mediated by external conditions such as legal recognition of digital records, digital infrastructure capability, and ecosystem-wide stakeholder inclusion. Existing literature tends to privilege digitally mature and regulatory-stable environments, leaving a gap in understanding how DLT performs in hybrid ecosystems where some actors are technologically equipped while others are marginalized.

The current research, therefore, aims to evaluate DLT's effectiveness in Kenya's maritime logistics sector while specifically accounting for moderating factors such as regulatory uncertainty, infrastructural disparities, and stakeholder digital preparedness. This contextual focus is essential to developing a nuanced understanding of DLT's performance and scalability within emerging maritime ecosystems.

2.3.3 Consensus Mechanisms and Supply Chain Performance

From a traceability and transparency perspective, Estima, da Cunha, and Barata (2025) confirmed that DLT reduces verification delays by synchronizing stakeholder activities, consistent with the theory of process synchronization and trust-building in decentralized systems. However, their findings are situated within jurisdictions where digital documentation holds legal validity, which aligns with institutional theory, emphasizing that technology adoption thrives where regulatory structures are mature. The current study extends this theoretical lens to Kenya, where inconsistent recognition of e-bills of lading introduces institutional constraints.

Similarly, Miron, Mureșan, and Hulea (2024) highlighted the theoretical capability of DLT particularly Hyperledger Fabric—to establish tamper-proof, synchronized logistics records. Their findings support the technology acceptance model (TAM) and innovation diffusion theory, which posit that perceived usefulness and trustworthiness drive adoption. However, as their review is based on technologically advanced environments, the present study tests TAM assumptions within Kenya's resource-constrained maritime ecosystem.

Njeri's (2024) empirical results from the Port of Mombasa confirm that DLT deployment through TradeLens improves operational performance, reducing clearance times by 23%. This aligns with the transaction cost theory, which suggests that blockchain reduces redundancies and coordination costs across logistics actors. However, the exclusion of small-scale logistics providers due to system incompatibility signals an infrastructural and inclusivity challenge grounded in digital divide theory. The current study builds on this by assessing how infrastructural disparities influence DLT's full-scale effectiveness in Kenya.

Regarding consensus mechanisms, Ni and Irannezhad's (2024) comparison of PoA and PBFT demonstrated gains in processing speed and data consistency, grounded in the consensus trust model, which emphasizes algorithmic agreement as a substitute for centralized authority. Yet, their simulations assume robust ICT environments, making them only partially applicable to Kenyan ports. This gap justifies the current study's inquiry into how consensus mechanisms perform under infrastructural constraints. Miron et al. (2024) further underscored the importance of consensus protocols in fostering trust and preventing fraud in decentralized logistics, reinforcing the trustless coordination theory. However, their acknowledgment of limited empirical application in Sub-Saharan Africa points to a need for localized evaluation—precisely the focus of the current study.

Lastly, Chege and Otieno (2023) provide Kenya-specific insights showing that permissioned consensus mechanisms improve dispute resolution and enhance inter-agency collaboration. Their findings emphasize the significance of context-fit theory, which argues that technological effectiveness depends on alignment with local infrastructure and expertise levels. Their identification of barriers such as limited technical skills and poor internet connectivity informs the present study's focus on infrastructural readiness as a moderating factor in DLT performance in Kenyan maritime logistics.

The reviewed literature establishes a theoretical and empirical foundation for understanding how blockchain-based distributed ledger technology (DLT) enhances transparency, trust, and operational efficiency in maritime logistics. However, it also highlights variations in contextual readiness—technological, regulatory, and infrastructural—which shape implementation outcomes. This aligns with the current study's objective of examining the effectiveness of DLT in Kenya's maritime logistics environment, where infrastructural constraints and regulatory inconsistencies may influence system performance.

Across the reviewed literature, theories such as institutional theory, technology acceptance model, transaction cost theory, digital divide theory, consensus trust model, and context-fit theory collectively highlight that while DLT and consensus mechanisms offer efficiency and transparency benefits, their effectiveness is heavily influenced by contextual factors. The current study situates these theoretical insights within Kenya's maritime logistics system to evaluate how infrastructural capacity, regulatory maturity, and inclusivity affect the operational impact of distributed ledger technologies.

2.3.4 Cryptographic Security and Supply Chain Performance

Chang, Iakovou, and Shi (2020) examined cryptographic security in North American and European maritime supply chains using a mixed-method approach that combined cybersecurity audits with stakeholder interviews. Their study showed that blockchain encryption reduced document tampering by 38% and prevented fraud involving counterfeit bills of lading. The study demonstrates blockchain's potential to secure logistics data and enhance stakeholder trust. However, it also highlights that encryption alone cannot address infrastructural vulnerabilities, such as system downtime or connectivity gaps. For Kenya, this indicates that the effectiveness of cryptography depends not only on the technology itself but also on reliable ICT infrastructure, a central focus of the present study.

Pereira, Moura, and Barbosa (2021) extended the analysis to cryptographic applications in Spain and Brazil, combining interviews with IT managers and breach data analysis. They found that blockchain-based public-key cryptography reduced breaches by 35% and strengthened data confidentiality. Importantly, they emphasized that successful implementation requires skilled IT personnel a resource often scarce in emerging economies. This limitation is directly relevant to Kenya, where human resource capacity constraints could limit the full security benefits of blockchain systems.

Closer to the study context, Farah, Ahmed, and Mwangi (2024) evaluated cryptographic applications at the Port of Mombasa, focusing on customs and ICT integration. Their survey revealed a 60% reduction in unauthorized access and increased stakeholder confidence in digital systems. Nevertheless, recurring power outages and unstable internet connectivity hindered consistent system availability. This finding underscores the critical role of infrastructural reliability in realizing the security advantages of blockchain cryptography in Kenyan maritime logistics.
Across these studies, blockchain cryptography consistently enhances data integrity, reduces fraud, and improves stakeholder confidence. However, its effectiveness is moderated by infrastructural readiness and human resource capacity. Literature from advanced economies often assumes reliable digital infrastructure and skilled personnel, while empirical evidence from Kenya indicates that operational challenges, such as power outages and connectivity instability, can diminish cryptography's impact.

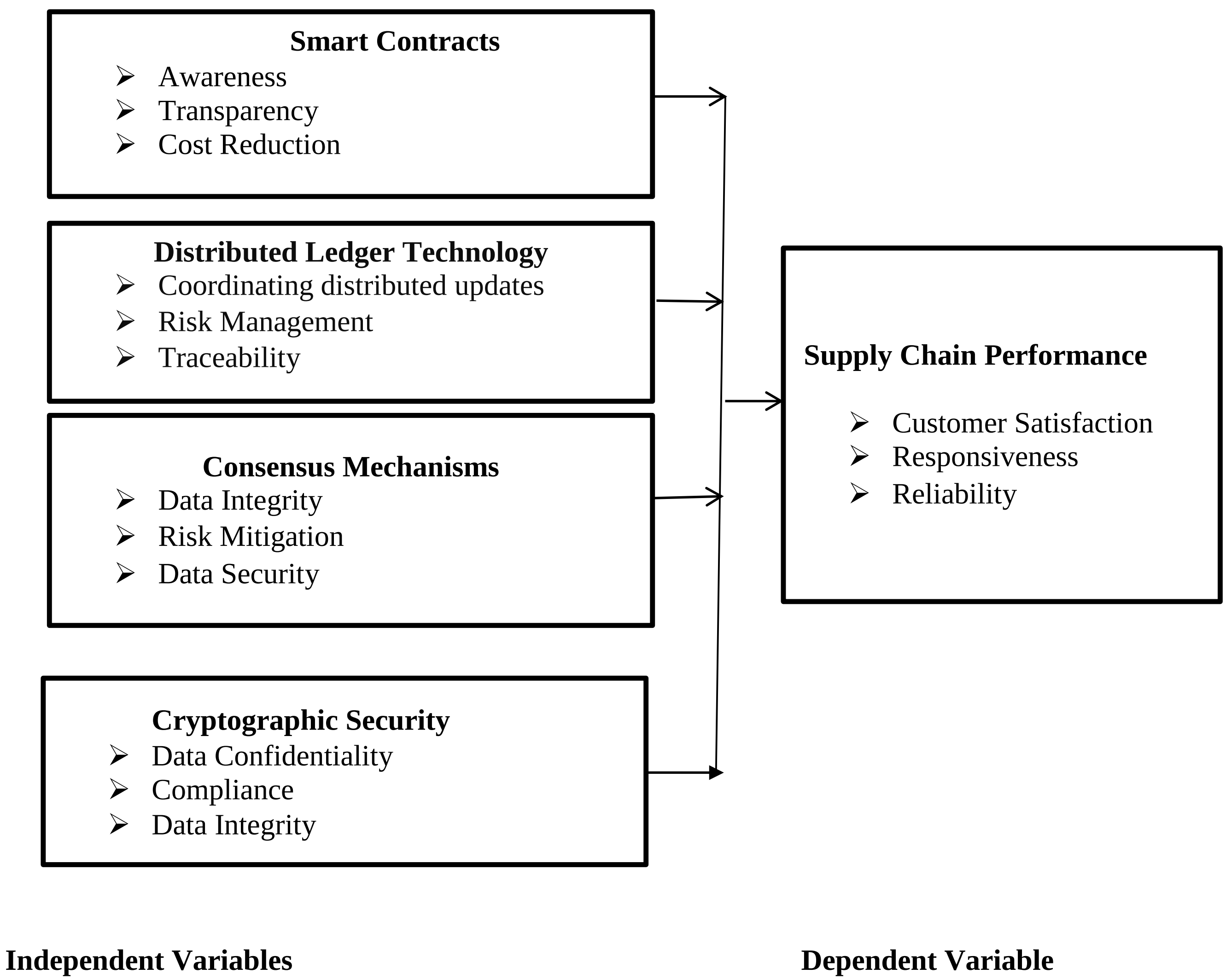
The current research addresses this gap by examining how cryptographic security interacts with infrastructural reliability and human capacity to influence blockchain performance in Kenya's maritime logistics sector. By integrating technological and contextual factors, the study aims to provide a realistic assessment of cryptography's operational benefits in an emerging economy.

2.4 Conceptual Framework

A conceptual framework offers a structured representation of the relationships between key study variables, guiding empirical inquiry and analysis (Creswell, 2014). It acts as a visual and theoretical map that connects the research problem, objectives, and hypotheses. In this study, the conceptual framework is derived from prior theoretical foundations including the Technology Acceptance Model (TAM), Diffusion of Innovation (DOI), Hybrid Supply Chain Theory (HSCT), and Stakeholder Theory as well as insights from recent empirical research on blockchain applications in maritime logistics. It captures how blockchain technology, through its core constructs, is hypothesized to influence the performance of Kenya's maritime logistics supply chains. The framework delineates the independent variables (smart contracts, DLT, consensus mechanisms, and cryptographic security) and their theorized effects on the dependent variable (supply chain performance), as operationalized through dimensions such as efficiency, transparency, reliability, and stakeholder trust.

