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USE OF BLOCKCHAIN TECHNOLOGY IN PHARMACEUTICAL SUPPLY CHAIN - A CASE STUDY OF NAIROBI COUNTY

By

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A project report submitted in partial fulfilment of the requirement of Master of Science in Information Technology Management, University of Nairobi.

August, 2023

DECLARATION

This project, as presented in this report, is my original work and has not been presented to any other university for any degree award.

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This project has been submitted in partial fulfilment of the requirements of the Master of Science Degree in Information Technology Management of the University of Nairobi with my approval as a university supervisor.

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ACKNOWLEDGEMENTS

I take this opportunity to thank God for providing me the strength to see my research project through to its completion. I am also grateful to my supervisor, Professor. Timothy Waema Mwololo for his unending guidance, and invaluable support during the entire period of this research. I also express my sincere gratitude to my lecturers who have laid the groundwork for my postgraduate education. Among them, I offer special appreciation to the panellists; Dr. Kahonge, Mr. Eric Ayienga and Mrs. Selina Ochukut, whose invaluable guidance and expertise played a crucial role in my research defence.

Finally, I am deeply thankful to my parents for their constant support, love, and encouragement throughout this journey; I truly couldn't have achieved this without them.

ABSTRACT

The use of substandard, unregistered and falsified pharmaceutical drugs does not only endanger health, promote spread of antimicrobial and drug-resistant infections but also undermines confidence in health professionals and health systems. Blockchain technology, with its distributed ledger and smart contract features, has the potential to address these challenges. Blockchain uses a digital ledger technology that securely records and stores transactions of data across computer systems. This research proposed a conceptual framework for assessing the adoption of blockchain technology in the pharmaceutical supply chain in Kenya. The study focused on the development of a blockchain system and the evaluation of its adoption, using the Technology Acceptance Model. This paper examined how blockchain can be used to increase transparency and accountability in the pharmaceutical supply chain distribution. Specifically, the study sought to establish the technical enablers for achieving provenance, transparency, and traceability by examining how hyperledger fabrics in blockchain can address confidentiality, integrity and authentication of data. Additionally, the project highlighted the perceived usefulness and perceived ease of using blockchain in the supply chain. The paper further discussed the drivers that enhance pharmaceutical organisations' attitude to adopt blockchain and assessed the respective adoption challenges. The paper concludes by recommending further research to assess the feasibility and effectiveness of using blockchain to enhance traceability in drug supply chain management, mitigate fraud and enhance the adoption of blockchain technology in the pharmaceutical industry in Kenya.

Key words: Technology Acceptance Model, Hyperledger Fabrics, Chaincode, Supply Chain

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LIST OF ABBREVIATIONS

CNT	Calling in the Numeric Token
DSR	Design Science Research
IACC	International Anti-Counterfeiting Coalition
IoT	Internet of Things
KAM	Kenya Association of Manufacturers
KEMSA	Kenya Medical Supplies Authority
PPB	Pharmacy and Poisons Board
RFID	Radio Frequency Identification
WHO	World Health Organization
UNODC	United Nations Office on Drugs and Crime
LMIS	Logistics Management Information System
TAM	Technology Acceptance Model
SPSS	Statistical Package for the Social Sciences
FG	Focus Group
DSR	Design Science Research
PU	Perceived Usefulness
PEU	Perceived Ease of Use
ATA	Attitude to Adopt

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CHAPTER ONE: INTRODUCTION

1.1 Background

The World Health Organization (WHO) (2020) describes a counterfeit drug as one that is created dishonestly, mislabeled, of poor quality, conceals the source's identity or details, and does not adhere to the established standards. The usage of this subpar, unconventional treatment has harmful effects and could raise mortality rates (Harris et al., 2019). Drugs that are falsified may have legitimate or active components, but the quantity of these substances is not right and may be high or low. They also contain hazardous contaminants during manufacturing, and using them can result in serious health problems (Soundarya & Pandey, 2021). Whilst the pharmaceutical sector faces a significant threat from counterfeit medications worldwide, the problem is exacerbated in developing nations when consumers discover that every 10^{th} drug they use is fake and of poor quality (Jamil et al., 2019). WHO (2020) estimates that between 10–15% of medications are fake globally, while that percentage is closer to 30% in underdeveloped nations. Only in Sub-Saharan Africa do falsified pharmaceuticals account for over 0.2 million of the region's 0.7 million annual fatalities from malaria and other diseases.

Utilising the most recent technologies to consistently monitor the drugs at every step in the supply chain is one of the few expert recommendations and opinions to conquer and inhibit falsified drug problems (Dégardin et al., 2021; Blackstone et al., 2022). Other recommendations include improving management and oversight of the drugs trade at the pharmacy, distribution companies, and hospital level. The effective management of the drug supply chain is crucial to averting this problem, as shown by the aforementioned considerations. To solve this issue, the most effective system that can monitor and oversee the delivery of drugs at each stage, starting with the raw materials from the supplier, manufacturing product, distributing stage, pharmacists, hospitals, and customers, correspondingly, is required (Dégardin et al., 2021). Moreover, Blockchain is the most recent development in computing that can manage the distribution network and monitor the goods. Blockchain technology can effectively safeguard the delivery process and monitor it (Jamil et al., 2019).

In essence, Blockchain is a cutting-edge technology that was specifically created to hold the transaction log of an internationally recognized cryptocurrency. A very comprehensive digital ledger software is offered by the blockchain to store data records and perform activity logs in the

manner of organised groups of blocks, as it is a robust distributed processing type (Metcalf et al., 2019). Each transaction's digital details, including the parties, time, price, and date engaged in the transactions, are recorded in a block. The distributed database is part of the blockchain network, where numerous independent nodes take part in the transaction validation process without any mutual understanding or trust (Viriyasitavat & Hoonsopon, 2019). Each unit in the system contains two hash codes, called the preceding and present hash codes. The current hash code is for the block itself, while the previous hash code is for the block before it. Also, if one structure's information changes, all of that block's data should also be updated (Pandey & Litoriya, 2020). The network's blocks are all closely connected to one another and secured with cryptographic and transactional codes. Strong mathematical methods are another crucial component since they enable miner nodes to authenticate these frames without having their data affected, and following verification, blocks can be uploaded to the blockchain network. Because of this, the blockchain technology guarantees both privacy and openness (Wu & Lin, 2019).

Blockchain technology is the ideal alternative for managing and securing the pharmaceutical drug supply chain process based on the aforementioned characteristics (Bryatov & Borodinov, 2019). In essence, the blockchain stores the hash code and information about the material providers. The producer comes next in the chain of distribution; they produce the medications and associate them with a special hash code. The blockchain stores the hash code and information about how the pharmaceuticals were manufactured. Distributor data follows in the supply chain, followed by retailers and medical facilities (Lokesh et al., 2021).

Blockchain has been adopted by some pharmaceutical corporations (Rabah, 2021). It offers an electronically distributed decentralised database through hyper ledger fabrics that allows all pair nodes that make up the network to observe and verify the data linked to payments, distributed ledger technology is the preferred choice for most sectors (Tseng et al., 2018). The smart pharmaceutical sector uses hyper ledger textiles, which can continually track and monitor the drug distribution process. Another feature is its consensus method, which enables the network to only store verified data in the repositories and solves the repeated transaction issue. Also, the connectivity issues risk is quite low so that more networks are operating than the failure barrier, and low latency is also very good (Lokesh et al., 2021).

Despite the promise that blockchain technology holds in addressing falsified drugs, this is yet to be fully adopted in the Kenyan pharmaceutical industry. At present, the traceability of drugs and other health products is conducted by a number of inefficient practices including comparisons of issue data with consumption data, reconciliations of documentation, physical service delivery locations visits and thorough reviews (Ministry of Health study, 2020). This is in combination with such legacy technologies as the Logistics Management Information System (LMIS) operated by the Kenya Medical Supplies Authority's (KEMSA). While in motion, there is no real-time stock visibility with this and therefore prone to data manipulation and human error (Munyao, 2022). The inefficiencies and inadequacy of the current measures are incapable of tracing drugs along the supply chain, presenting a window for falsified drugs to get injected into the Kenyan pharmaceutical industry.

1.2 Problem Statement

According to the International Anti-Counterfeiting Coalition (IACC), the market for phoney pharmaceutical manufacturers is expanding, making falsified, unregistered and substandard drugs one of the biggest criminal enterprises of the twenty-first century (Justice, 2020; Roxanne & Lisa, 2022). In the United States, Williams and McKnight (2021) report around $200 billion dollars in yearly business loss by US pharmaceutical corporations as a result of these fake drugs. According to the global health organisation, the trafficking in fake drugs is thought to be responsible for roughly 100,000 annual fatalities in Africa (WHO, 2020). The Kenya Association of Manufacturers (KAM) in Kenya discovered that more than 30% of all pharmaceuticals supplied are falsified. The Mombasa port has been specifically noted as a notorious entrance point for offshore smuggling of bogus veterinarians and vital medications into the eastern African market (Gumba, 2020).

As aforementioned, blockchain technology is touted as an effective strategy that can be used to trace drugs from the source, along the supply chain, down to the consumer. This is however not taken up in the Kenyan pharmaceutical industry, as such legacy technologies and measures including KEMSA’s LMIS and physical audits are presently practised (Munyao, 2022). These have proven inadequate and prone to data manipulation and human error, as falsified drugs still flock the market (Gumba, 2020; Merab & Kilonzo, 2020). Against this backdrop, the present

study sets out to build a blockchain technology that can trace drug movement along the supply chain from the source to the retailer through a web application.

1.4 Objectives

The main objective of this research was to address the lack of transparency, authenticity and traceability of drugs in the pharmaceutical supply chain using blockchain-based technology and assess the adoption of the blockchain technology.

1.4.1 Specific Objectives

i. To establish how traceability of drugs can be improved in the pharmaceutical supply chain using blockchain technology.

ii. To develop a blockchain-based system that was used along the pharmaceutical supply chain.

iii. To assess the adoption of the blockchain technology in the pharmaceutical supply chain.

1.3 Research questions

i. How can blockchain enhance traceability of drugs in the pharmaceutical supply chain in Kenya?

ii. What are the gaps and effectiveness of the existing technologies in the facilitation of drug traceability in the pharmaceutical supply chain?

iii. What are the technological adaptability enablers of blockchain technology along the pharmaceutical supply chain?

1.5 Scope

The study sought to build and assess for adoption of blockchain technology that can trace drug movement along the pharmaceutical supply chain from the source to the retailer through a web application. To this end, the conceptual scope of the study includes establishing the technical enablers and the use of hyper ledger fabrics to achieve continuous tracking of drugs and visibility, as well as a determination of how blockchain secures data handling to address data manipulation and human error along the pharmaceutical supply chain.

The geographic scope of the study was Nairobi County, as it harbours the greatest number of stakeholders in the pharmaceutical supply chain. These include the suppliers, manufacturers, the distributors, health facilities as well as the regulatory authority, that is the Pharmacy and Poisons Board (PPB) and KEMSA, whose mission is to acquire, store, and supply medical supplies to public health clinics. Therefore, the selection of participants was chosen from every group of stakeholders for data collection. The time scope of the study was a period of three months.