FIGURE 1

Conceptual Framework



2.5 The summary and Research Gaps

The reviewed studies highlight that blockchain applications in the maritime logistics industry have generated measurable efficiency gains across different regions, particularly in Europe, Asia, and Latin America. However, these findings often emerge from settings with advanced digital infrastructure, supportive regulatory environments, and robust institutional frameworks. When transposed to Kenya, these assumptions face significant challenges, exposing both empirical and theoretical gaps. From an empirical perspective, several limitations emerge. First, while smart contracts have proven effective in reducing delays and improving trust in Indian and European ports (Philipp, Prause, & Gerlitz, 2019; Gupta & Jain, 2021), their enforceability in Kenya remains uncertain due to the absence of comprehensive legal recognition. This raises the researchable question: How do weak regulatory frameworks influence the operational effectiveness of blockchain-enabled smart contracts in Kenya's maritime logistics sector?

Second, distributed ledger technologies (DLT) such as TradeLens have demonstrated strong performance in Brazil, Portugal, and even in early Mombasa pilots (Estima, da Cunha, & Barata, 2025; Njeri, 2024). Yet, infrastructural limitations—including lack of digital integration among small-scale logistics providers—continue to undermine scalability. This invites inquiry into: To what extent does infrastructural disparity between large and small logistics firms affect the inclusivity and performance of blockchain-based DLT in Kenya? Third, consensus mechanisms have been shown to reduce disputes and increase data-sharing efficiency in technologically advanced contexts like China (Ni & Irannezhad, 2024). Kenyan evidence (Chege & Otieno, 2023), however, highlights barriers such as inconsistent internet connectivity and limited technical expertise. This contrast generates a pertinent research question: Which consensus protocols are most adaptable to infrastructural constraints in Kenya's maritime logistics ecosystem?

Fourth, cryptographic security has delivered strong fraud prevention results in North America and Europe (Chang, Iakovou, & Shi, 2020), but Kenyan studies (Farah, Ahmed, & Mwangi, 2024) suggest that persistent power outages and unstable internet connectivity undermine these security gains. Hence, the research must address: How do infrastructural instabilities mediate the effectiveness of blockchain's cryptographic security features in Kenyan maritime logistics? From a theoretical standpoint, the literature demonstrates an over-reliance on frameworks such as institutional theory, which often assumes that supportive regulatory environments facilitate technology adoption. While this may explain blockchain integration in Europe or India, it does not adequately account for Kenya's adoption lag despite demonstrated efficiency gains. Thus, a broader question emerges: Does institutional theory sufficiently explain blockchain adoption in contexts of regulatory and infrastructural fragility, or is there a need to integrate complementary perspectives such as the resource-based view (RBV) or socio-technical systems theory?

Together, these gaps signal the need for context-sensitive inquiry. By investigating the interplay between infrastructural constraints, legal ambiguity, and theoretical adequacy, the current study contributes to both the empirical literature on blockchain in maritime logistics and to the refinement of theories explaining technology adoption in emerging economies.

2.6 Operationalization of Study Variables

In this study, operationalization is critical in aligning the research variables with data collection instruments (specifically, the questionnaire) and subsequent statistical analysis. It provides the blueprint for measuring the impact of each blockchain construct on the dimensions of supply chain performance within Kenya's maritime logistics sector.

TABLE 1

Operationalization of Variables

Variable	Variable Type	Indicator	Data Analysis
Smart Contracts	Independent Variable	➢ Awareness ➢ Transparency ➢ Cost Reduction	Regression Analysis
Distributed Ledger Technology	Independent Variable	➢ Coordinating distributed updates ➢ Risk Management ➢ Traceability	Regression Analysis
Consensus Mechanisms	Independent Variable	➢ Data Integrity ➢ Risk Mitigation ➢ Data Security	Regression Analysis
Cryptographic Security	Independent Variable	➢ Data Confidentiality ➢ Compliance ➢ Data Integrity	Regression Analysis
Supply Chain Performance	Dependent Variable	➢ Customer Satisfaction ➢ Responsiveness ➢ Reliability	Regression Analysis

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is described as a way to systematically solve the research problem (Baker, 2016). This chapter discussed the methods and techniques employed in carrying out the research to attain the stated objectives of the study. It deliberated on the research design, target population, sample size and sampling techniques, data collection procedures, data analysis methods, and ethical considerations.

3.2 Research Design

Research design was defined as an overall plan for the method used to collect and analyze the data of a research study (Bryman & Bell, 2015). This study adopted a descriptive research design to examine blockchain adoption and its impact on supply chain performance in Kenya's maritime logistics industry. The design captured actual practices of key blockchain components—smart contracts, distributed ledger technology, consensus mechanisms, and cryptographic security—among stakeholders such as customs officers, IT managers, and freight managers. It focused on the Port of Mombasa and Nairobi logistics hubs, assessing how blockchain enhanced efficiency, transparency, security, and trust. The approach provided both practical industry insights and theoretical contributions by evaluating frameworks such as institutional theory in explaining Kenya's adoption patterns.

3.3 Target Population

A target population in research referred to the complete set of elements i.e, individuals, firms, or institutions that possessed attributes relevant to the research problem (Willie, 2024). In this study, which sought to assess the influence of blockchain technology on supply chain performance in Kenya's maritime logistics sector, the target population consisted of maritime logistics companies involved in port operations, shipping, freight forwarding, customs clearance, and trade digitization, primarily at the Port of Mombasa. According to the Kenya Maritime Authority (2025), there were 37 licensed maritime logistics companies engaged in trade facilitation, logistics management, regulatory enforcement, and technology integration at the Port of Mombasa. The study focused on Supply Chain/Logistics Managers, IT Managers, Operations/Freight Managers, and Customs & Compliance Officers from each firm, giving a total of 148 respondents.

TABLE 2

Target Population

Category of Respondents	**Respondents per Institution**	**Percentage**
Supply Chain / Logistics Managers	28	18.9
IT Managers	34	23.0
Operations / Freight Managers	37	25.0
Customs & Compliance Officers	49	33.1
Total	**148**	**100**

3.4 Sample and Sampling Technique

The study conducted a census of 148 targeted professionals across four strata—Customs & Compliance Officers (49), Operations/Freight Managers (37), IT Managers (34), and Supply Chain/Logistics Managers (28)—but explicitly recognized that there was no prior evidence that every targeted individual would participate. Access to the full list proceeded in four steps. First, a sampling frame was constructed from official organizational rosters and duty lists maintained by relevant port and logistics entities (e.g., customs and border agencies, port authority departments, terminal operators, shipping lines/agents, freight forwarders, and port community system administrators). Each organization's HR/administration unit nominated named contacts who met the eligibility criteria (current role in the category and ≥ six months tenure).

Second, the research office issued institutional access letters and data-protection undertakings to gatekeepers, requesting named email addresses and phone contacts. Third, gatekeepers circulated a pre-notification to the nominees, after which the researcher sent individualized invitations containing a study information sheet, consent form, a unique survey link, and the option to schedule 15–20 minutes to complete a secure online questionnaire. Fourth, for on-site staff, data collection included in-person sessions at agreed locations (port offices and Nairobi logistics hubs), with paper/QR-code options provided for shifts that had limited computer access.

3.5 Data Collection Instrument

The study made use of primary data. According to Ghauri and Gronhaug (2018), primary data is data that is collected by a researcher from first-hand sources. The research utilized structured closed-ended questionnaires as the primary data collection instrument, supplemented by semi-structured interviews. According to Saunders, Lewis, and Thornhill (2019), structured questionnaires enhanced comparability and allowed for quantitative analysis across diverse groups. The questionnaire was structured into four parts: Section A covered demographic data; Section B focused on blockchain components; Section C explored optional motivators for blockchain adoption; and Section D addressed supply chain performance indicators.

3.6 Pilot Test

A pilot study was conducted prior to the main data collection exercise to assess the clarity, relevance, and reliability of the research instruments. According to Kothari (2014), conducting a pilot involved a few members of the target population being given the questionnaires with the intention of pre-testing the questions. Approximately 10% of the intended sample size, equivalent to 15 participants, was drawn from relevant logistics and regulatory institutions, such as shipping firms, customs offices, and IT solution providers. These pilot participants were excluded from the final data collection to avoid bias. According to Teresi et al. (2022), conducting pilot tests ensured that questionnaires were comprehensible, context-appropriate, and logically sequenced, thereby reducing the chances of ambiguity or misinterpretation during the main study.

3.6.1 Validity of Research Instrument

Validity refers to the extent to which the research instrument measured what it intended to measure. To ensure content, construct, and face validity, a multi-tiered approach was adopted. First, the questionnaire items were derived from an extensive review of literature on blockchain technology and supply chain performance in both global and Kenyan contexts (Chang, Iakovou, & Shi, 2020; Farah, Ahmed, & Mwangi, 2024). Second, expert reviews were conducted with logistics professionals, blockchain system developers, and university faculty members from business and IT departments to refine the instrument. Face validity was ensured by designing concise, unambiguous, and context-relevant items. Construct validity was achieved by ensuring that each major concept, such as transparency or smart contracts, was represented through multiple, thematically linked items in the questionnaire. This comprehensive approach guaranteed that the questionnaire adequately captured the theoretical constructs and empirical dimensions relevant to Kenya's maritime logistics environment (Ahmed & Ishtiaq, 2021; Lim, 2024).

3.6.2 Reliability of Research Instrument

Reliability refer to the consistency and stability of an instrument in yielding similar results under consistent conditions. To evaluate internal reliability, a Cronbach's alpha test was employed on data obtained during the pilot study. A Cronbach's alpha value of 0.70 or higher was considered acceptable, indicating that the items within each construct had high internal consistency (Sukmawati, 2023). According to Chetwynd (2022), Cronbach's alpha remained the most widely adopted metric for measuring reliability in behavioral and social sciences. Additionally, standardized Likert scales and question formats were used to minimize respondent variability, while a structured interview guide ensured consistency across interviews.

3.7 Data Collection Procedure

Ghauri and Gronhaug (2018) defined data collection as the precise, systematic gathering of information relevant to the research sub-problems, using methods such as interviews, participant observations, focus group discussions, narratives, and case histories. Mugenda and Mugenda (2012) emphasized the need for respondents' assistance and collaboration in order to ensure that the data obtained was accurate. To start with, the researcher obtained an official research authorization letter from KCA University, which was used to apply for a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI). Upon receiving the research permit, the researcher formally requested participation from the relevant maritime logistics stakeholders through organizational contact points such as human resources or departmental heads.