1.6 Assumptions

The study proceeded with a number of assumptions. The first assumption is that all stakeholders involved, including the suppliers, manufacturers, the distributors, health facilities, the regulatory authority and patients are willing to play their part in tracking drugs along the pharmaceutical supply chain using blockchain. This presupposes that awareness is raised among the different stakeholder groups. It is also assumed that there was institutional capacity and political goodwill to promote the adoption of blockchain to trace drug movement along the pharmaceutical supply chain from the source to the consumer.

1.7 Significance

The use of a blockchain technology along the pharmaceutical supply chain through a web application in the country is likely to result in a good deal of health, operational and financial benefits for various stakeholders involved. The final consumer was able to access good quality and genuine drugs that were effective in treating respective ailments, diseases and conditions. Providing customers with legitimate medications would prevent exposure to risky or inefficient

items, which would eliminate issues brought on by fake medications. The distributors stand to gain financial benefits, by eliminating the labour-intensive process of manual verification and costs associated with printing volumes of paper for the manual data gathering and verification process. It also lowers the regulatory and compliance expenses for PPB. The pharmaceuticals benefit from a faster, more efficient and convenient process as repetitive auditing and data gathering processes were reduced.

1.8 Limitations

The solution was not applicable to drugs with a distinctive identification feature such as a QR code. Additionally, certain drugs are sold singularly rather than in a package or sachet, rendering the created application ineffective in aiding consumers to authenticate drugs that do not have a unique identifier. The solution was not applicable to supply chains where pharmaceutical drugs have been sourced and imported from external manufacturers. This may not accurately represent how the current supply chain system works in a real-world scenario as it follows a controlled environment supply chain circuit.

There may be cultural, social, and economic factors that may impact the adoption of blockchain in the pharmaceutical sector in Kenya. This calls for increased engagement with relevant stakeholders to understand their concerns, needs, and expectations regarding the adoption of blockchain. Ahmed F. et al. (2020).

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter gives a critical review of the theoretical underpinnings, empirical literature as well as the adoption conceptual framework. Under the theoretical review, the chapter identifies and discusses theories relevant to building a blockchain technology that can trace drug movement along the pharmaceutical supply chain through a web application. The empirical literature on the other hand delves into a critical review of extant related scholarly works. The conceptual framework further presents a diagrammatic illustration of how the study system was adopted by various stakeholders in the Kenyan pharmaceutical distribution network.

2.2 Theoretical Adoption Framework Review

This chapter gives a review of the adoption frameworks that have been considered when implementing the blockchain system. The adoption framework reviewed include: Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Capability Maturity Model Integration (CMMI) and Diffusion of Innovations (DoI). This section discusses how TAM has been selected for adoption of blockchain technology in this research over other reviewed models.

2.2.1 Unified Theory of Acceptance and Use of Technology (UTAUT)

According to Venkatesh et al. (2003) The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed to explain the four factors that influence users' acceptance and adoption of a new technology. UTAUT was established on four theoretical constructs representing determinants of intention to use which play essential roles as surrogates of Technology Acceptance (Venkatesh V, et al., 2016).

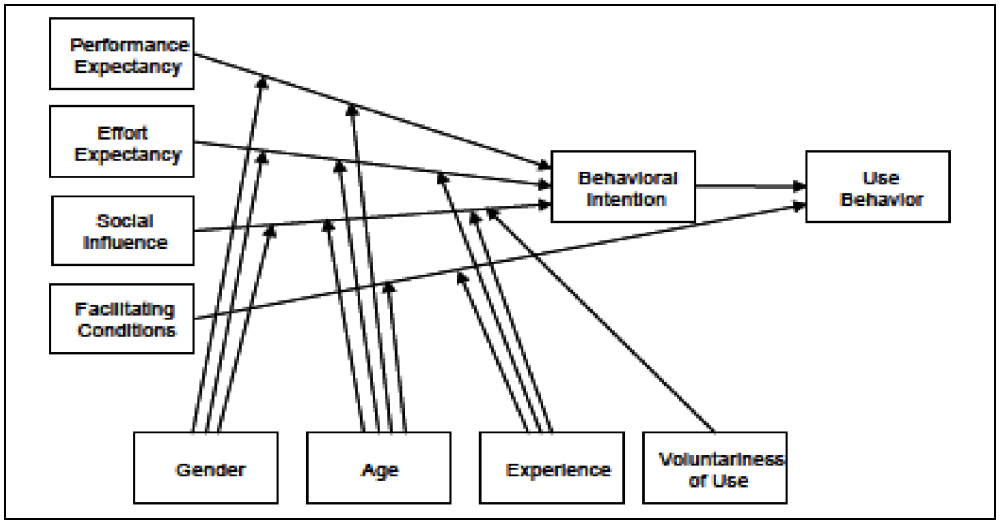

Figure 2. Unified Theory of Acceptance and Use of Technology (2003)

The theory is based on four main ideas that explain why people might use or not use technology. These ideas are Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. These factors act as important predictors of whether someone will accept technology or not. The theory also takes into account other factors that might affect the relationship between these ideas and someone's intention to use technology. These factors are called Moderators, and they include Gender, Age, Experience, and whether the use of the technology is voluntary or not. While the Unified Theory of Acceptance and Use of Technology (UTAUT) builds upon the Technology Acceptance Model (TAM) by adding new constructs such as performance expectancy and social influence, it still has its limitations. UTAUT's focus on intention to use technology may not always translate into actual use, and the model does not consider individual differences in behavior and cognition. In contrast, the Extended Technology Acceptance Model (ETAM) addresses these limitations by incorporating additional constructs such as habit and perceived risk. While UTAUT remains a valuable tool for understanding technology adoption, organizations should also consider complementary models like ETAM to ensure they are addressing all relevant factors.

2.2.2 Capability Maturity Model Integration (CMMI)

The Capability Maturity Model Integration is an improvement model that can be adapted to find problems, improve and solve performance issues in an organisation (Nielsen et al., 2018).The CMMI was developed by the Software Engineering Institute (SEI) at Carnegie Mellon University and has been adopted widely in the software industry (SEI, 2021). The model is based

on five maturity levels that organisations can use to assess their process maturity and identify areas for improvement (Chrissis, et. al., 2011).

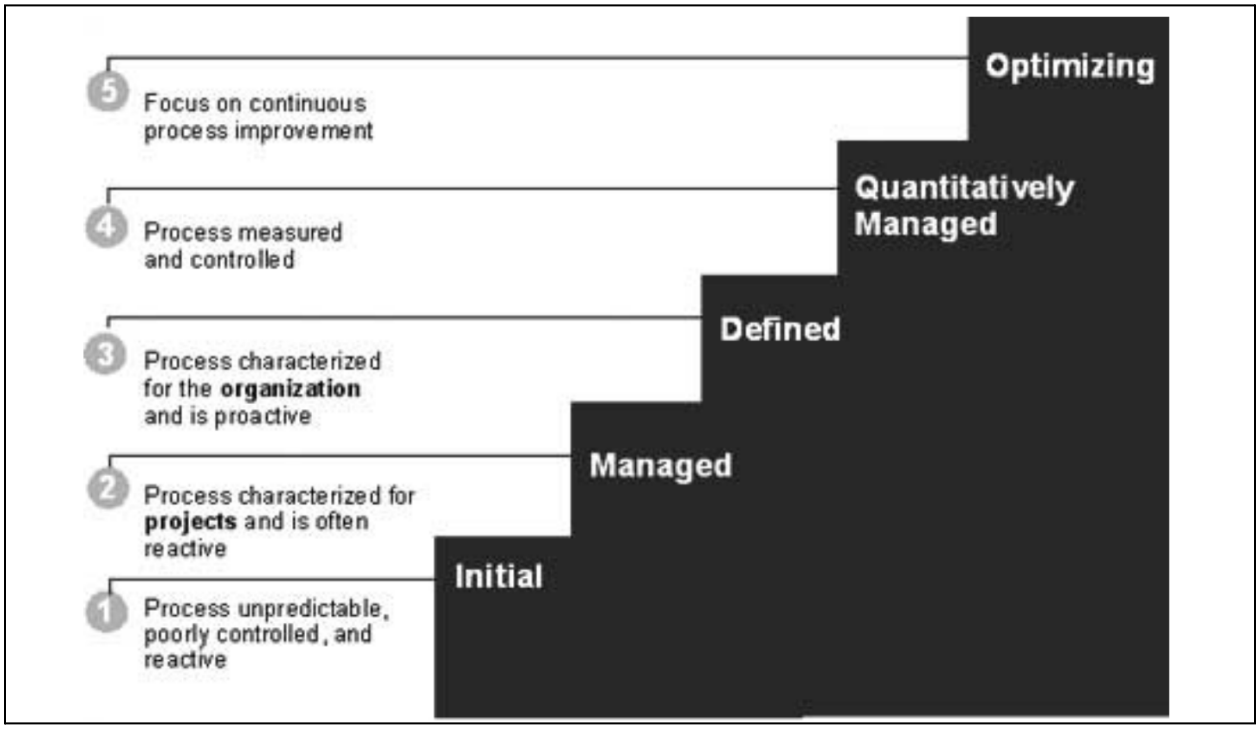

Figure 3. Capability Maturity Model Integration

While CMMI provides a valuable framework for improving processes in the software industry, it has its limitations. The model's focus on process improvement that can result in a lack of attention to the human and organisational factors that impact technology adoption. In contrast, the Technology Acceptance Model (TAM) offers a broader perspective on technology adoption by considering factors such as perceived usefulness and ease of use. TAM's emphasis on user behaviour makes it particularly useful for organizations seeking to implement new technology solutions. Therefore, while CMMI remains a valuable tool for process improvement in the software industry, organizations should also consider complementary frameworks like TAM to ensure they are addressing all aspects of technology adoption.

2.2.3 Diffusion of Innovations (DoI)

The Diffusion of Innovations (DoI) model explains how new ideas, products, and technologies spread through a social system (Everett R 1962). The DoI model identifies five stages of the diffusion process: knowledge, persuasion, decision, implementation, and confirmation. Rogers (2003) defined the classifications of members of a social system on the basis of innovativeness

which includes innovators, early adopters, early majority, late majority, and laggards. According to Rogers (2003), Innovativeness is defined as the degree to which an individual will relatively adopt new ideas than other members of a system.

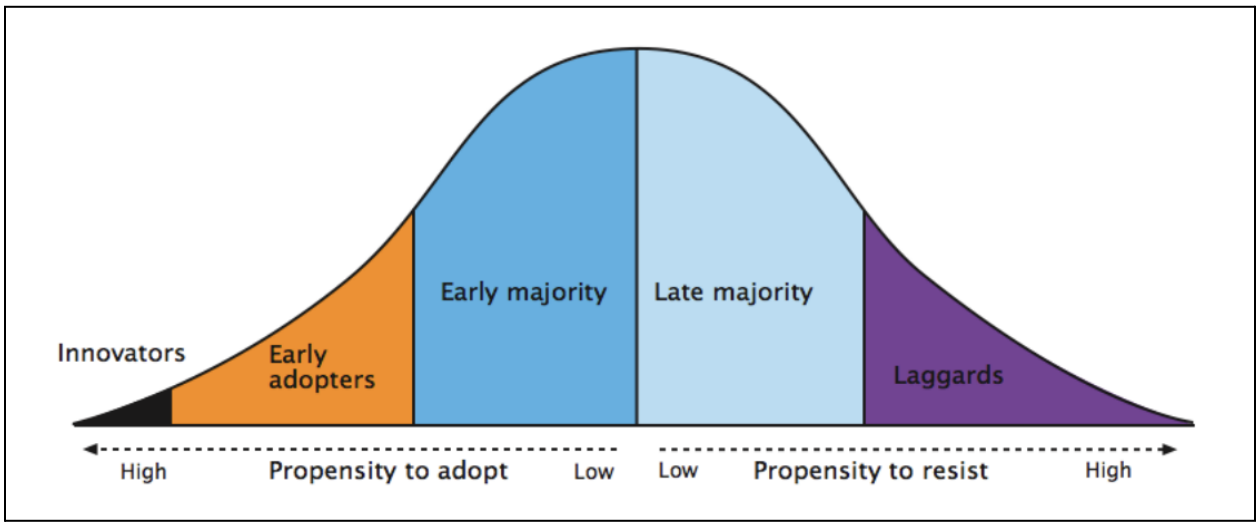

Figure 4. Adopter Categorization on the Basis of Diffusion Innovations Model

While the Diffusion of Innovations (DoI) Model and Technology Acceptance Model (TAM) are both useful in explaining the adoption of new innovations, they have distinct limitations. The DoI Model focuses on the process of diffusion through a social system and may not account for individual-level factors that influence adoption decisions, such as perceived ease of use and usefulness, which are central to the TAM. Furthermore, the DoI Model may not adequately account for the heterogeneity of potential adopters, including differences in demographics, culture, and prior experience with the innovation. The TAM, on the other hand, focuses more on individual-level factors and is better suited to explaining technology adoption in a specific context. However, it may not account for the influence of external factors that shape the adoption process, such as social norms or institutional pressures. Therefore, while both models are valuable, it is important to consider their respective limitations when using them to inform strategies for promoting the adoption of new technologies or innovations.

2.3 Pharmaceutical Drugs Supply Chain

From locating the active substances for a drug (the supplier) to producing the finished product (the medicine), distribution, and delivery to patients (the consumers), a pharmaceutical supply chain maintains an end-to-end procedure (Saxena et al., 2020). Distributing authentic, high-quality pharmaceuticals at the proper time is the main responsibility of supply chain partners because it directly impacts the well-being and security of consumers (Soundarya & Pandey, 2021). Currently used medicine delivery and logistics operations have significantly risen in size and complexity. The employment of centralised third-party solutions to collect and validate data is usually necessary due to the lack of a full view of the entire distribution chain (Harris et al., 2019).

There are many parties involved in the pharmaceutical supply chain, such as those who provide raw ingredients, producers, wholesalers, regulatory agencies, pharmacists, clinics, and consumers (McGhin et al., 2019). A high-level perspective of the major players in the supply chain for pharmaceuticals is shown in Figure 5 (Uddin et al., 2021).

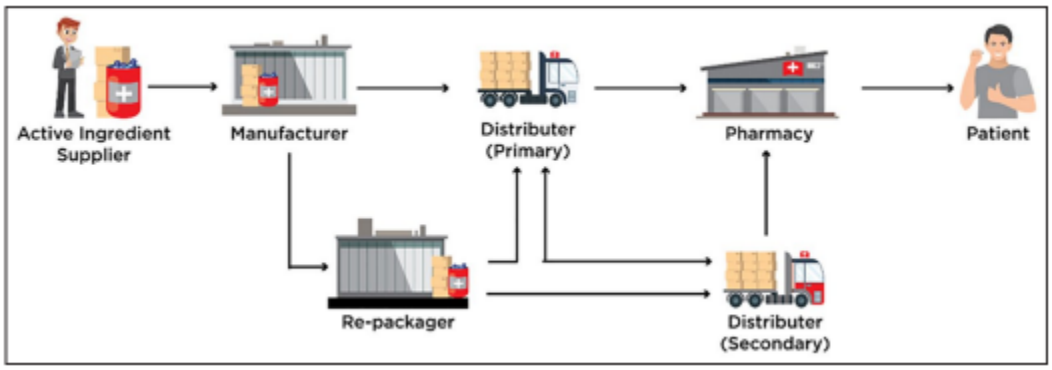

Figure 5. Pharmaceutical Supply Chain

Source: Uddin et al. (2021)

Before a medication's final recipe is created, its ingredients are typically gathered from a variety of sources. The medication can be administered once the final formula has been created (Agbo et al., 2019). The drug was transferred across numerous parties throughout the supply chain product lifecycle, particularly between the producer and the patients. Every transfer presents a chance for products that are fake or counterfeit to enter the industry's supply chain (McGhin et al., 2019). The responsibility of the manufacturers in the supply chain is to make sure that their drug stock

is prepared for distribution to distributors. Upon the receipt of orders from wholesalers and distributors, manufacturers ship the ordered goods to the distributors' facilities for warehousing. To preserve transparency all through the procedure, wholesalers supply manufacturers with reports on stock levels (Soundarya & Pandey, 2021).

Distributors have the responsibility of streamlining and streamlining the process of buying pharmaceuticals. Thousands of pharmacists and dispensers are connected to by distributors, who also provide to them (Dégardin et al., 2021). As a result, manufacturers can send huge quantities of medicines to a comparatively small amount of wholesalers instead of having to ship pharmaceuticals to pharmacists independently. After the goods are in the wholesaler's possession, they offer a variety of services, such as reprocessing, computerised order facilities, and drug delivery (Jamil et al., 2019).

Before reaching the patients, pharmacists and facilities are the last organisations in the supply chain. The market for prescription drugs is dominated by pharmacies at around 75%, with non-retail suppliers like hospitals making the rest of the 25%. (WHO, 2020). Items are bought by pharmacies and medical facilities from wholesalers before being distributed to the user. Direct distribution agreements between primary wholesalers and the manufacturers they buy from. While secondary wholesalers buy goods from a variety of other vendors (Mackey & Liang, 2021). It may not always be clear whether a business is a subsidiary or a primary distribution, as the arrows between the two wholesalers in Figure 2.1 demonstrate. For instance, according to the need for particular medicines, a primary distribution could buy products not just directly from the producer but also via secondary distributors (Uddin et al. 2021).

2.3.1 Falsified, Unregistered and Substandard Drugs

The presence of falsified, unregistered and substandard drugs throughout the supply chain is caused by a number of circumstances, some of which include the unauthorised importation of inferior medications, inadequate production and storage procedures, theft, and the introduction of inferior drugs (Clark, 2020). Throughout the sector, wholesalers frequently buy from and sell to one another. Prior to actually reaching the patient, commodities can be continuously repackaging by each distributor as they move between a wide range of businesses. At the wholesalers, a

procedure known as "Sating" allows for the blending of fake medications with real ones (Mackey & Liang, 2021). Unknowingly purchasing counterfeit goods through a secondary wholesaler business, for instance, can lead to this if a distributor makes a buy from them. The fake medications can be given real labels when they are repackaged at the wholesaler. Drugs are initially delivered by manufacturers in wrapping designed to prevent fraud. During the bundling process, these can be deleted, and batch identifiers can be reproduced (Blackstone et al., 2022).

Drug diversion is another typical entrance channel for fake medications into the pharmaceutical manufacturing process, according to Williams and McKnight (2021). When narcotics that are legal to sell in one country are instead sold in another, this is known as drug diversion. Criminals use supply chain sections where things exit a verified custody network so they can introduce fake goods (Justice, 2020). The term "grey markets" refers to markets that deal in medications that have been diverted yet typically have little oversight from regulators. Hacking into the database is another way that fake pharmaceuticals might enter the pharmaceutical supply chain. Several partners in a supply chain administration may use various databases or servers, as per Metcalf et al. (2019). Hackers may have access to the data. The database may be injected with the hacker's own collection of information. This data could relate to bogus pharmaceuticals that could enter the supply chain masquerading as real ones.

The producer is the initial link in the drug supply chain, according to Wu and Lin (2019). This area is the most likely location for an unregistered chemical or component to enter circulation as there are numerous ways for items to be substandard. In some instances, the wrong prescriptions are written on containers, and inferior cures are promoted in place of effective treatments. The providers may also produce substandard drugs (Lokesh et al., 2021). Due to the large number of suppliers using the network, it is possible for a member of the inside to engage in illicit practices. They could simply alter the database and conceal the bogus pharmaceuticals in the supplier relationships. Via retail stores, fake medications can also get into the pharmaceutical supply chain. even if the medications are lawfully delivered to the retail locations. Medicines can also simply be substituted inside store outlets. The real medicines can then be resold for a premium cost or in any other method, and the falsified drugs can subsequently be used as the actual ones (Rabah, 2021).

2.3.2 Traceability in the Pharmaceutical Supply Chain

In order to identify the present and all prior product managers, an efficient traceability system is required due to the complexity of the products and transactional flows in the drug supply chain (Tseng et al., 2018). Computerising the tracking and identification procedure also significantly improves regulatory control and guarantees the quality of the product. The creation of a decentralised shared information platform for an unchangeable, reliable, responsible, and comprehensive system in the drug supply chain is possible with the help of blockchain-based medication tracing (Figorilli et al., 2018).

The Hyperledger fabric is a popular blockchain-based architecture that has been hailed in empirical research as meeting crucial needs for medication tracking (Bryatov & Borodinov, 2019). When contrasted to other blockchain networks like Ethereum, Quorum, and BigChain, this offers a superior level of trust, independence, openness, confidentiality, safety, integrity of information, scalability, adaptability, and durability (Pandey & Litoriya, 2020). This technology may be a crucial facilitator for creating private blockchain system settings where regulatory bodies and participants will enrol, administer, and regulate pharmaceutical companies and their end consumers under the supervision of the administration or a group of regulatory bodies (Viriyasitavat & Hoonsopon, 2019).

Although medical system traceability offers benefits, it cannot simultaneously support decentralised data storage (Chen et al., 2018). Informationization, complete, impenetrable data, and privacy rights are the three needs. Blockchain technology offers unique advantages in the setting of visibility systems since its autonomous and decentralised digital library can ensure the veracity of information. The features of technology tracking and data tamper susceptibility can efficiently control the supply chain problem, as can access to information and total reliability of data flow; faking and substandard problems; anti-tampering and time stamps of blockchain application data (Viriyasitavat & Hoonsopon, 2019). The traits may be employed to establish proof, hold people accountable, and settle conflicts between different parties. A blockchain-assisted medication traceability system is suggested to prevent difficulties with falsified drugs in the market without integrating the technological benefits of the blockchain and the drawbacks of the present healthcare anti-counterfeiting public blockchain (Mani et al., 2022).

2.4 Legacy Technologies in Pharmaceutical Supply Chain

To increase stakeholder trust and increase product visibility in supply chains, many technology-driven strategies have been employed, including e-pedigree, RFID tags, serialisation, and IoT (Wu & Lin, 2019; Bryatov & Borodinov, 2019). These technologies are centralised, though, and they have significant flaws in terms of security, privacy, interoperability, and scalability when it pertains to avoiding falsified goods in supply chains.

2.4.1 Barcoding

At the packaging level, barcoding is a low-cost technology that can systematise and spot fake medications. To prevent these shipments from being stolen, bar codes should be printed and attached (Pandey & Litoriya, 2020). The use of barcodes to automate fake product authentication at the attribute level has now become standard procedure in the pharmaceutical sector (Lin et al., 2021). Barcoding's price and familiarity are two of its main advantages. Also, it is an easy process because phoney pharmaceuticals are easily distinguished once the objects have been marked. A duplicate code would be detected by the barcode reader, prompting an investigation into potential fake goods. Also, it is simply scaleable, independent of the infrastructure set up (Amin, 2020). Barcoding's primary flaw is its screening processes (Pandey & Litoriya, 2020). The manpower cost increases as one's level of granularity increases (Rabah, 2021). It is still a relatively recent development, with global legal permissions being its most challenging hurdle (Caro et al., 2018).