Questionnaires were distributed using a drop-and-pick-later approach to offices located in Mombasa, including customs clearance units, port operations departments, freight forwarding firms, and blockchain solution providers. For respondents operating remotely or from satellite offices, the researcher shared an electronic version of the questionnaire via Google Forms and SurveyMonkey. A personalized cover letter accompanied every questionnaire, clearly explaining the study's purpose, ensuring confidentiality, and seeking voluntary informed consent in accordance with ethical standards. This approach guaranteed flexibility for participants and broadened accessibility across different locations and organizational roles.

3.8 Data Analysis and Presentation

Data analysis relied on both descriptive and inferential statistics to generate meaningful insights. Descriptive statistics were applied to summarize and present the characteristics of the collected data in a clear and concise manner. This included the use of frequencies, percentages, means, and standard deviations to describe demographic information, blockchain adoption levels, and supply chain performance indicators. Tables, charts, and graphs were used to present these summaries for ease of interpretation. Inferential statistics were then employed to test relationships and draw conclusions beyond the immediate data. Spearman correlation was applied to examine the strength and direction of associations between blockchain constructs and supply chain performance.

The Chi-square test of independence was used to analyze categorical relationships, while multiple linear regression served as the core model for assessing the predictive contribution of blockchain constructs—namely smart contracts, distributed ledger technology, consensus mechanisms, and cryptographic security—on supply chain performance. All inferential analyses were conducted at a 95% confidence level to ensure reliability and validity of the results. The model was expressed as:

$$\mathbf{Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \varepsilon}$$

Where:

Y= Supply Chain Performance

$\boldsymbol{\beta_0}$ = Intercept (constant)

$\mathbf{X_1}$ = Smart Contracts

$\mathbf{X_2}$ = Distributed Ledger Technology

$\mathbf{X_3}$ = Consensus Mechanisms

$\mathbf{X_4}$ = Cryptographic Security

$\boldsymbol{\varepsilon}$ = Error term

$\boldsymbol{\beta_1}$–$\boldsymbol{\beta_4}$ = Regression coefficients representing the effect of each independent variable

The significance level (α) was set at 0.05, in accordance with conventional practices in logistics and technology adoption research (Bryman & Bell, 2015). This supported hypothesis testing and enabled the researcher to assess the statistical significance and predictive strength of the blockchain constructs.

3.9 Diagnostic Tests

To ensure the accuracy, stability, and appropriateness of the regression model employed in the study, several diagnostic tests were carried out. These diagnostic checks served to assess whether the collected data satisfied key statistical assumptions necessary for valid regression analysis. Performing these tests enhanced the dependability of the model and improved the interpretive value of the research findings, as emphasized by Bayman and Dexter (2021).

3.9.1 Normality Test

A normality test was conducted to determine whether the distribution of the data approximated a normal curve, which was a critical assumption in multiple linear regression. The Shapiro-Wilk test was used to assess the statistical distribution of responses. According to Alita et al. (2021), a p-value greater than 0.05 in these tests indicated a normal distribution, supporting the retention of the null hypothesis. Additionally, histogram plots with superimposed normal curves were used for visual assessment of the distribution. All variables were tested for the normality assumption.

3.9.2 Multicollinearity Test

Multicollinearity among independent variables was evaluated to ensure that no strong correlation existed between them, which could distort coefficient estimates. The study used the Variance Inflation Factor (VIF) and Tolerance Value (TV) to assess multicollinearity. Following the guidelines of Bayman and Dexter (2021), VIF values above 10 and tolerance values below 0.1 signaled problematic multicollinearity. If detected, remedial measures such as variable elimination or transformation were considered.

3.10 Ethical Considerations

Adherence to ethical principles was paramount in conducting and reporting this research, particularly as it involved the participation of human respondents from Kenya's maritime logistics sector. The study was guided by academic research ethics that ensured respect, autonomy, and protection of all participants while maintaining the scientific credibility of the results. Special attention was given to obtaining necessary approvals, securing informed consent, and protecting participant data. Prior to commencing data collection, the researcher sought formal ethical clearance from KCA University's Institutional Review Board (IRB) and obtained a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI). Once authorized, the researcher proceeded to engage target organizations and participants in line with institutional protocols and professional guidelines.

Participation in the study was entirely voluntary, and each respondent was informed about the objectives of the research, their right to withdraw at any time, and the confidentiality of their responses. Informed consent was sought in writing before any data were collected. As part of ethical compliance, all information was treated with strict confidentiality and anonymity. No identifiable personal data, including names or organizational affiliations, were published or shared without explicit permission. To ensure data protection, digital records such as filled questionnaires and interview transcripts were stored securely in password-protected systems, and physical materials were locked in secure cabinets. Data were retained only for as long as required for academic purposes and then securely disposed of. This was in accordance with the Kenyan Data Protection Act (2019) and international data ethics principles.

Finally, the entire research process, from instrument design to analysis and reporting, was conducted objectively and impartially. Researcher bias was minimized, and care was taken to ensure that all findings were presented truthfully based on collected data. These measures collectively reinforced the integrity, trustworthiness, and ethical standards of the research.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Introduction

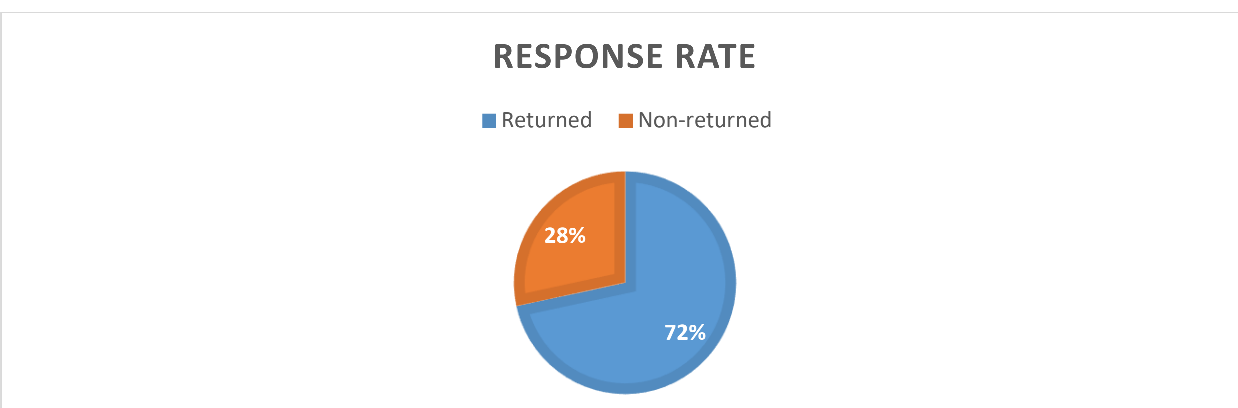
This chapter presents the findings of the study by first assessing the reliability of the data and then summarizing the key descriptive statistics. The study aimed to investigate the effect of blockchain technology on supply chain performance in the maritime logistics industry in Kenya. The results are organized in line with the study objectives and are presented using both descriptive and inferential statistics to provide a clear understanding of the relationships between the variables.

4.2 Response Rate

A total of 148 questionnaires were disseminated to the targeted respondents by the researcher with the assistance of research assistants.

FIGURE 2

Response Rate



Out of these, 106 were duly completed and returned, while the remaining 42 were not received back. This translates to a response rate of 71.6%, which is considered adequate for analysis and reporting according to Mugenda and Mugenda (2003), who recommend a response rate of 50% as sufficient, 60% as good, and 70% and above as very good. The response rate results are presented in figure 4.1 below.

4.3 Pilot Study Results

4.3.1 Reliability Test Results

TABLE 3

Reliability of Research Instrument

Variable	**Cronbach's Alpha**	**Number of Items**
Smart Contracts	.709	6
Distributed Ledger Technology	.745	6
Consensus Mechanisms	.721	6
Cryptographic Security	.759	6
Supply Chain Performance	.802	6

The Cronbach's alpha coefficient for the five constructs—Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, Cryptographic Security, and Supply Chain Performance—yielded values of 0.709, 0.745, 0.721, 0.759, and 0.802 respectively. Each of these coefficients is above the acceptable threshold of 0.7, as suggested by Bryman (2008). It was therefore concluded that the research instrument was reliable and suitable for further analysis.

4.3.2 Validity Test Results

Content validity was used to ascertain the validity of research instrument. Content validity refers to the extent to which a measurement instrument adequately represents all facets of the construct it intends to measure. It ensures that the items used in the instrument are both relevant and comprehensive in covering the conceptual domain of each variable (Zikmund et al., 2010). In this study, content validity was established through a structured review by three subject-matter experts with relevant expertise in blockchain technology, supply chain management, and academic research methodology. The experts were requested to assess each item in the questionnaire for clarity, relevance, and comprehensiveness in relation to the five core constructs: Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, Cryptographic Security, and Supply Chain Performance.

Based on the experts' evaluations: Minor revisions were made to the phrasing of certain items to improve clarity and eliminate ambiguity. Redundant items were removed to enhance the overall coherence and focus of the instrument. Terminological adjustments were implemented to ensure alignment with both academic literature and industry terminology in the fields under investigation. The expert feedback confirmed that the items were appropriate, well-structured, and theoretically aligned with their respective constructs. As such, the instrument was considered to demonstrate adequate content validity.