2.4.2 RFID Tags

Modern identifying techniques like radio frequency identification can increase transparency in the supply chain of pharmaceuticals (Clauson et al., 2018). A RFID tag is concealed within a regular label to trace the movement of the medication across the supply chain. Any goods that cannot be linked to the maker utilising RFID identification is rejected. However, the metal packing for medical supplies, such as pipes, could make the process of identification more difficult and lead to errors (Xie et al., 2021).

The fact that RFID tags are secure when stored is one of its key advantages. It is seen to be a good technique to guarantee the security of the container that is being marked, not the goods

being transported (Sahoo et al., 2020). Also, because there is no human participation and scanning is often performed by fixed scanners, there is less chance of error. The biggest drawbacks are that it needs a lot of equipment and that it doesn't even have end-to-end security. Moreover, it has no capacity to offer in-transit protection (Longo et al., 2019). RFID only functions at a storage unit; it is ineffective while items are being transported by more than one means of transport. Due to their "expensive cost per tag" in comparison to barcodes, RFID tags are also exclusively used to mark parcels. Because specific drug packets are difficult to tag, it is simple to recreate these packages in an FTL or LTL shipment with phoney items. Due to the lack of standardised solutions that would facilitate integration, flexibility, and execution, RFID tags ultimately lack complete interchange (Shu et al., 2020).

2.4.3 Calling in the Numeric Token (CNT)

The Calling in the Numeric Token (CNT) technique makes use of alphanumeric tokens, ID-codes, and pharma industry associations (Kim et al., 2019). Cachin (2021) cites three guidelines for the strategy: The ID-codes must be unexpected, random, and distinctive for each sample holder inside a specific Lot. Additionally, there must be at minimum 1000 times more potential ID-codes than there are real product vessels within that Lot (Khan & Byun, 2020). In databases under the authority of the supplier, valid ID codes are preserved. The consumer dials the ID-code found on the container's numbered token when they want to verify the legitimacy of the item they just purchased (Longo et al., 2019). The consumer is informed if the goods are real if the ID-code is a legitimate number. The buyer is informed that their purchase is a fake if another caller placed a matching ID code previously. This approach is straightforward yet dangerous when used by a first caller who might have not received adequate warning and choose not to purchase the item, causing a subsequent caller to incorrectly declare the identical genuine item to be a replica (Kim et al., 2019).

The process is based on a safe registry that is managed by the pharmaceutical package's manufacturer or supplier (Molina et al., 2019). Listings of time-controlled ID characters are stored in the database and are also etched in a transitory computer memory on each encrypt active RFID tag. Whenever the tag is set up for delivery, a pseudorandom code source creates the ID-codes (Kumar & Tripathi, 2019). Having a backup strategy is helpful in the event that

anything fails but it's not a must. The label and the item that must be sent out are sealed together (Ekblaw, 2020). The label is activated when the sealing is destroyed, which can happen when someone attempts to alter the items or when a client opens the product package. The tag completes a number of duties at such an occurrence. An inside register is updated with the ID-code linked to the moment the biological clock is recording (Prisco, 2019).

2.4.4 Serialisation

Data replication is a technology that uses radio waves to track and identify things and people (Molina et al., 2019). Producers can assign distinctive identities to packages using RFID coding. A chip reader records the product's characteristics as it travels through into the supply chain (Shu et al., 2020). To prevent manipulation, the chips can be concealed among sizable batches of goods. A fundamental benefit of serialisation is the capacity to monitor and trace transactions, and big batches of microchip can be camouflaged to prevent fraud. The fact that it is expensive and vulnerable to cyberattacks is a major drawback. Furthermore, there are interoperability problems and the possibility of chip tampering (Wu & Lin, 2019).

2.4.5 Blockchain Technology

A series of blocks carrying transaction information makes up the digital technology paradigm known as blockchain, which can be used to store data (Metcalf et al., 2019). It is a decentralised technology that enables encrypted data sharing via networks. A transfer must first be confirmed by the network elements using an overwhelming consensus process, where all nodes in the network concur that the transaction is valid, before it can be published to a Blockchain (Williams & McKnight, 2021). To build the safe chain, integrity-protected blocks are hashed together. Each block of data in the Blockchain is assigned a distinct unique identifier (the hash) that is identical to the contents in that block (Roxanne & Lisa, 2022).

A framework for decentralised blockchain solutions, Hyperledger Fabric is reinforced by a system structure that offers great degrees of security, robustness, scalability, and adaptability (Astarita et al., 2020). It is a distributed ledger technology of the enterprise-grade level constructed on the blockchain, which uses payment methods to maintain credibility between many participants. Although Hyperledger Fabric eliminates the notion of extraction, it keeps

many of the advantageous characteristics of a standard crypto currency blockchain (such as Ethereum or Bitcoin), including block irreversibility, consequentialism regarding the order of events, and the capacity to avoid dual expenditure, among many others (McGhin et al., 2019). It has been proven that Hyperledger Fabric offers enhanced transactional bandwidth, up to several thousands of transactions per second. Such features, among others, make Hyperledger fabric an excellent option for intricate supply chain architectures with various logical and physical activities and players. By using NodeJS, Go, and Java among other languages as opposed to specialised development tools, the acceptance barrier for these innovations is reduced (Saxena et al., 2020).

Three important features set apart blockchain as the suitable technology for addressing counterfeit drugs through tracking its movement along the supply chain. These include consensus & immutability, private keys and decentralisation (Chen et al., 2018).

Consensus and Immutability: Among the key factors driving businesses to adopt blockchain technology is its unchangeable properties. A block will separate from the preceding blocks if it is changed. A modified block must be connected to the other transactions for it to be approved on the Blockchain. The cable network nodes collaborate to reach an agreement on which transactions are legitimate and those that aren't. The Blockchain's consumers were informed that information has been changed and can choose to accept or reject the modification. After then, the Blockchain was restored to a former condition in which all of the transactions are still linked collectively (Dégardin et al., 2021).

Private keys are given to collaborating nodes of a network and are connected to the operations they carry out. Each transaction is signed with a digital signature made using the encryption key. A cryptographic signature is given to each network node, thereby establishing ownership of their entering data (Xu et al., 2018).

Decentralisation: Blockchain is totally decentralised, thus it doesn't rely on a single repository to safeguard transaction records. It follows that there isn't a single failure point. As there are several duplicates of the identical operations since the system is decentralised, a hacker would have to alter all versions and violate the consensus mechanism prior to being able to change something (Bocek et al., 2019).

2.4.6 IoT Integrated Blockchain

When combined, blockchain and Internet of Things (IoT) can greatly aid in the fight against pharmaceutical product fraud and theft (Figorilli et al., 2018). The pharmaceutical distribution network was totally automated and tamper-proof at the same time. The automated information capture that the current methods lacked is what this tech mix offers to the scene. Smart applications like honeybees, which can record specimen containers and status both in the warehouses and during transportation, are important among these (Chen et al., 2018).

The main pros of using IoT Integrated Blockchain include zero human intervention, as almost anything can be automated once a blockchain system and IoT are combined, including data collection. Additionally, there is no room for error (Agbo et al., 2019). Full automation gets rid of every possibility of error (caused by manual information management) that hinders the achievement of the flawless system that one strives for. There is absolutely nil need for organisational transformation (Saxena et al., 2020). If one were to automate the system or handle any aspect of its setup, administration, or assessment by themselves, they wouldn't need to have the same level of process architecture (Harris et al., 2019).

2.6 Gap Statement

The gap warranting the present study is twofold, that is practice gap and knowledge. The gap in practice is that several innovation initiatives have been used, such as barcode scanners, e-pedigree, RFID tags, serialisation, and IoT to increase stakeholder confidence and enhance brand awareness in distribution networks (Wu & Lin, 2019; Bryatov & Borodinov, 2019). However, these systems are centralised and have significant drawbacks in regards to safety, confidentiality, compatibility, and scaling when it involves avoiding counterfeit goods in distribution networks.

The knowledge gap warranting the study is that a cross-section of studies has been conducted pertinent to drug counterfeiting within the network of pharmacies. Most studies regard traceability to be important in the fight versus counterfeit pharmaceuticals. While several technology strategies have been used to guarantee traceability, most studies have however used the Ethereum blockchain platform to build their advanced solutions (Astarita et al., 2020). This

has however been found to register weakness in such pertinent areas as trust, scalability, decentralisation, modularity, transparency, security, privacy, deployment and data integrity. Conversely, several academics concur that blockchain technology would be very useful (Uddin et al., 2021). Since Hyperledger fabric has conversely recorded strengths in these areas, the present study sets out to use the Hyperledger fabric architecture to build a blockchain technology that can trace drug movement along the pharmaceutical supply chain.

2.7 Conceptual Framework

From locating the active substances for a drug (the supplier) to producing the finished product (the medicine), distribution, and delivery to patients (the consumers), a pharmaceutical supply chain maintains an end-to-end procedure (Saxena et al., 2020). There are various variables involved in the pharmaceutical supply chain, such as those who provide raw ingredients, producers, wholesalers, regulatory agencies, pharmacists, clinics, and consumers. Before arriving at their final formula, components for medicines are typically collected from a variety of sources (McGhin et al., 2019). The responsibility of the manufacturers in the distribution network is to make sure that their drug stockpile is prepared for distribution to wholesalers. Upon the receipt of orders from retailers and wholesalers, manufacturers ship the ordered goods to the vendors' facilities for storage. To preserve transparency all across the process, wholesalers will give manufacturers reports on inventory data. Thousands of pharmacists and dispensers are connected via wholesalers, who also provide deliveries (Uddin et al., 2021).

The presence of counterfeit drugs throughout the supply chain is caused by a number of circumstances, some of which include the unauthorised importation of inferior medications, inadequate production and storage procedures, theft, and the introduction of inferior drugs (Clark, 2020). The distribution network for pharmaceuticals frequently sees counterfeit drugs enter through drug diversion. Lawbreakers use supply chain sections where things exit a verified custody network so they can introduce fake goods (Justice, 2020). Also, attackers have the ability to add their own information to the database. The creation of a decentralised shared data platform for an unchangeable, reliable, responsible, and transparent process in the medicine supply chain is possible with the help of blockchain-based medication tracing (Mackey & Liang, 2021). The Hyperledger fabric is a popular blockchain-based framework that has been hailed in

empirical research as meeting crucial needs for medication tracking (Bryatov & Borodinov, 2019). When contrasted to other public blockchains like BigChain, Quorum, and Ethereum, this offers a superior level of trust, independence, openness, anonymity, safety, integrity of data, installation, adaptability, and scaling (Pandey & Litoriya, 2020).