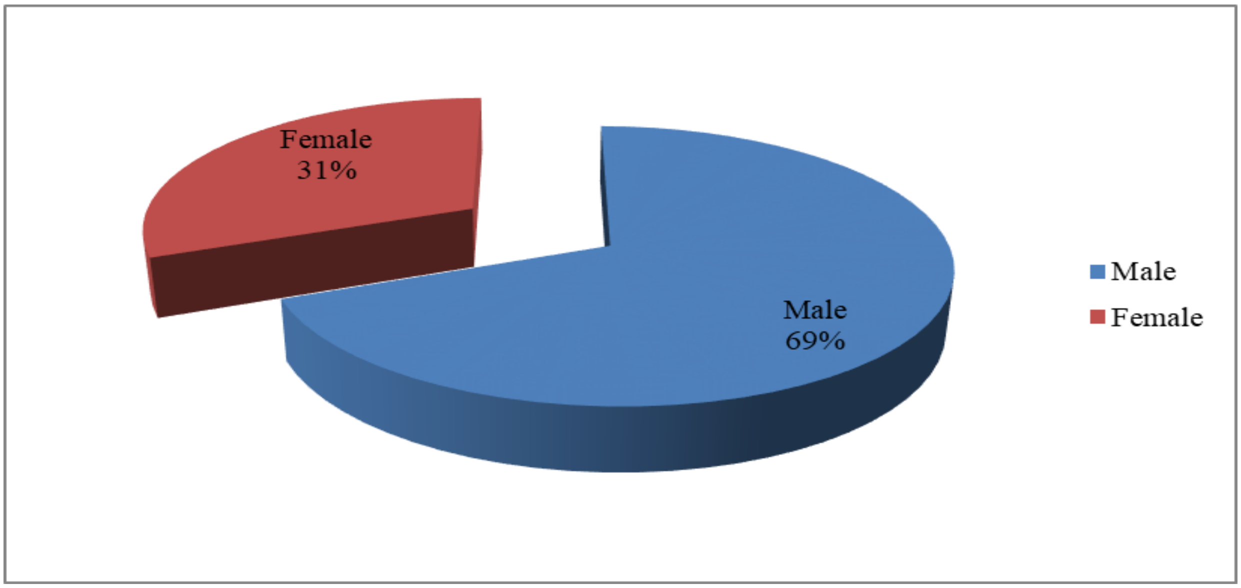
These findings are consistent with validation practices reported in previous research. For instance, Queiroz and Wamba (2019) emphasized the role of expert judgment in validating instruments measuring blockchain adoption and impact. Similarly, Tapscott and Tapscott (2017) highlighted the importance of ensuring terminological clarity and conceptual coverage when developing instruments related to blockchain applications. The reliance on expert review for content validation is also consistent with methodological recommendations by Zikmund et al. (2010) and Sekaran and Bougie (2016), who advocate for systematic expert input during the instrument development phase.

4.4 Demographic Analysis

4.4.1 Gender Distribution of the Respondents

FIGURE 3

Gender of Respondent



The respondents were required to indicate their gender, and the results are presented in Figure 4.2. Out of the 106 participants, 69% were male, while 31% were female. This demonstrates that the majority of respondents were male. Nevertheless, there has been a noticeable increase in women's participation in both formal and informal employment sectors in recent years. The Constitution of Kenya (2010), under Articles 97 and 98, mandates compliance with the two-thirds gender rule, which stipulates that no single gender should exceed two-thirds of the total representation. To this effect, policies and institutional frameworks have been put in place to promote gender inclusivity and ensure equitable representation across different sectors. This analysis determines the gender balance of the respondents, helping to evaluate inclusivity and understand whether trade facilitation perceptions may reflect gender-related participation trends within the Malaba OSBP environment.

4.4.2 Education level

FIGURE

4 Education level

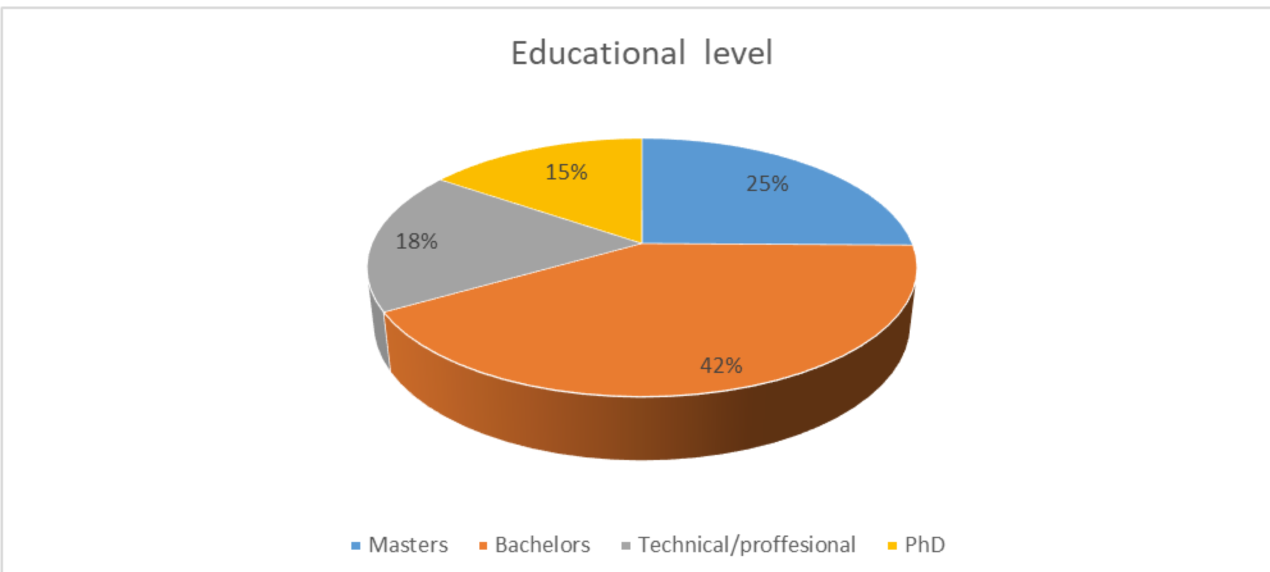


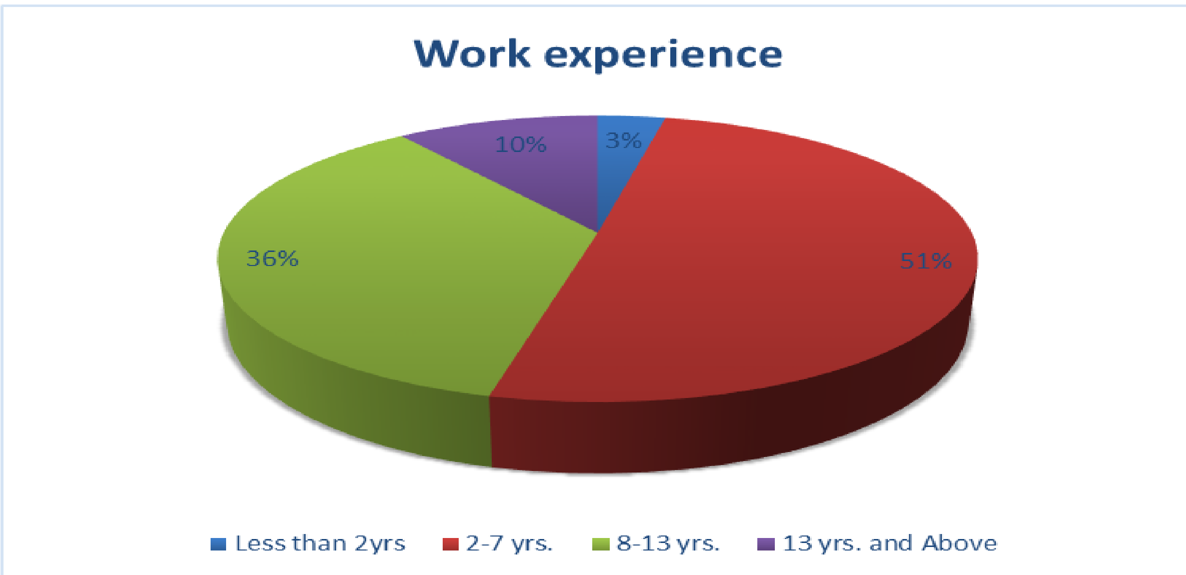
Figure 4.2 presents the distribution of respondents by their highest level of education. Out of the 106 participants, the majority (42%) reported having attained a bachelor's degree. A further 25% indicated that they had completed a master's degree, while 18% specified that their highest level of education was in a technical or professional field. Lastly, 15% of the respondents reported holding a PhD. These findings suggest that most participants had attained formal education, equipping them with the ability to independently complete the questionnaires without the need for

assistance or interpretation. Assessing respondents' highest level of education provides insight into their level of understanding and capacity to provide informed responses regarding trade facilitation processes and systems.

4.4.4 Work Experience

FIGURE 5

Work Experience



The majority of respondents (51%) have 2–7 years of experience, indicating a strong mid-level presence—possibly early-career professionals building expertise. The next largest group, 36%, falls into the 8–13 years range, suggesting a solid base of experienced individuals. Only 10% reported having 13 years or more, and just 3% have less than 2 years, showing minimal participation from either highly experienced or very new individuals. Evaluating the respondents' years of experience helps to determine their level of exposure to border operations and trade facilitation mechanisms, thereby supporting the credibility and depth of their perspectives.

4.5 Descriptive Statistics

4.5.1 Supply Chain Performance

TABLE 4

Supply Chain Performance

Supply Chain Performance	**N**	**Mean**	**Std. Dev.**
Our maritime logistics operations are executed efficiently and with minimal delays.	106	2.4434	1.01494
Customers are generally satisfied with delivery times and communication.	106	3.8962	.88295
We have real-time visibility into shipment status and supply chain operations.	106	3.3962	.95298
The use of technology has reduced manual interventions and administrative costs.	106	3.6321	.72145
Turnaround time at ports has improved in the past 12 months.	106	3.4528	1.00600
Valid N (listwise)	106		

According to the descriptive statistics, respondents reported a low average score of 2.4434 (SD = 1.01494) regarding the efficiency of maritime logistics operations, suggesting that port and shipping processes are not perceived to operate with minimal delays. These findings align with Chege and Otieno (2023), who similarly reported that inefficiencies in customs clearance and port congestion continue to hinder maritime logistics in Kenya. In contrast, Estima et al. (2025), in their study of Brazil and Portugal, found that distributed ledger technologies had reduced verification delays by over 30%, highlighting the disparity between technologically mature and emerging port systems.

Conversely, customer satisfaction with delivery times and communication scored relatively high, with a mean of 3.8962 (SD = 0.88295). This indicates that end-users of logistics services perceive communication and timeliness positively, despite the internal inefficiencies in port operations. These findings are in line with Farah et al. (2024), who observed improved trust and satisfaction among stakeholders at the Port of Mombasa following the implementation of digital contract systems. However, Gupta and Jain (2021) found that customer satisfaction was closely tied to operational efficiency in Indian ports, implying that perceived satisfaction in Kenya may be influenced by other factors, such as improved tracking or customer service communication, rather than actual process efficiency.

Respondents also moderately agreed that they had real-time visibility into shipment status and operations, as reflected by a mean score of 3.3962 (SD = 0.95298). This supports findings by Miron et al. (2024), who argued that visibility is one of the most immediate benefits of blockchain adoption in supply chain networks. However, the moderate level of agreement in the present study suggests partial or uneven implementation, which is echoed by Njeri (2024), who noted that while systems like TradeLens had been introduced at the Port of Mombasa, many small-scale logistics providers lacked integration capabilities.

Technology use was also perceived as beneficial, with respondents agreeing that it reduced manual interventions and administrative costs (mean = 3.6321, SD = 0.72145). The low standard deviation indicates a strong consensus among respondents. These results reinforce the work of

Pereira et al. (2021), who found that cryptographic and digital ledger tools significantly reduced bureaucratic overhead in Brazil and Spain. Similarly, Chang et al. (2020) reported a 38% reduction in document tampering and fraud, further validating the role of technology in enhancing administrative efficiency.