Stakeholders are able to monitor the flow of goods across the supply chain using the conceptual model depicted in Figure 2.2. (Mani et al., 2022). Seeing the background of the pharmaceutical supply chain is made secure and safe with the help of hyperledger fabric. The Hyperledger fabric can process over 3,500 transactions per second (Williams & McKnight, 2021). The customer is guided by this technology through the ordering, delivery, and enrollment processes. Consumers can follow the progress of their purchases from beginning to end thanks to total supply chain insight. The software displays a retailer's previous orders, shipment history, and receipts history as well as the background of the user who signed in to the software (Molina et al., 2019). All instructions in the system are accessible to the regulators, who are responsible for ensuring that the procedures are followed correctly. The hash code and the hash of the material providers are both kept on the blockchain network. The producer comes next in the chain of distribution; they produce the medications and associate them with a special hash code. The block chain stores the hash code and information about how the pharmaceuticals were manufactured. Vendor data is next in the distribution network, followed by retail and healthcare centres (Lokesh et al., 2021).

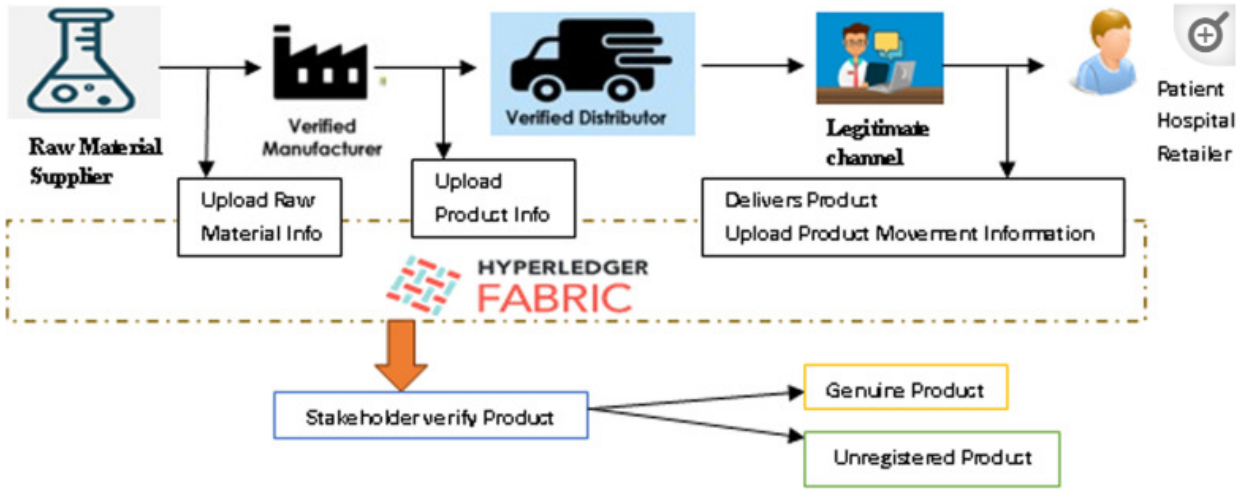

Figure 6. Adoption Conceptual Model

Source: Mani et al. (2022)

2.8 Technology Adoption Model

The present study was anchored on the Technology Acceptance Model (TAM) proposed by Davis (1989). TAM is a theory of information systems that simulates how users adopt and use new technology. Davis (1985) asserts that user incentive, which in return is significantly inspired by an environmental stimulation consisting of the characteristics and abilities of the real system, may be used to forecast the actual software use, resulting in the end-point where humans use technologies (Figure 7).

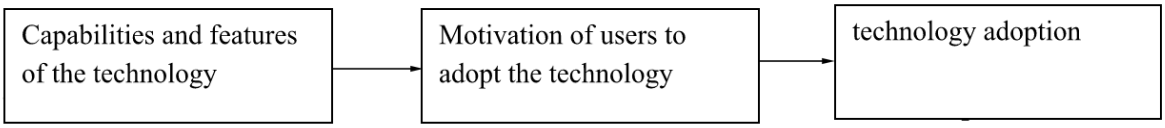

Figure 7. Conceptual Model for Technology Acceptance Model (Davis, 1985)

Davis (1989) developed his conceptual framework in response to Fishbein and Ajzen (1985) and proposed the TAM shown in Figure 2. According to the concept, a user's attitude toward a technology is a key factor in determining whether they will really utilise or refuse the technology. Two (2) beliefs, namely perceived utility and usability, have an impact on attitude.

According to Davis (1989), PU is the extent that one thinks that utilising a given system would improve their ability to accomplish their task. This indicates if one thinks the technology to be beneficial for what they desire to perform. On the opposite hand, perceived easiness is characterised as the extent to which one thinks utilising a specific technology would be effortless (Davis, 1989). The hurdles are overcome if the device is simple to use. Nobody has a favourable impression of anything if it is difficult to use and has a confusing UI. The systems engineering traits, which are expressed by X1, X2, and X3, have a direct impact on the two perceptions (utility and usability).

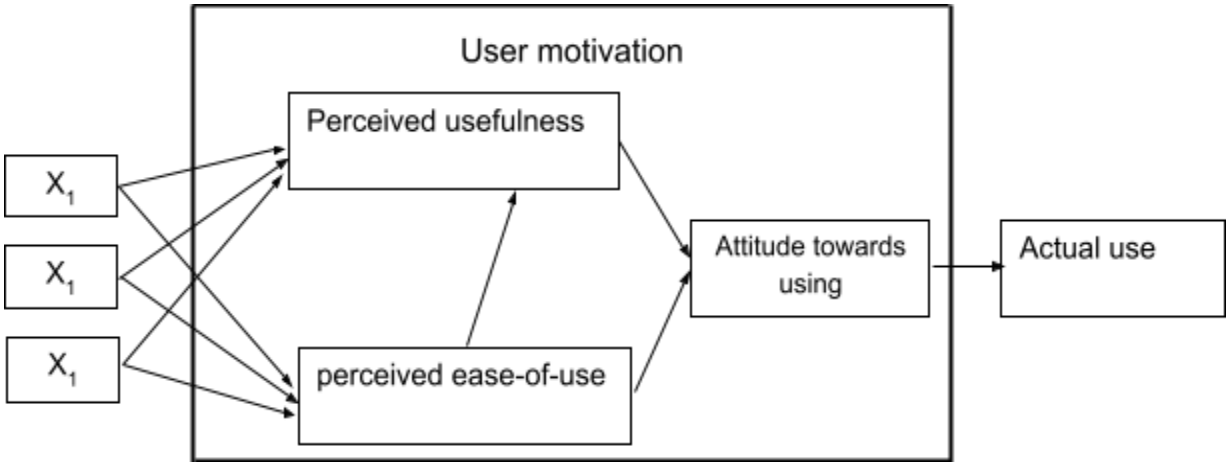

Figure 8. Original TAM Proposed by Davis (1986)

In line with TAM, this paper argues that the adoption of a blockchain technology can improve the pharmaceutical supply chain depending on its capabilities, perceived usefulness, easiness and usability.

CHAPTER THREE: METHODOLOGY

This chapter defines the research design that was adopted. It then introduces the research methodology followed by revealing answers to the research questions. It further discusses the target population, sampling technique, sample size, data collection and data analysis alongside with justification.

3.1 Research Design

Nachmias (2010) defines research design as a mathematical formalism of proof that enables the study to infer causal relationships between the ideas under investigation. This study has adopted the Design Science Research (DSR) with Focus Group (FG) that guided the researcher in developing and testing an instrument on a specific population. A focus group qualitative research technique was used to bring together a selected demographic of respondents to assess the findings of the data collected.

The DSR is a framework that guides the researcher in developing and testing an instrument on a specific population. The DSR process ensures that the production of main pieces of information are in accordance with the FG sessions (Henriques and O'Neill's, 2019). According to Henriques and O'Neill's (2019) there must exist traceability between problem, requirements, solution and the produced artefact. DSR involves a qualitative research phase, where the researcher reviews existing literature to gain insight into the research topic, and a subsequent quantitative phase where the researcher tests the instrument they have created. In the case of this research project, the study was on the pharmaceutical supply chain, and the aim was to create an artefact using blockchain technology. The qualitative data was used to build the expected user requirements. The system's functional and non-functional needs were tested using actual smart labels in a simulated environment to determine the system functionality. The outcome of the research was communicated to the relevant stakeholders, and recommendations made based on the findings.

A process model that has been used to support the inherited designed science research requirements was developed by Gregor and Hevner (2013),. It includes the main activities directly related with the Focus Group sessions, which are associated with the preparation of the session development processes. The diagram below indicates the main activities that are directly

related with the focus group sessions, which are associated with the session Development processes used in this research.

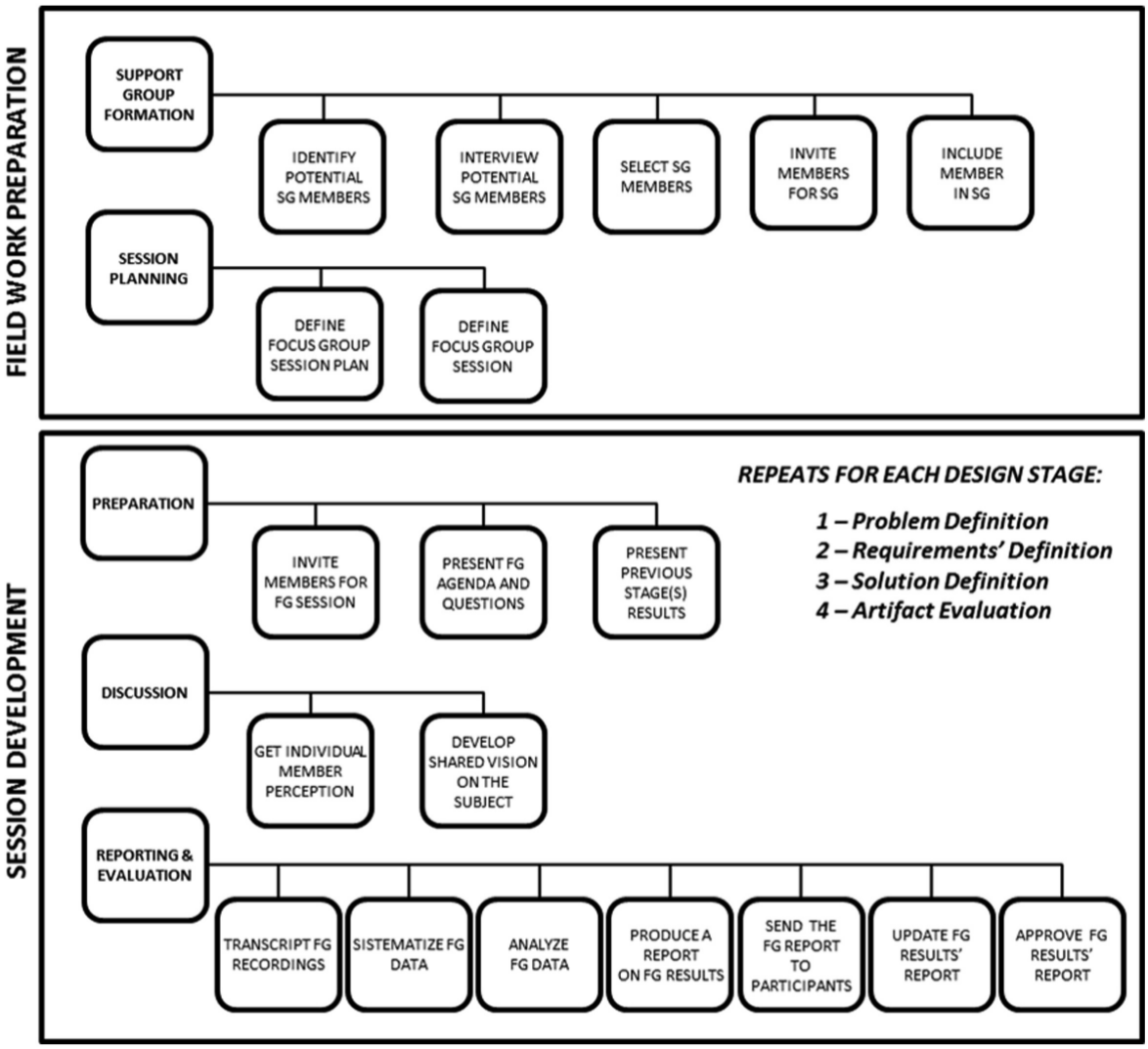

Figure 9. FG Session Development Model.