Finally, the study found that turnaround times at ports have improved over the past year, as indicated by a mean of 3.4528 (SD = 1.00600). This is consistent with findings from Farah et al. (2024), who documented improved operational timing at the Port of Mombasa due to smart contract implementation. However, Ni and Irannezhad (2024) noted that significant reductions in turnaround time in Chinese ports were dependent on advanced consensus mechanisms and ICT infrastructure, conditions that are only partially present in the Kenyan context.

4.5.2 Smart Contracts and Supply Chain Performance

TABLE 5

Mart Contracts

Smart Contracts	**N**	**Mean**	**Std. Dev.**
I am familiar with the concept of smart contracts and how they are applied in logistics.	106	2.6415	1.23588
Using smart contracts improves cargo tracking and inventory visibility.	106	3.5849	1.03158
Smart contracts improve trust among supply chain partners by making transactions transparent.	106	3.5849	.89302
Implementing smart contracts can reduce operational costs in the long term.	106	3.7170	.85918
Smart contracts lead to better coordination and real-time decision-making across the supply chain.	106	3.1132	1.08952
Valid N (listwise)	106		

According to the descriptive statistics, respondents reported a relatively low mean score of 2.6415 (SD = 1.23588) concerning their familiarity with the concept of smart contracts and their application in logistics. The high standard deviation suggests a wide variation in awareness, indicating that while some respondents were well-informed, others had limited or no understanding of the concept. This finding is consistent with Farah et al. (2024), who noted that limited blockchain literacy among Kenyan logistics professionals remains a major barrier to adoption. Similarly, Chege and Otieno (2023) observed that while awareness of blockchain was growing, technical understanding of smart contract functionality remained concentrated among larger, tech-enabled firms.

In contrast, the use of smart contracts for cargo tracking and inventory visibility received a mean score of 3.5849 (SD = 1.03158). This suggests general agreement that smart contracts can enhance supply chain visibility, although the moderate standard deviation reflects some variation in respondent perceptions. These findings support those of Gupta and Jain (2021), who reported that Indian logistics firms experienced significant visibility improvements due to automated contract execution. However, Miron et al. (2024) caution that such benefits are contingent on interoperability with existing enterprise systems, which may still be limited in emerging markets like Kenya.

Respondents also agreed that smart contracts enhance trust among supply chain partners by providing transparent and immutable transaction records, again with a mean score of 3.5849, but with a lower standard deviation (SD = 0.89302), indicating greater consistency in responses. This aligns with the conclusions of Ni and Irannezhad (2024), who found that trust in decentralized port operations improved significantly when blockchain systems were deployed using smart contracts. Tapscott and Tapscott (2017) similarly argue that blockchain's transparency mechanisms play a foundational role in creating a trust-based supply chain environment.

The perception that smart contracts reduce operational costs in the long term was supported by a mean of 3.7170 (SD = 0.85918). The low standard deviation indicates a strong consensus among respondents. This finding corroborates Pereira et al. (2021), who found that automation through smart contracts reduced administrative overhead and eliminated many transaction inefficiencies in Brazil and Spain. However, Philipp et al. (2019) cautioned that cost savings are highly dependent on legal enforceability and digital infrastructure—areas where many developing economies still lag behind.

Lastly, respondents somewhat agreed that smart contracts improve coordination and real-time decision-making across the supply chain, as shown by a mean of 3.1132 (SD = 1.08952). The higher standard deviation indicates mixed perceptions, which may reflect uneven implementation or varied organizational capacity to leverage real-time data. This is echoed by Njeri (2024), who observed that while systems like TradeLens introduced real-time data-sharing capabilities at the Port of Mombasa, smaller firms lacked the infrastructure or training to take full advantage of them.

4.5.3 Distributed Ledger Technology and Organizational Performance

TABLE 6

Distributed Ledger Technology

Distributed Ledger Technology	**N**	**Mean**	**Std. Dev.**
DLT improves visibility and traceability across the maritime supply chain.	106	3.0943	1.29856
DLT can streamline customs procedures and documentation in maritime logistics.	106	2.7736	1.03540
DLT enhances risk management by providing immutable and verifiable transaction records.	106	3.6698	.77732
The use of DLT can prevent fraud and increase accountability in maritime logistics.	106	3.1415	1.01830
DLT reduces time delays and increases the overall responsiveness of the supply chain.	106	3.3585	1.18875
Valid N (listwise)	106		

The descriptive statistics show that respondents gave a mean score of 3.0943 (SD = 1.29856) for the statement that DLT improves visibility and traceability across the maritime supply chain. The mean suggests moderate agreement, while the relatively high standard deviation reflects divergent perceptions, indicating that while some respondents recognized DLT's potential in enhancing traceability, others remained skeptical. This aligns with the findings of Estima et al. (2025), who demonstrated that blockchain improved traceability by 32% in Brazil and Portugal's port logistics. However, their study also emphasized that such improvements were closely tied to strong digital infrastructure and regulatory backing conditions that may be lacking in Kenya, which could explain the variation observed in the current data.

Regarding the role of DLT in streamlining customs procedures and documentation, the results show a lower mean score of 2.7736 (SD = 1.03540), indicating limited agreement among respondents. The moderate spread suggests inconsistent views, potentially due to uneven implementation or lack of integration with existing customs systems. This finding resonates with Njeri (2024), who noted that while DLT platforms like TradeLens had reduced clearance delays at the Port of Mombasa, fragmented ICT systems among stakeholders limited full-scale adoption and interoperability. In contrast, Gupta and Jain (2021) found higher agreement levels in Indian ports, where e-documentation is legally supported and widely used, suggesting that regulatory maturity is a key determinant of DLT effectiveness in customs.

A stronger consensus emerged regarding the use of DLT for risk management, particularly in providing immutable and verifiable transaction records, with a mean score of 3.6698 (SD = 0.77732). The low standard deviation indicates consistent agreement among respondents. These findings are supported by Miron et al. (2024), who emphasized the role of blockchain in enhancing auditability and reducing operational risks in decentralized logistics systems. Similarly, Chang et al. (2020) reported that encrypted blockchain records significantly reduced fraudulent claims and unauthorized access in transatlantic shipping networks, reinforcing the current study's findings on the value of DLT in risk mitigation.

The study also examined the perception that DLT can prevent fraud and increase accountability within maritime logistics, which received a moderate mean score of 3.1415 (SD = 1.01830). The variation in responses suggests that while many participants recognize the anti-fraud capabilities of DLT, others remain uncertain—possibly due to limited implementation experience or insufficient system trust. This is consistent with the mixed findings of Pereira et al. (2021), who noted that while blockchain improved data integrity in Spain and Brazil, its actual impact depended on the technical capacity of port authorities and logistics operators.

Finally, the proposition that DLT reduces time delays and improves the overall responsiveness of the supply chain received a mean of 3.3585 (SD = 1.18875). This indicates general agreement, but with noticeable variability in responses. The findings mirror those of Farah et al. (2024), who observed moderate improvements in responsiveness at the Port of Mombasa following the partial adoption of blockchain tools. However, as noted by Chege and Otieno (2023), such outcomes are often influenced by infrastructural bottlenecks and inconsistent digital adoption, which may explain the variability in perceptions captured in the current data.

4.5.4 Consensus Mechanisms and Organizational Performance

TABLE 7

Consensus Mechanisms

Consensus Mechanisms	**N**	**Mean**	**Std. Dev.**
Consensus mechanisms help ensure data accuracy and trust in maritime logistics records.	106	3.0000	1.27988
Efficient consensus mechanisms contribute to faster transaction validation and processing in supply chains.	106	3.4623	.97760
Distributed consensus mechanisms reduce the risk of fraud in maritime logistics operations.	106	3.6321	.78468
Consensus-based validation minimizes the chances of disputes over shipping and transaction records.	106	2.7642	1.14269
Using decentralized consensus increases confidence in supply chain data sharing across stakeholders.	106	3.1509	1.23282
Valid N (listwise)	106		

The descriptive statistics indicate that consensus mechanisms were rated at a mean score of 3.0000 (SD = 1.27988) for ensuring data accuracy and trust in maritime logistics records. This neutral rating, coupled with a relatively high standard deviation, suggests a wide divergence of opinion among respondents. Some likely recognized the value of consensus in securing shared records, while others may have been uncertain about the technology's reliability or its applicability within their specific operational contexts. These findings align with Miron et al. (2024), who found that trust in consensus-based validation systems was highly contingent on user familiarity and ICT maturity, particularly in developing countries.

In contrast, efficient transaction validation and processing through consensus mechanisms received a higher level of support, with a mean of 3.4623 (SD = 0.97760). The narrower spread of responses indicates greater agreement among respondents, reinforcing the perception that consensus protocols can streamline operations. This is supported by Ni and Irannezhad (2024), whose simulation-based study in China demonstrated that Practical Byzantine Fault Tolerance (PBFT) and Proof-of-Authority (PoA) protocols significantly improved processing speed and reliability in port-based transactions. However, the current findings also hint that such efficiencies may not be uniformly recognized in Kenya, potentially due to limited implementation or knowledge gaps.

A stronger level of confidence was expressed regarding the role of distributed consensus in reducing fraud risks, as reflected by a mean score of 3.6321 (SD = 0.78468). The low standard deviation reveals a high degree of consensus, suggesting that stakeholders widely recognize the anti-fraud potential of consensus algorithms. This mirrors findings from Chang et al. (2020), who observed that blockchain-enabled consensus mechanisms dramatically reduced fraudulent documentation in North American and European maritime supply chains. Similarly, Pereira et al. (2021) noted that permissioned consensus protocols enhanced the integrity and non-repudiation of shipping data in Spain and Brazil.

On the other hand, the notion that consensus-based validation minimizes disputes over shipping and transaction records received a lower mean of 2.7642 (SD = 1.14269), suggesting weaker agreement and greater variation in responses. This could imply that while consensus algorithms theoretically reduce disputes, the lack of real-world adoption or legal recognition in the Kenyan maritime context limits perceived effectiveness. These findings echo Philipp et al. (2019), who warned that legal enforceability of digitally validated records remains a key barrier to realizing the full benefits of consensus in jurisdictions with underdeveloped legal frameworks.

Lastly, the use of decentralized consensus to increase stakeholder confidence in data sharing received a moderate mean score of 3.1509 (SD = 1.23282). Although there is general agreement on its usefulness, the high standard deviation highlights differing levels of conviction and trust in decentralized models. This observation aligns with Chege and Otieno (2023), who found that while Kenyan logistics professionals recognize the theoretical advantages of decentralization, concerns persist around data governance, system compatibility, and institutional readiness.

4.5.5 Cryptographic Security and Organizational Performance

TABLE 8

Cryptographic Security

Cryptographic Security	N	Mean	Std. Dev.
I understand how cryptographic tools such as encryption and digital signatures are used in securing supply chain data.	106	3.1321	1.28044
Cryptographic techniques improve transparency by making tampering with data easily detectable.	106	3.6132	1.10040
Cryptographic methods ensure the confidentiality of shipping and customs data.	106	3.7736	.89744
The use of cryptographic security builds trust between trading partners and logistics providers.	106	3.4811	.90744
Cryptographic security helps prevent unauthorized access to shipping and inventory systems.	106	2.8491	1.24818

The analysis of responses reveals that participants reported a mean score of 3.1321 (SD = 1.28044) concerning their understanding of how cryptographic tools—such as encryption and digital signatures—are applied to secure supply chain data. This score indicates a moderate level of familiarity, though the relatively high standard deviation suggests that knowledge levels varied widely. This variation could stem from differences in training, exposure to blockchain systems, or roles within the logistics ecosystem. These findings align with Pereira et al. (2021), who found that while cryptographic protocols were generally recognized as important in Spain and Brazil, technical understanding among logistics personnel was uneven, especially in decentralized or resource-constrained environments.

Respondents generally agreed that cryptographic techniques enhance data transparency, with a mean score of 3.6132 (SD = 1.10040). This suggests that many participants recognized the role of cryptographic hashes and digital signatures in making data tampering more detectable. However, the spread in responses reflects differing levels of confidence or practical experience. This is consistent with findings by Chang, Iakovou, and Shi (2020), who reported that blockchain encryption in maritime logistics improved tamper resistance, although its effectiveness depended heavily on the integration quality of security systems and the technical capabilities of users.

The highest-rated benefit was the ensuring of confidentiality in shipping and customs documentation, with a mean of 3.7736 (SD = 0.89744). This indicates a strong consensus that cryptographic methods (especially symmetric and public-key encryption) are effective in protecting sensitive information. The relatively low standard deviation further supports this view. These results are echoed by Farah, Ahmed, and Mwangi (2024), who found that encryption significantly reduced unauthorized access incidents at the Port of Mombasa, enhancing compliance with customs and security regulations. Similarly, Pereira et al. (2021) noted a 35% reduction in data breaches after the implementation of public-key infrastructure in Brazilian logistics hubs.

Trust-building between trading partners and logistics stakeholders was also acknowledged, with a mean score of 3.4811 (SD = 0.90744). The low variability suggests broad agreement that cryptographic security supports inter-organizational trust, particularly when systems offer non-repudiation and verifiable authentication. This aligns with Miron et al. (2024), who argued that permissioned blockchain systems—secured through cryptographic consensus—improve trust by ensuring transaction integrity and data provenance, especially in collaborative logistics environments.

By contrast, the lowest-rated statement concerned the prevention of unauthorized access to shipping and inventory systems, which received a mean of 2.8491 (SD = 1.24818). The high standard deviation suggests that while some respondents viewed cryptographic tools as effective, others were less convinced or lacked confidence in current implementations. This may point to infrastructural limitations, outdated systems, or insufficient enforcement of access controls. These concerns are corroborated by Chege and Otieno (2023), who found that in Kenya, power outages, weak cybersecurity protocols, and limited technical expertise can undermine even well-designed cryptographic systems, reducing their ability to prevent unauthorized access consistently.

4.6 Diagnostic Tests

4.5.1 Normality test

TABLE 9

Normality test

Variable	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Smart Contracts	.345	206	.059
Distributed Ledger Technology			
Consensus Mechanisms	.432	206	.060
Cryptographic Security	.514	206	.051
Supply Chain Performance	.352	206	.055

The data's normality was assessed using the Shapiro–Wilk test. The p-values for Smart Contracts, Consensus Mechanisms, Cryptographic Security, and Supply Chain Performance were 0.059, 0.060, 0.051, and 0.055, respectively. Since all the p-values are greater than the selected alpha threshold of 0.05, the null hypothesis that the data originated from a normally distributed population cannot be rejected (Razali and Wah, 2011). This indicates that the variables satisfy the assumption of normality required for further parametric analysis.

4.4.2 Multicollinearity Test

TABLE 10

Multicollinearity Test

Variables	**Collinearity Statistics**	
	Tolerance	**VIF**
Smart Contracts	.774	1.292
Distributed Ledger Technology	.930	1.076
Consensus Mechanisms	.960	1.042
Cryptographic Security	.799	1.251

The results in Table 4.8 showed that the VIFs (Variance Inflation Factors) for Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, and Cryptographic Security were 1.292, 1.076, 1.042, and 1.251, respectively. Since all four independent variables had VIF values below the threshold of 10, this indicates the absence of multicollinearity among the predictors. On this basis, regression analysis was deemed appropriate to assess the impact of the independent variables on supply chain performance.

4.7 Inferential Results

4.7.1 Correlation Analysis

TABLE 11

Correlation Matrix

		SCP	SC	DTL	CM	CS
Supply Chain Performance (SCP)	Pearson Correlation	1				
	N	106				
Smart Contracts (SC)	Pearson Correlation	.633**	1			
	Sig. (2-tailed)	.000				
	N	106	106			
Distributed Ledger Technology (DTL)	Pearson Correlation	.367**	.255**	1		
	Sig. (2-tailed)	.000	.004			
	N	106	106	106		
Consensus Mechanisms (CM)	Pearson Correlation	.290**	.088	.070	1	
	Sig. (2-tailed)	.001	.184	.238		
	N	106	106	106	106	
Cryptographic Security (CS)	Pearson Correlation	.449**	.417**	.064	.192*	1
	Sig. (2-tailed)	.000	.000	.257	.024	
	N	106	106	106	106	106

Findings in Table 4.9 indicate that Smart Contracts had a strong and significant positive correlation with supply chain performance (R = 0.633; p = 0.000 < 0.05). This implies that increased adoption of smart contracts would lead to improved supply chain performance. Similarly, Distributed Ledger Technology exhibited a moderate and significant positive correlation with supply chain performance (R = 0.367; p = 0.000 < 0.05), suggesting that greater use of DLT would enhance performance outcomes in the supply chain. Further, the results show that Consensus Mechanisms had a weak but significant positive correlation with supply chain performance (R = 0.290; p = 0.001 < 0.05). This indicates that stronger reliance on consensus mechanisms would contribute, though to a lesser extent, to improved performance. Lastly, Cryptographic Security demonstrated a moderate and significant positive correlation with supply chain performance (R = 0.449; p = 0.000 < 0.05). The implication is that increased application of cryptographic security practices would also lead to better performance within the supply chain.

4.7.2 Regression Analysis

4.7.2.1 Model Summary

TABLE 12

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.726[a]	.528	.509	.25646

a. Predictors: (Constant), Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, Cryptographic Security

b. Dependent: Supply Chain Performance

Findings in table 4.10 indicate that the independent variables (Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, and Cryptographic Security) collectively had a strong positive relationship with supply chain performance (R = 0.726). The model explained approximately 52.8% of the variance in supply chain performance, as reflected by the R Square value of 0.528. The Adjusted R Square value of 0.509 confirms that, even after adjusting for the number of predictors in the model, about 50.9% of the variation in supply chain performance can still be attributed to the four independent variables. The Standard Error of the Estimate was 0.25646, indicating a relatively small average distance between the observed and predicted values, and therefore suggesting good model fit.

4.7.2.2 Analysis of Variance

TABLE 13

Analysis of Variance

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	7.421	4	1.855	28.207	.000[b]
	Residual	6.643	101	.066		
	Total	14.064	105			

a. Dependent Variable: Supply Chain Performance

b. Predictors: (Constant), Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, Cryptographic Security

Findings in Table 4.11 show that the regression model was statistically significant in explaining the effect of Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, and Cryptographic Security on supply chain performance. The results reveal an F-statistic of 28.207 with a significance value of $p = 0.000 < 0.05$. This indicates that the combined effect of the four independent variables significantly predicts supply chain performance. The regression sum of squares (7.421) compared to the residual sum of squares (6.643) suggests that a greater proportion of the total variance in supply chain performance is explained by the predictors, confirming the model's robustness.

4.7.2.3 Regression Coefficients

TABLE 14

Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.389	.296		1.312	.193
	Smart Contracts	.436	.071	.476	6.130	.000
	Distributed Ledger Technology	.164	.053	.219	3.087	.003
	Consensus Mechanisms	.167	.060	.194	2.780	.006
	Cryptographic Security	.137	.053	.200	2.610	.010

a. **Dependent Variable:** Supply Chain Performance

The regression equation was established as:

$$\mathbf{Y = 0.389 + 0.436X_1 + 0.164X_2 + 0.167X_3 + 0.137X_4}$$

where:

- X_1 = Smart Contracts
- X_2 = Distributed Ledger Technology

- X_3 = Consensus Mechanisms
- X_4 = Cryptographic Security

After considering all factors and setting all variables to zero, the constant value was determined to be 0.389 ($\beta_0 = 0.389$; $p = 0.193 > 0.05$, $t = 1.312$). This constant suggests that in the absence of the four predictors, supply chain performance would remain at a baseline level of 0.389, though this effect was not statistically significant. The beta coefficient for Smart Contracts ($\beta_1 = 0.436$; $p = 0.000 < 0.05$, $t = 6.130$) indicates a positive and significant relationship. This means that a one-unit increase in the use of Smart Contracts, while holding other factors constant, would result in a 43.6% improvement in supply chain performance. For Distributed Ledger Technology ($\beta_2 = 0.164$; $p = 0.003 < 0.05$, $t = 3.087$), the positive and significant coefficient suggests that increasing its application enhances supply chain performance by 16.4%, assuming all other factors remain unchanged. Similarly, Consensus Mechanisms ($\beta_3 = 0.167$; $p = 0.006 < 0.05$, $t = 2.780$) showed a positive and significant influence, meaning that their effective use would improve supply chain performance by 16.7%, when other factors are held constant. Lastly, Cryptographic Security ($\beta_4 = 0.137$; $p = 0.010 < 0.05$, $t = 2.610$) also demonstrated a positive and significant effect. This implies that for every one-unit increase in the application of cryptographic security, supply chain performance would increase by 13.7%, all else being equal. At a 5% significance level, all four predictor variables were found to have a statistically significant effect on supply chain performance, with Smart Contracts ($\beta_1 = 0.436$) exerting the strongest influence.