From the illustration above it can be noted that the identification of main activities to be conducted for each DSR stage reveals the corresponding focus group sessions and their primary objective.

3.1.1 Target Population

According to Tashakkori and Teddlie (2008)., study population may be categorised into two, that is target population and accessible population. Bryman (2004) defines target population as the complete set of items or cases from which a suitable sample is engaged to study and for which inferences are to be made. The accessible population is on the other hand defined by Kumar (2011) as members of the target population who are willing to participate and were available at the time of the study. The target population includes all stakeholders in the pharmaceutical supply chain in Kenya. These include manufacturers, distributors, PPB as the Drug Regulatory Authority, KEMSA, pharmacies and hospitals. The accessible population on the other hand includes manufacturers, distributors, PPB, KEMSA, pharmacies and hospitals based in Nairobi County (Table 3.1). The identified target population is deemed appropriate for the present study owing to its relevance in the subject matter, as the study seeks to give an accurate account of a blockchain technology that can trace drug movement along the pharmaceutical supply chain through a web application.

3.1.2 Sampling

Kothari (2004) defines sampling techniques as the various methods that assist researchers to reduce the amount of data that they would need to collect by narrowing down to a specific sub-group rather than the total population. Sampling could entail either probability or non-probability techniques (Stevens, 2002). Non-probability method entails non-random choosing according to ease of use or other considerations, making it simple to gather data. Probabilistic sampling involves random assortment, permitting one to draw robust statistical conclusions about the entire population.

In the study, a combination of stratified sampling (probability) and purposive (non-probability) sampling techniques was employed. Stratified sampling was used at the organisational level, whereby the different stakeholder groups formed the strata. Non-probability sampling was then used to select individual respondents, whereby the researcher selected people out of convenience. The most relevant participants for this investigation were those who work with the partner organisations' inventory information management.

3.1.3 Sample Size

In sampling participant stakeholder categories, stratified sampling was employed whereby one stakeholder entity was selected across the supply chain. In this regard, the key most participant manufacturer, distributors and retailers was selected per category based on their market share within the Kenyan pharmaceutical industry. To this end, the study samples GlaxoSmithKline (GSK) Laboratory and Allied Ltd Limited to represent the pharmaceuticals manufacturing industry, as the company was not only considered to have the biggest market share (Abuyeka, 2021), but has also been successfully sampled before in a related study by Munyao (2022). Two GSK's distributors were then sampled; one for distribution to private sector pharmacies, and KEMSA as the sole distributor to public hospitals. One major pharmaceutical retailer was then sampled, along with a public hospital to represent the retail end in the public sector. As for public hospitals, a level 2 hospital was purposely selected owing to ease of access to data compared to higher level hospitals. The reason for sampling both private sector pharmacies and a public hospital was that the two value chains (private and public) may harbour different entry points for drugs owing to the operational differences thereof. As indicated in Table 3.1, 10 users were then uniformly and purposively sampled in each respondent organisation, bringing the total sample size to 50. These were drawn from the procurement/inventory units in respective organisations.

Category	**Sample Size**
Manufacturers	30
Private sector distributors	20
KEMSA	20
Public hospitals	20
Retail pharmacies	20
Total	**110**

Table 1. Sample Determination

3.1.4 Data Collection

The research study relied on primary data, which was collected by use of a semi-structured questionnaire as illustrated in Appendix I. A semi-structured questionnaire was utilised for the reasons it was able to provide adequate time for respondents to answer back to the items; it also confines response to a set of predetermined questions aimed at directly addressing the study

objectives. A semi-structured questionnaire also has the ability to reach a large number of participants in a short period of time; and that it provides a sense of confidentiality to the participant; and it was an ideal methodology with no bias associated with personal character traits (Kumar, 2011). Creswell (2003) recommends the use of semi-structured questionnaires because they are advantaged in being easy to administer, analyse and time efficient.

The TAM was used to understand and explain the adoption of blockchain technology in the pharmaceutical supply chain. The TAM dependents are Perceived Ease of Use (PEU), Perceived Usefulness (PU) and Attitude to Adopt (ATA). This research present the following hypotheses:

H1: There is a relationship between Perceived Usefulness (PU) and the Attitude to Adopt (Attitude to Adopt) blockchain technology in the pharmaceutical supply chain.

H2: There is a relationship between Perceived Usefulness (PU) and the Perceived Ease of Use (PEU) of adopting blockchain technology in the pharmaceutical supply chain.

H3: There is a relationship between Perceived Ease of Use (PEU) and Attitude to Adopt (ATA) blockchain technology in the pharmaceutical supply chain.

The measures for PU and PEU and ATA were assessed using a five-point Likert type scale ranging from 1= strongly disagree to 5= strongly agree. A total of 110 respondents filled the questionnaire. The questionnaire was thematically structured, as per the study objectives. The first part of the questionnaires captured demographic characteristics, while the second part contained questions pertinent to the first objective, that is the adoption of blockchain technology in the pharmaceutical supply chain. The third part covered the second objective, that is how hyper ledger fabrics in blockchain improve traceability of drugs along the pharmaceutical supply chain. The fourth part delved into questions pertinent to the third objective, that is how blockchain secures data handling to address data manipulation and human error along the pharmaceutical supply chain.

Kothari (2004) identifies two broad methods of data collection, that is researcher-administered and self-administered. When a responder completes a questionnaire independently, it is referred to as self-administered. When an investigator administers a questionnaire through an examination, it is referred to as research conducted. In the present study, the self-administered

method of data collection was employed. The questionnaire was particularly administered on a 'drop and pick' approach, whereby the researcher administered the questionnaire to respondents who were then given ample time to respond. The researcher then collected the duly filled questionnaires at respondents' convenience.

Information on system requirements for the blockchain solution was gathered by use of literature review. In this regard, the following literature sources were used for this review:

- Elsevier,
- ScienceDirect,
- Google Scholar,
- Research Gate,
- Scopus,
- Springer SpringerLink,
- Academia,
- IEEE Xplore.

The papers selected fulfilled the inclusion criteria, which include having been published from the year 2016 or later; the paper was written in English; and the use of blockchain in the pharmaceutical supply chain was referenced in the title. The following keywords that were used to conduct the search across these databases: blockchain, traceability of drugs, pharmaceutical supply chain, hyperledger fabric, human error and data manipulation. The following search strings were used: blockchain and traceability of drugs; traceability and pharmaceutical supply chain; data manipulation and human error along the pharmaceutical supply chain.

3.1.5 Data Analysis

After collection of the data, the study assessed the questionnaires for completeness after which coding and entry of the data followed. Data analysis was then conducted using Statistical Packages for Social Sciences (SPSS) version 26. Both inferential and descriptive analyses were utilized in analysing the quantitative data obtained from the questionnaire. Descriptive analysis involved means, frequency counts, and percentages; while inferential analytics included both regression analysis and Pearson correlation. Regression computation was used to determine

whether the outcome and the predictor variables are related. The study used the following regression equation:

$$Y = \beta 0 + \beta X + \varepsilon$$

Y = Traceability of drugs

β0 = Constant

β = Beta coefficients

X = Blockchain technology

ε = Error term

3.2 Design Science Research Methodology

According to Hevner et al. (2004), the DSR process involves six steps: problem recognition and motivations, description of the aims for a resolution, development and design, presentation, assessment, and communications. Moreover, there are four potential entrance points. the problem-centred approach, the goal-centred approach, the design and advancement approach, and the client/context approach.

3.2.1 Problem Identification

In this action, the particular research issue is explained, and the necessity of a fix is advocated (Gregor & Hevner, 2013). In addition to inspiring the investigator and the study's audiences to pursue the resolution, demonstrating. The value of a resolution also allows the reader to gauge the author's understanding of the problem at question. Understanding of the present state of the issue and the importance of figuring out a remedy was one of the resources needed for this task (Tashakkori & Teddlie, 2008). As a component of the issue detection phase, a thorough review of academic sources was done to determine the issue. Distributed ledger technology, pharmaceutical distribution chain, transparency in the drug supply chain utilizing blockchain, hyper ledger fabrics in blockchain, and medication tracking are among the keywords used in the searching for publications according to the study's title and aims.

3.2.2 Definition of the Objectives

An explanation of the issue and understanding of what is realistic and achievable may be utilised to deduce a software's objectives (Bryman, 2004). The aims are subjective, including explanation of how a new artefact was intended to enable answers to issues that have not yet been resolved, or quantifiable, such as terms whereby a desirable answer would be superior to present ones (Kumar, 2011). The goals should be logically deduced from the statement of the problem. In the present study, the three set objectives are both quantitative and qualitative in nature. Data towards the realization of the objectives was gathered by use of a semi-structured questionnaire.

3.2.3 Design and development

A piece of art is produced. A DSR artefact can hypothetically be anything created that entails a scholarly contribution to the layout (Stevens, 2002). This procedure determines the item's infrastructure needed and utility before the object itself is constructed. In the present study, the Hyperledger Fabric architecture was used to design and develop the system. Because it offers decentralised blockchain systems and is supported by a system structure that offers high levels of privacy, robustness, scalability, and durability, the Hyperledger Fabric was recommended in the study. Superior processing bandwidth of up to a few thousands of transactions every second has been demonstrated. Hyperledger fabric is an ideal choice for complicated supply-chain structures with numerous both logical and physical operations and counterparties because of these qualities, among others.

3.2.4 Demonstration

This activity shows how to apply the object to address one or more occurrences of the issue (Creswell, 2003). This might entail applying it to an investigation, model, case analysis, piece of evidence, or other applicable task. A chosen representative group of the parties concerned witness the investigator show how to make use of the artefact.

3.2.5 Evaluation

The evaluation gauges how effectively the artefact promotes a problem-solving strategy (Kumar, 2011). Comparing a software's objectives to the results actually attained while utilising the artefact in its authorised context was the purpose of this activity. Assessment could take a variety

of forms according to the issue, the setting, and the artefact (Kothari, 2004). At the conclusion of this exercise, the investigators can select to either go on to communications and allow further development to subsequent projects, or loop back to phase three to try to enhance the efficacy of the artefact. To accomplish the goals of the study, a platform designed on the Hyperledger fabric topology would be employed in conjunction with semi-structured questionnaires in the current study.

3.2.6 Communication

Ultimately, the specifics of the issue and the desired solution are communicated to all relevant parties. According to the study's goals and the population, such as researchers and practitioners, effective communications methods are used (Bryman, 2004). The operation of the system, whether it was successful in achieving its goals, and the user's experiences following system interaction are all covered in this section. Whether the system in this study was successful in achieving visibility as its primary goal. A report was used as the means of communication, and it was given to the statistical sample.