4.8 Discussion of Findings

4.8.1 Smart Contracts and Supply Chain Performance

The strong and statistically significant relationship between Smart Contracts and supply chain performance aligns with existing blockchain theory, which posits that automated contract execution enhances operational efficiency, transparency, and trust among stakeholders (Saberi et al., 2019). The findings from this study—highlighting improved cargo tracking, inventory visibility, reduced costs, and real-time decision-making—reflect the principles of transaction cost theory (Williamson, 1985), which suggests that technology reducing information asymmetry and monitoring costs improves inter-firm coordination.

These results also support Tapscott and Tapscott's (2017) assertion that Smart Contracts foster trust in decentralized environments, especially when formal institutions may be underdeveloped. However, the observed low familiarity among users may indicate a limited depth of adoption, suggesting that while the benefits are evident, broader implementation may be hindered by skills gaps or legal uncertainty. This is consistent with the technology–organization–environment (TOE) framework (Tornatzky & Fleischer, 1990), which underscores the importance of institutional and human capacity readiness in driving successful technology adoption. Thus, while Smart Contracts offer high-impact potential, their success in the Kenyan logistics context depends on improving user competence and developing supportive legal frameworks.

4.8.2 Distributed Ledger Technology (DLT) and Supply Chain Performance

The moderate positive relationship between Distributed Ledger Technology (DLT) and supply chain performance corresponds with literature emphasizing DLT's value in enhancing traceability, data integrity, and fraud reduction (Francisco & Swanson, 2018). The study's findings that DLT contributes to risk mitigation through immutable and verifiable transaction records echo the resource-based view (Barney, 1991), which sees secure and transparent data systems as strategic assets in global logistics.

Nonetheless, the weaker agreement among respondents regarding DLT's ability to streamline customs procedures and documentation suggests implementation challenges, particularly in institutional interoperability and regulatory alignment. This limitation is consistent with findings by Njeri (2024), who noted that in the Kenyan maritime context, small logistics firms often lack systems that are compatible with blockchain-based platforms. As suggested by the socio-technical systems theory (Trist & Bamforth, 1951), the effectiveness of technological tools like DLT depends on the simultaneous evolution of technical infrastructure and organizational capabilities. Therefore, while DLT can enhance supply chain performance, its success hinges on broader systemic readiness and inclusive digital transformation across supply chain actors.

4.8.3 Consensus Mechanisms and Supply Chain Performance

The study found a weak but statistically significant positive relationship between Consensus Mechanisms and supply chain performance. Descriptively, respondents recognized the role of consensus algorithms in validating logistics records and reducing fraud, aligning with the foundational principles of blockchain architecture (Nakamoto, 2008), which emphasize decentralized trust and data consistency through algorithmic agreement.

However, the relatively low agreement on their role in minimizing disputes or improving inter-party communication highlights the less visible or indirect nature of consensus protocols compared to more tangible applications like Smart Contracts. These results parallel Ni and Irannezhad's (2024) simulation-based findings, which showed that consensus models improved performance in ICT-rich port environments but were less impactful where digital infrastructure is limited. From the lens of contingency theory (Burns & Stalker, 1961), consensus mechanisms may only yield strong performance benefits when aligned with robust digital ecosystems—a condition still developing in Kenya. Therefore, while consensus protocols are technically essential, their operational impact remains constrained by infrastructural and digital literacy barriers in emerging economies.

4.8.4 Cryptographic Security and Supply Chain Performance

The moderate and statistically significant influence of Cryptographic Security on supply chain performance confirms its crucial role in protecting data integrity, building trust, and enhancing transparency—key enablers in global logistics networks. These findings are consistent with prior research (Chang et al., 2020), which emphasizes encryption's ability to prevent document tampering and safeguard confidential information. The high respondent appreciation for data confidentiality reflects increasing awareness of cybersecurity as a strategic concern in supply chain management, resonating with information security theory (Dhillon & Backhouse, 2001), which argues that trust in digital systems is fundamental for technology-enabled collaboration.

However, the mixed perceptions about its effectiveness in controlling unauthorized access to inventory systems likely stem from infrastructural fragilities, such as power outages or inconsistent internet connectivity, which were also identified in Farah, Ahmed, and Mwangi's (2024) study at the Port of Mombasa. This supports the argument that while cryptographic tools are technically sound, their effectiveness is mediated by environmental factors—echoing the institutional theory (Scott, 1995), which emphasizes the role of external structures in shaping the efficacy of organizational practices. Therefore, cryptographic security offers critical value but must be supported by stable ICT infrastructure and trained personnel to fully realize its performance-enhancing potential.

CHAPTER FIVE

SUMMARY OF FINDINGS CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter covers summary, conclusions and recommendations based on the objectives. The recommendations were done to policy makers, practitioners and also to the scholars. The summary shows how the dependent variable and independent variable relates.

5.2 Summary of Findings

5.2.1 Smart Contracts and Supply Chain Performance

The study found that Smart Contracts significantly enhance supply chain performance by improving trust, reducing operational costs, and supporting real-time decision-making. Respondents agreed that Smart Contracts improve coordination and cargo visibility. These findings align with Philipp, Prause, and Gerlitz (2019), who reported a 35% reduction in customs verification times in European ports due to smart contract automation, and Gupta and Jain (2021), who observed efficiency gains and reduced payment errors in Indian seaports. However, while European and Indian studies focused on regions with supportive legal frameworks, the current study highlights that even in a developing country context like Kenya—where familiarity with Smart Contracts is low—the technology still has a measurable positive impact on trust and operational efficiency. This contrasts with Farah, Ahmed, and Mahmoud (2024), who emphasized that the lack of legal recognition in Kenya limits scalability and dispute resolution. Hence, while the Kenyan context presents regulatory challenges, this study demonstrates that operational benefits are realized at the firm level even before full institutional support.

5.2.2 Distributed Ledger Technology (DLT) and Supply Chain Performance

DLT was found to enhance risk management, traceability, and fraud reduction, though respondents were less certain about its effect on customs process efficiency. This partially aligns with Estima, da Cunha, and Barata (2025), who reported a 32% reduction in verification delays in Brazil and Portugal due to DLT, and Njeri (2024), who found clearance times decreased by 23% at the Port of Mombasa. The contrast lies in contextual constraints: while DLT improves transparency and record integrity globally, the current study shows that infrastructural readiness and digital inclusivity significantly mediate its effectiveness in Kenya. Small-scale logistics providers' limited access to compatible systems echoes Njeri's findings, confirming that DLT benefits are not uniformly distributed, unlike in fully digitized and legally mature environments.

5.2.3 Consensus Mechanisms and Supply Chain Performance

Consensus Mechanisms were acknowledged for reducing fraud and enhancing transaction trust, but there was less agreement on their ability to minimize disputes. This finding is consistent with Ni and Irannezhad (2024), who reported improved consistency and reduced processing time using PBFT in Chinese ports, and Miron et al. (2024), who emphasized trust-building in permissioned blockchains. However, the weaker relationship in the Kenyan context contrasts with these advanced settings. Chege and Otieno (2023) noted similar challenges, highlighting limited expertise and inconsistent internet connectivity as barriers. Therefore, while consensus mechanisms are theoretically effective, their operational impact in Kenya is constrained by infrastructural and human capacity limitations, making their contribution to performance moderate rather than strong.

5.2.4 Cryptographic Security and Supply Chain Performance

The study found that cryptographic security improves transparency, builds stakeholder trust, and safeguards shipping and customs data, although respondents were mixed on its ability to prevent unauthorized access to inventory systems. These findings are consistent with Chang, Iakovou, and Shi (2020), who reported a 38% reduction in document tampering, and Pereira, Moura, and Barbosa (2021), who found encryption strengthens confidentiality. Farah, Ahmed, and Mwangi (2024) also reported enhanced trust but highlighted vulnerabilities due to unstable electricity and internet connectivity. The contrast here lies in Kenya's infrastructural challenges, which moderate cryptography's effectiveness. While cryptography theoretically offers robust protection, in practice, inconsistent connectivity and power disruptions can reduce its impact on performance outcomes. This reinforces the need to integrate technological solutions with infrastructure improvements for full effectiveness.

5.3 Conclusions

5.3.1 Smart Contracts and Supply Chain Performance

The correlation and regression findings indicated that Smart Contracts have a strong and significant positive effect on supply chain performance. The study concluded that greater adoption of Smart Contracts—particularly in automating transactions, improving transparency, and reducing costs—would significantly enhance coordination, trust, and efficiency in the maritime logistics supply chain.

5.3.2 Distributed Ledger Technology and Supply Chain Performance

Distributed Ledger Technology was found to have a moderate and significant positive influence on supply chain performance. The study concluded that increasing the use of DLT, particularly for traceability, fraud prevention, and risk management, would improve accountability and reliability within supply chain operations, though more integration is needed to optimize customs and documentation processes.

5.3.3 Consensus Mechanisms and Supply Chain Performance

The results revealed that Consensus Mechanisms have a positive but relatively weaker impact on supply chain performance compared to other factors. The study concluded that the adoption of efficient and decentralized consensus models would improve trust in shared data, reduce fraud, and ensure faster validation of logistics transactions, thereby supporting performance improvement.

5.3.4 Cryptographic Security and Supply Chain Performance

Cryptographic Security was found to have a moderate and significant positive effect on supply chain performance. The study concluded that applying advanced cryptographic techniques—such as encryption and digital signatures—enhances data confidentiality, strengthens trust between stakeholders, and safeguards logistics systems, thereby contributing to better supply chain outcomes.

5.4 Recommendations

5.4.1 Smart Contracts and Supply Chain Performance

The study recommends that maritime logistics firms and regulators should increase the adoption of Smart Contracts to automate trade agreements, customs documentation, and payments. Emphasis should be placed on designing transparent, fair, and standardized smart contract templates that can be easily adopted across different stakeholders, including shippers, customs authorities, and financial institutions. This would reduce manual errors, minimize disputes, and accelerate clearance processes.

5.4.2 Distributed Ledger Technology and Supply Chain Performance

The study recommends that maritime industry stakeholders adopt Distributed Ledger Technology (DLT) to strengthen traceability and visibility within the supply chain. Policymakers should create regulatory frameworks that support interoperability of ledgers across ports, customs, and logistics companies. Training programs should also be introduced to equip staff with the technical skills needed to manage blockchain-based record systems for improved accountability and fraud reduction**.**

5.4.3 Consensus Mechanisms and Supply Chain Performance

The study recommends that logistics firms should adopt more efficient consensus mechanisms that balance speed, cost, and security. Collaborative initiatives should be established among key industry players to develop industry-specific consensus models suitable for maritime logistics transactions. This would improve the integrity of shared data, enhance trust among stakeholders, and ensure smoother verification of logistics processes.

5.4.4 Cryptographic Security and Supply Chain Performance

The study recommends that maritime supply chain actors should prioritize robust cryptographic security systems to safeguard sensitive trade data and ensure confidentiality in electronic documentation. Investment should be directed toward advanced encryption, secure digital signatures, and multi-factor authentication to protect against cyberattacks and unauthorized data access. Regular system audits and staff training on cybersecurity best practices should also be encouraged to strengthen resilience.

5.5 Suggestion for Further Studies

This study investigated the effect of Smart Contracts, Distributed Ledger Technology, Consensus Mechanisms, and Cryptographic Security on supply chain performance within Kenya's maritime logistics sector. While the findings provide critical insights, the researcher proposes the following areas for further research: Future research could examine how blockchain technologies influence supply chain performance in other industries such as agriculture, healthcare, and manufacturing to establish whether similar patterns and outcomes exist beyond the maritime sector. Since blockchain adoption is still at an early stage in Kenya, future studies should adopt a longitudinal research design to track how the gradual integration of blockchain technologies affects supply chain performance over time.

Further research should focus on evaluating the economic implications and return on investment (ROI) of implementing blockchain solutions in logistics operations. This will help stakeholders assess the financial sustainability of full-scale adoption. Studies should explore how blockchain can be integrated with other digital technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and Big Data Analytics to create more resilient and adaptive maritime supply chains. Future studies should examine the role of government regulations, legal frameworks, and international trade policies in shaping the adoption and effectiveness of blockchain technologies in maritime logistics.

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APPENDICES

APPENDIX I: INTRODUCTION LETTER

KIOKO PATIENCE

P.O Box 1776-50100,

Nairobi

To the respondent

RE: QUESTIONNAIRE

The above named is a second-year student at KCAU. In order to fulfil the requirements of the school, i am undertaking a research on **BLOCKCHAIN TECHNOLOGY AND SUPPLY CHAIN PERFORMANCE IN THE MARITIME LOGISTICS INDUSTRY, KENYA.** You are among the chosen respondents of my study. I hereby, kindly ask you to respond to the questionnaire to the best of your knowledge. Confidentiality of the information given will be guaranteed.

Your cooperation will be highly appreciated.

p.k

Yours Sincerely,

KIOKO PATIENCE

APPENDIX II: QUESTIONNAIRE

(Tick applicable boxes)

PART A: BIODATA

Please provide the following information. Your responses will be kept strictly confidential and used for academic purposes only.

1. **Gender:**

   ☐Male

   ☐ Female

2. **Age Group (Years):**

   ☐Below25-years

   ☐25–34-years

   ☐35–44-years

   ☐45–54-years

   ☐ 55 years and above

3. **Highest Level of Education Completed:**

   ☐Certificate/Diploma

   ☐Bachelor’s-Degree

   ☐Master’s-Degree

☐Doctorate-(PhD)

☐ Other (please specify): ___________

PART B: SMART CONTRACTS ON SUPPLY CHAIN PERFORMANCE

1. In a 5-point Likert scale where ***1=very small extent, 2=small extent, 3=moderate extent, 4=great extent, and 5=very great extent,*** what is your opinion on the following propositions regarding effect of smart contracts on supply chain performance?

SMART CONTRACTS		**1**	**2**	**3**	**4**	**5**
i.	I am familiar with the concept of smart contracts and how they are applied in logistics.					
ii.	Using smart contracts improves cargo tracking and inventory visibility.					
iii.	Smart contracts improve trust among supply chain partners by making transactions transparent.					
iv.	Implementing smart contracts can reduce operational costs in the long term.					
v.	Smart contracts lead to better coordination and real-time decision-making across the supply chain.					

PART C: DISTRIBUTED LEDGER TECHNOLOGY

2. In a 5-point Likert scale where ***1=very small extent, 2=small extent, 3=moderate extent, 4=great extent, and 5=very great extent,*** how much would you agree with

the following propositions regarding the effect of effect of distributed ledger technology on supply chain performance?

	DISTRIBUTED LEDGER TECHNOLOGY	1	2	3	4	5
i.	DLT improves visibility and traceability across the maritime supply chain.					
ii.	DLT can streamline customs procedures and documentation in maritime logistics.					
iii.	DLT enhances risk management by providing immutable and verifiable transaction records.					
iv.	The use of DLT can prevent fraud and increase accountability in maritime logistics.					
v.	DLT reduces time delays and increases the overall responsiveness of the supply chain.					

PART D: CONSENSUS MECHANISMS AND SUPPLY CHAIN PERFORMANCE

3. In a 5-point Likert scale where ***1=very small extent, 2=small extent, 3=moderate extent, 4=great extent, and 5=very great extent,*** how much would you agree with the following propositions regarding effect of consensus mechanisms on supply chain performance?

CONSENSUS MECHANISMS		1	2	3	4	5
i.	Consensus mechanisms help ensure data accuracy and trust in maritime logistics records.					
ii.	Efficient consensus mechanisms contribute to faster transaction validation and processing in supply chains.					
iii.	Distributed consensus mechanisms reduce the risk of fraud in maritime logistics operations.					
iv.	Consensus-based validation minimizes the chances of disputes over shipping and transaction records.					
v.	Using decentralized consensus increases confidence in supply chain data sharing across stakeholders.					

PART F: CRYPTOGRAPHIC SECURITY AND SUPPLY CHAIN PERFORMANCE

4. In a 5-point Likert scale where ***1=very small extent, 2=small extent, 3=moderate extent, 4=great extent, and 5=very great extent,*** what is your opinion on the following propositions regarding effect of cryptographic security and supply chain performance?

CRYPTOGRAPHIC SECURITY		1	2	3	4	5
i.	I understand how cryptographic tools such as encryption and digital signatures are used in securing supply chain data.					
ii.	Cryptographic techniques improve transparency by making tampering with data easily detectable.					
iii.	Cryptographic methods ensure the confidentiality of shipping and customs data.					
iv.	The use of cryptographic security builds trust between trading partners and logistics providers.					
v.	Cryptographic security helps prevent unauthorized access to shipping and inventory systems.					

PART F: SUPPLY CHAIN PERFORMANCE IN MARITIME LOGISTICS IN KENYA

5. In a 5-point Likert scale where ***1=very small extent, 2=small extent, 3=moderate extent, 4=great extent, and 5=very great extent,*** what is your opinion on the following propositions regarding supply chain performance in maritime logistics in Kenya?

SUPPLY CHAIN PERFORMANCE		1	2	3	4	5
i.	Our maritime logistics operations are executed efficiently and with minimal delays.					
ii.	Customers are generally satisfied with delivery times and communication.					
	We have real-time visibility into shipment status and supply chain operations.					
iii.	The use of technology has reduced manual interventions and administrative costs.					
Iv.	Turnaround time at ports has improved in the past 12 months.					

APPENDIX III: ETHICS CLEARANCE CERTIFICATE

KCA
UNIVERSITY

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KCA UNIVERSITY SCIENTIFIC & ETHICS REVIEW COMMITTEE

REF: **KCAU/SERC/SOB0223** **DATE: 18TH AUGUST 2025**

TO: **KIOKO PATIENCE (17/02515)**

Dear Sir/Madam,

RE: BLOCKCHAIN TECHNOLOGY AND SUPPLY CHAIN PERFORMANCE IN THE MARITIME LOGISTICS INDUSTRY, KENYA

This is to inform you that the KCA University Scientific Ethics Review Committee (KCAUSERC) has reviewed and approved your research proposal. Your application approval number is ***KCAUSERC/SOB0223.*** The approval period is ***18th August 2025 – 18th August, 2026.***
This approval is subject to compliance with the following requirements.

i. Only approved documents, including informed consents, study instruments, and MTAs, will be used.
ii. All changes, including (amendments, deviations, and violations), are submitted for review and approval by ***KCAUSERC.***
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events, whether related or unrelated to the study, must be reported to **KCAU*SERC*** within 72 hours of notification.
iv. Any changes, anticipated or otherwise, that may increase the risks or affect the safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KCAUSERC*** within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days before expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***KCAUSERC.***

Before commencing your study, you will be expected to obtain a research license from the National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

Scientific and Ethics
KCA UNIVERSITY
Review Committee

Dr. Caroline Ntara,
Chairperson,
KCA University Scientific & Ethics Review Committee.

Advancing Knowledge, Driving Change

APPENDIX IV. NACOSTI FORM

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 180458

Date of Issue: 12/September/2025

RESEARCH LICENSE

This is to Certify that Ms.. Kioko Mutete Patience of KCA University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Mombasa on the topic: Blockchain technology and supply chain performance in the maritime logistics industry,kenya for the period ending : 12/September/2026.

License No: **NACOSTI/P/25/4179451**

180458

Applicant Identification Number

Ag. Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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See overleaf for conditions

APPENDIX V: LIST OF COMPANIES REFERENCED IN THE RESEARCH

1. Acceler Shipping Service Nairobi
2. Access Shipping Agency Ltd
3. Air Cargo Global
4. Alpha Logistics Services (EPZ) Ltd.
5. APM Terminals Kenya
6. Bolloré Transports & Logistics
7. Century Cargo Shipping Co.
8. CMA CGM Kenya Ltd.
9. Coastal and Support Logistics
10. Comarco Group
11. Emirates Shipping East Africa Ltd
12. ESL Forwarders
13. Express Shipping and Logistics (EA) Ltd.
14. Global Freight Logistics Ltd
15. Global Shipping Lines
16. Golden Gate Cargo Services
17. Great Circle Line Kenya Ltd, Harbour Agency Ltd,
18. International Shipping Agency Ltd,
19. Liberty Afrika Technologies Ltd.
20. Maersk Kenya Ltd.
21. Mitchell Cotts Kenya Ltd.
22. Mombasa Ocean Agency (K) Ltd.
23. MSC Kenya Ltd.
24. NISOMAR Kenya Ltd.
25. PACELINE Cargo Ltd
26. Salihiya Cargo Shipping Agency
27. Sea Bulk Chartering & Trading Ltd
28. Sheffield Cargo Logistics Ltd –
29. Ship Agencies & Maritime Service Providers
30. Shipmarc Agency & Logistics Ltd

31. Siginon Group
32. Sima Marine Ltd,
33. Skyway International Logistics
34. Storm Shipping Agency Ltd
35. Union Logistics Ltd
36. W.E.C. Lines Kenya Ltd.
37. Wilhelmsen Ships Service Ltd

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REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 653095

Date of Issue: 28/May/2025

RESEARCH LICENSE

This is to Certify that Miss.. VERONICAH KAJIRA KIRUGI of KCA University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: INFLUENCE OF ORGANIZATIONAL CULTURE ON EMPLOYEE PERFORMANCE IN THE MANUFACTURING FIRMS LISTED IN NAIROBI SECURITIES EXCHANGE for the ending : 28/May/2026.

License No: NACOSTI/P/25/117478

653095

Applicant Identification Number

Deputy Director
NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY &
INNOVATION

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