3.3 Focus Group Methodology

A Focus Group (FG) is a method that uses qualitative research where the researcher conducts a group interview with participants who share common demographic backgrounds with the same characteristics (Mulry, M. H, 2008). According to Murly, (2008) the focus group sessions foster open communication and leverage participant interaction to gather unique data that cannot be obtained through surveys.

3.3.1 Focus Group Findings

The focus group research technique involves bringing together selected participants to take part in the focus group discussion in reviewing the specific key findings related to the research. The participants are selected because they have specific characteristics in common in relation to the subject topic under review (Krueger and Casey, 2015). The participants in the focus group discussion are members who participated in the research survey. According to Krueger and Casey (2015), a virtual meeting can be conducted where the key findings of the research analysis

were presented to the focus group participants. The discussions are meant to provide valuable insights as to how various ideas are viewed by the research respondents.

3.3.2 Focus Group Discussions

The focus group discussion endorses the design science research through planning and developing discussion activities that fulfil the related DSR needs (Fang, Y., & Zhang, J., 2020). According to Kreugeur (2015), focus group discussions have distinctive traits that involve a small group of participants providing qualitative data in a discussion to aid in understanding the subject of interest. Selected 6-8 participants are allowed to express their attitude towards blockchain technology, emphasising its usefulness in increasing transparency, accountability, and traceability of drugs in the pharmaceutical supply chain. Several challenges that could hinder the adoption of blockchain are discussed. This also includes their view on cost associated with implementation, initial investment on infrastructure development, and maintenance are classified as factors that can affect adoption.

According to Fang, Y., & Zhang, J. (2020), a meta-model for design science research with focus groups can be presented as integrating four main perspectives. These perspectives include:

I. Focus group related sub-processes and activities,
II. Interface between design science research stages and focus group sessions,
III. Focus group related data components and relationships, and,
IV. Integrated perspective of focus group activities and data.

The meta-model has been applied in conducting the focus group discussions by developing facilitation and operationalization of design science research methodology.

3.4 System Validation

The Hyperledger fabrics were used in setting up the blockchain technology. To do this, the technology was initially evaluated in a simulated setting to see if it complies with the standards of a blockchain network. All of the collaborating companies' capacity to track pharmaceuticals along the distribution network was verified. The effectiveness of the system in preventing fake products was evaluated by taking into account a scenario in which dishonest parties introduce imitators into the distribution network. The mechanism was then shown to the participants. Some respondents participated in an online meeting to conduct this activity. They were shown a sample

of the web user's activities. They were then questioned and asked to give their comments on the system based on a number of criteria, including user-friendliness, drug tracing, and the likelihood that the approach was successful.

3.5 Ethical Concerns

3.5.1 Obtaining Consent

The researcher guaranteed that in the entire research process, ethics in research were observed. Permission was first sought by the researcher from the pertinent authorities prior to embarking on data collection. The study particularly ensured that information given by participants were exclusively utilized for addressing the research objectives and for academic purposes. The researcher respected participants' rights to refrain from responding to the questionnaire. The investigator exercised extreme caution to avoid pressuring participants to provide information without consent.

3.5.2 Information Gathering

The participants were guaranteed that their data remained confidential. The investigator exercised care in this respect to avoid publishing any data given in confidence or sufficient private details to reveal the participants' identities. To ensure this, the investigator stayed away from personal characteristics like names, addresses, and dates of birth, among other things. Confidentiality was further observed through adequate data security and management.

3.5.3 Avoiding Bias

Also, the investigation did abide by the standards of integrity and prevent plagiarism and biases. By documenting techniques, methods, findings, data, and publishing progress as accurately as feasible, the study assured objectivity. There won't be any manufactured, false, or misrepresented data. By appropriately crediting sources using both in-text references and citations, the investigation only further avoided plagiarism.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter covers the analysis of results as obtained from the field, and their subsequent discussions with reflections from previous related studies. The analysis was conducted with the aid of SPSS version 27, results from which are presented in both tabular and graphical forms. The chapter is structured into five main sections, including introductory analysis which entails the response rate; descriptive analysis covering demographic information and descriptive statistics for the five study variables; inferential analysis which includes both Pearson correlation and regression analysis; and discussion of findings.

4.2 Response Rate

As per the determined sample size, a total of 110 questionnaires were administered by stratified random sampling technique, with the different stakeholder categories creating the strata from which respondents were picked at random. Out of the 110 questionnaires, 93 were responded to and returned. This makes a response rate of 84.5% as broken down in Table 4.1.

	Frequency	**Percentage**
Response	93	84.5
Non-Response	17	15.5
Total	110	100.0

Table 2. Response Rate

Source: Survey Data (2023)

Consistent with Creswell (2013), the established return rate of 84.5% was regarded as excellent and adequate for both descriptive and inferential data analysis of data. Similarly, Collis and Hussey (2009) posit that a rate of return of 70% and above is “excellent”, a return rate of 60% is “good” and a return rate of 50% is “adequate”. The excellent return rate is ascribed to the

recruitment and training of 5 research assistants to aid in the administration of the questionnaires under the guidance and supervision of the researcher.

4.3 Respondent Profile

The study sought to provide a general impression of respondents' profiles. This would serve to ascertain that the study findings are representative of diverse opinions based on the different stakeholder profiles. In this regard, the information that was sought consisted of the respondent category, that is pharmaceutical manufacturer/distributor/pharmacist; and years of experience in the pharmaceutical industry. The outcomes are reported in percentages and frequencies and presented in tables and graphs.

4.3.1 Response by Stakeholder Category

Participants were requested to state their role within the pharmaceutical supply chain, that is whether pharmaceutical manufacturer, distributor or pharmacist. This would ensure that the study findings are representative of any differences in perception of blockchain technology in the pharmaceutical supply chain, based on stakeholder category. Figure 4.1 gives a depiction of the outcomes.

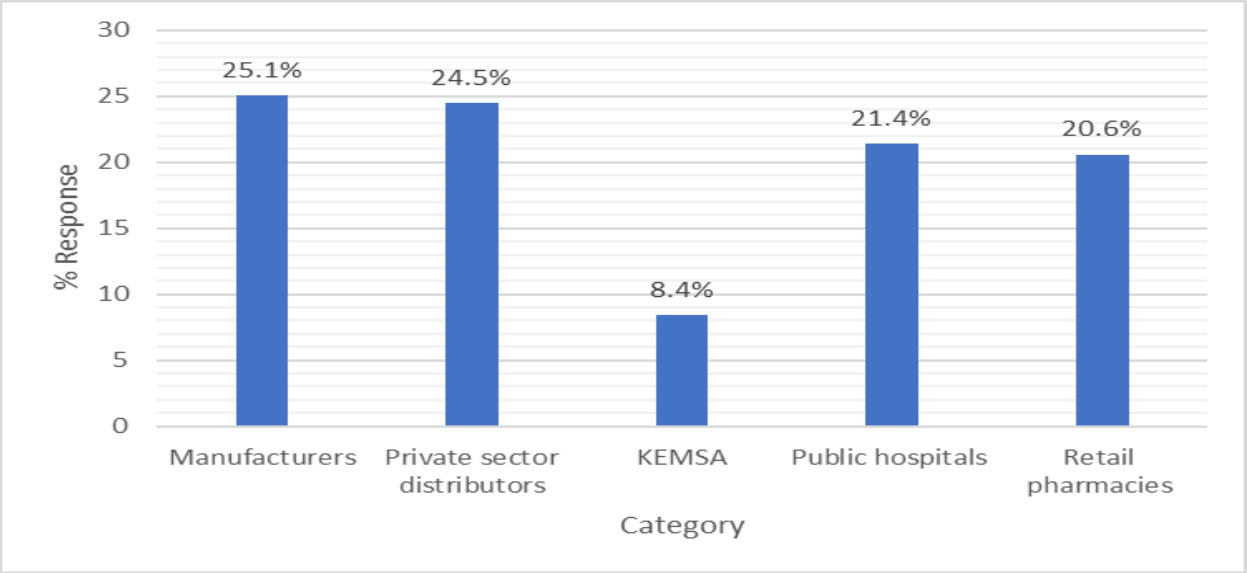

Figure 10. Response by Stakeholder Category

Source: Survey Data (2023)

Based on the depiction advanced in Figure 10, a majority of participants (25.1%) were manufacturers, followed by 24.5% who were private sector distributors; while 21.4% were public hospitals. A further 20.6% were retail pharmacies, while only 8.4% were from KEMSA. The finding implies that the study is representative of the various perceptions, scales of operation and lived experiences relevant to the use of blockchain technology in the pharmaceutical supply chain, based on stakeholder categories.

4.3.2 Response by Years of Experience

The study sought to find out respondents' years of experience. This was deemed important as it would ensure representativeness of the diverse perceptions and lived experiences relevant to blockchain technology in the pharmaceutical supply chain, based on length of operation within the industry. Figure 4.2 illustrates the findings.

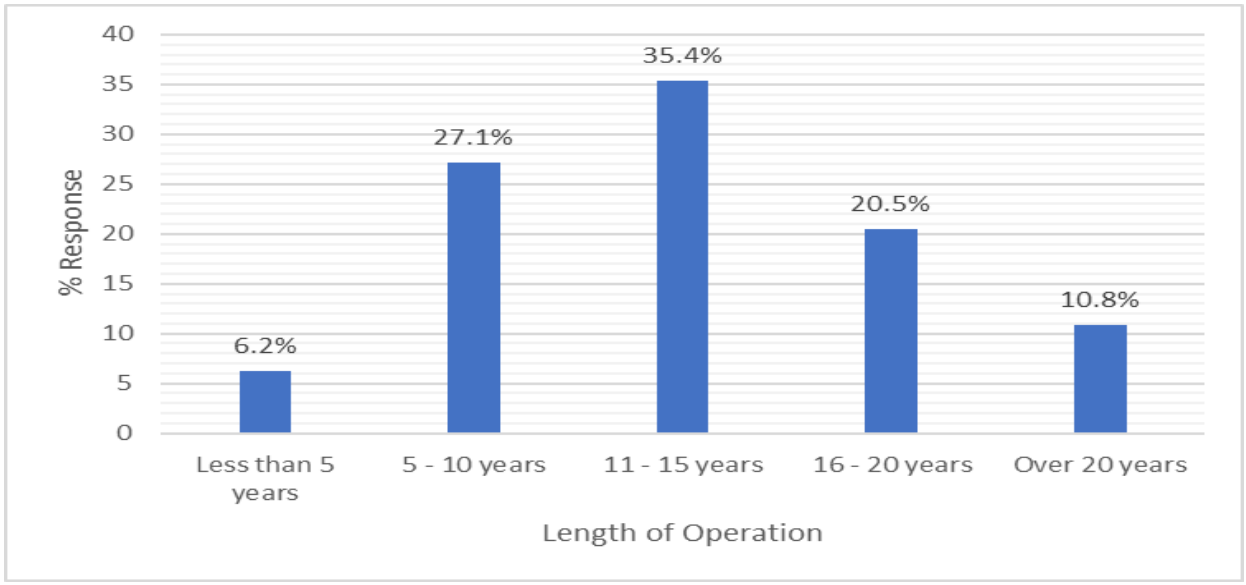

Figure 11. Response by Years of Experience

Source: Survey Data (2023)

Findings illustrated in Figure 11 reveal that a majority of respondents (35.4%) had operated for between 11 and 15 years, followed by 27.1% affirming to having been in operation for between 5 and 10 years. A further 20.5% indicated that they had operated for between 16 and 20 years; while 10.8% affirmed to having been in operation for over 20 years. Only 6.2% of respondent entities affirmed to have operated for less than 5 years. It is inferable from the results that cumulatively, most of the respondent categories had been in operation for at least 10 years, implying that they are well versed with hotel operations and the operating environment for a sufficient amount of time. The finding also means that the study is representative of the diverse perceptions with regard to the perceptions and lived experiences relevant to the use of blockchain technology in the pharmaceutical supply chain, based on stakeholder categories length of operation.

4.4 Descriptive Analysis

This section presents an analysis of the main variables explored in the study with a view to determine how a majority of respondents answered against the questions asked. To achieve this,

the study generated means from the responses provided based on a 5-point Likert scale. The variables in this regard include ease of use, perceived usefulness, awareness and perception of blockchain technology, attitude towards using, technical enablers and barriers; and the adoption readiness and intentions.

4.4.1 Ease of Use, Awareness and Perception of Blockchain Technology

Respondents were asked to rate their respective opinions regarding the ease of use, awareness, and perception of blockchain technology in the pharmaceutical supply chain. This was on a "5-point Likert scale", with "strongly disagree" denoted by number 1, "disagree" denoted by number 2, "neutral" denoted by number 3, "agree" denoted by number 4 and "strongly agree" denoted by number 5. Table 4.2 presents the results.

	Mean	**Std. Dev**
I find the user interface and functionality of blockchain technology in the pharmaceutical supply chain to be intuitive and easy to understand	3.924	0.373
The integration of blockchain technology into existing processes and systems within the pharmaceutical supply chain is perceived as seamless	3.409	0.277
Overall Mean	**3.667**	**0.325**

Table 3. Descriptive Statistics for Ease of Use, Awareness and Perception of Blockchain Technology
Source: Survey Data (2023)

The findings presented in Table above depict an overall mean of 3.667 and a standard deviation of 0.325. This means that a majority of the respondents highly affirm the ease of use, awareness and perception of blockchain technology. The standard deviation of 0.325 is less than 1 implying that a majority of the responses did not deviate significantly from the mean, in that most respondents affirmed to 'agree'. More specifically, a majority of respondents highly agree that they find the user interface and functionality of blockchain technology in the pharmaceutical supply chain to be intuitive and easy to understand (3.924). A majority however only moderately

agreed that the integration of blockchain technology into existing processes and systems within the pharmaceutical supply chain is perceived as seamless (3.409).

To assess the awareness of blockchain technology, respondents were asked to define the concept in their own words. It was established that there are moderate to low levels of awareness of the concept of blockchain technology among most respondents.

4.4.2 Perceived Usefulness

Respondents were also asked to rate their respective opinions regarding the perceived usefulness of blockchain technology in the pharmaceutical supply chain. This was also on a "5-point Likert scale", with "strongly disagree" denoted by number 1, "disagree" denoted by number 2, "neutral" denoted by number 3, "agree" denoted by number 4 and "strongly agree" denoted by number 5. Table 4.3 presents the results.

Blockchain technology has the potential to:	**Mean**	**Std. Dev**
Increase transparency in the pharmaceutical supply chain	4.155	0.450
Increase accountability in the pharmaceutical supply chain	4.167	0.441
Improve traceability in the pharmaceutical supply chain	4.183	0.388
Increase drug authenticity in the pharmaceutical supply chain	4.202	0.403
Reduce fraud in the pharmaceutical supply chain	4.173	0.380
Enhance supply chain visibility in the pharmaceutical supply chain	4.200	0.319
Overall Mean	**4.180**	**0.397**

Table 4. Descriptive Statistics for Perceived Usefulness of Blockchain Technology
Source: Survey Data (2023)

The findings presented in Table 4 depict an overall mean of 4.180 and a standard deviation of 0.397. This means that a majority of the respondents highly affirm the perceived usefulness of

blockchain technology. The standard deviation of 0.397 is less than 1 implying that a majority of the responses did not deviate significantly from the mean, in that most respondents affirmed to 'agree'. More specifically, a majority of respondents highly agree that blockchain technology has the potential to increase drug authenticity in the pharmaceutical supply chain (4.202); enhance supply chain visibility in the pharmaceutical supply chain (4.200); improve traceability in the pharmaceutical supply chain (4.183); reduce fraud in the pharmaceutical supply chain (4.173); increase accountability in the pharmaceutical supply chain (4.167); and increase transparency in the pharmaceutical supply chain (4.155).

4.4.3 Challenges in Adopting Blockchain Technology

Respondents were also asked to rate their respective opinions regarding the perceived usefulness of blockchain technology in the pharmaceutical supply chain. This was also on a "5-point Likert scale", with "strongly disagree" denoted by number 1, "disagree" denoted by number 2, "neutral" denoted by number 3, "agree" denoted by number 4 and "strongly agree" denoted by number 5. Table 4.4 presents the results.

	Mean	**Std. Dev**
Cost	4.127	0.542
Technical Complexity	3.885	0.527
Regulatory Issues	2.212	0.422
Resistance to change	3.875	0.649
Overall Mean	**3.525**	**0.535**

Table 5. Descriptive Statistics for Challenges in Adopting Blockchain Technology
Source: Survey Data (2023)

The findings presented in Table 5 depict an overall mean of 3.525 and a standard deviation of 0.535. This means that a majority of the respondents highly affirm the challenges foreseen or

experienced in using blockchain technology. The standard deviation of 0.535 is less than 1 implying that a majority of the responses did not deviate significantly from the mean, in that most respondents affirmed to 'agree'. More specifically, a majority of respondents highly affirmed cost (4.127); technical complexity (3.885); and resistance to change (3.875). a majority however dissented to regulatory issues (2.212).

4.4.4 Adoption Readiness and Intentions

Respondents were further asked to rate their readiness to adopt blockchain technology in the pharmaceutical supply chain, as whether not ready at all, somewhat ready and moderately ready. Findings are presented in Figure 4.3.

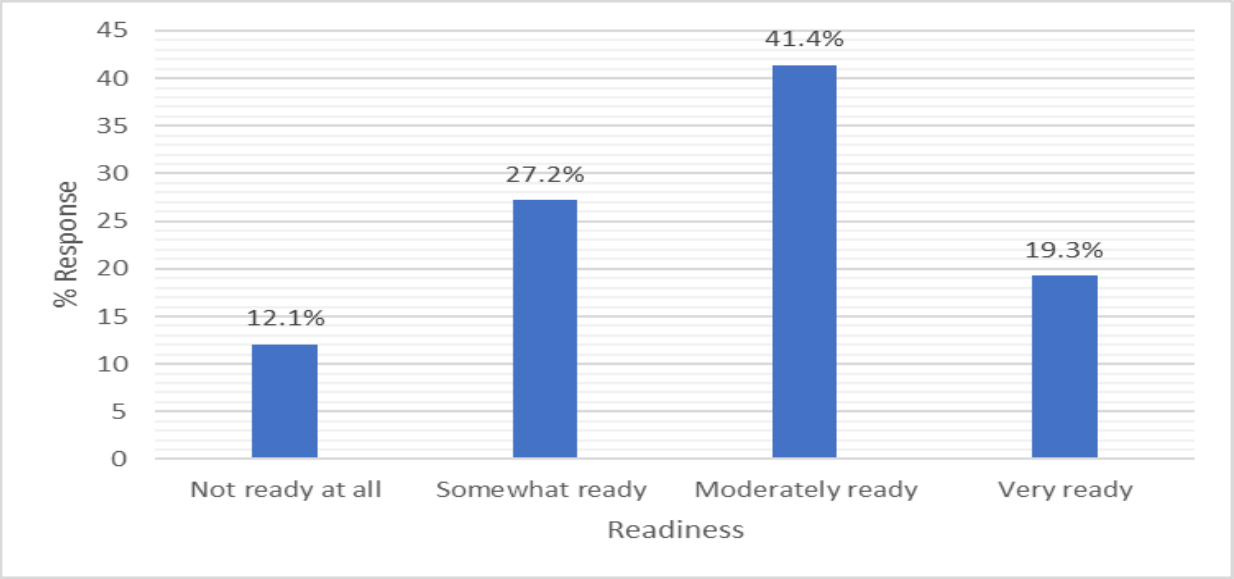

Figure 12. Adoption Readiness

Source: Survey Data (2023)

As illustrated on Figure 12, a majority of respondents (41.4%) indicated that they are moderately ready to adopt blockchain technology in the pharmaceutical supply chain. Respondents were then asked to indicate how likely they were to adopt blockchain technology in the pharmaceutical supply chain. Findings are presented in Figure 4.4.

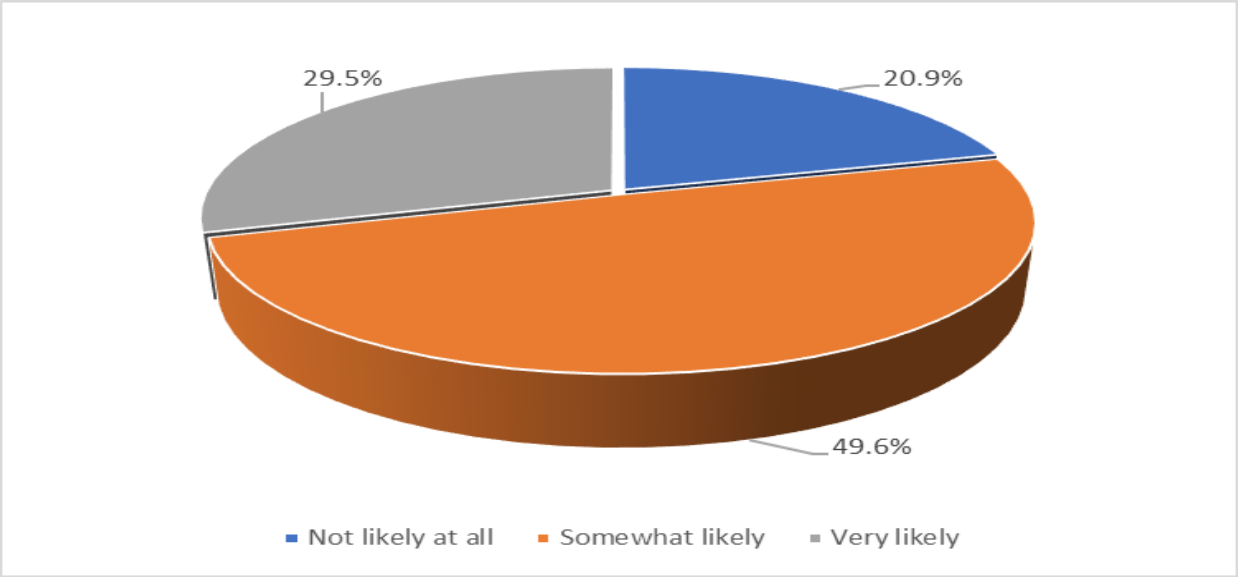

Figure 13. Likelihood of Adoption

Source: Survey Data (2023)

As shown in Figure 13, a majority of respondents are somewhat likely (49.6%) to adopt blockchain technology in the pharmaceutical supply chain. In this regard, the study further prompted to find out the factors that would influence their decision to adopt blockchain technology. Findings are presented in Figure 4.5.

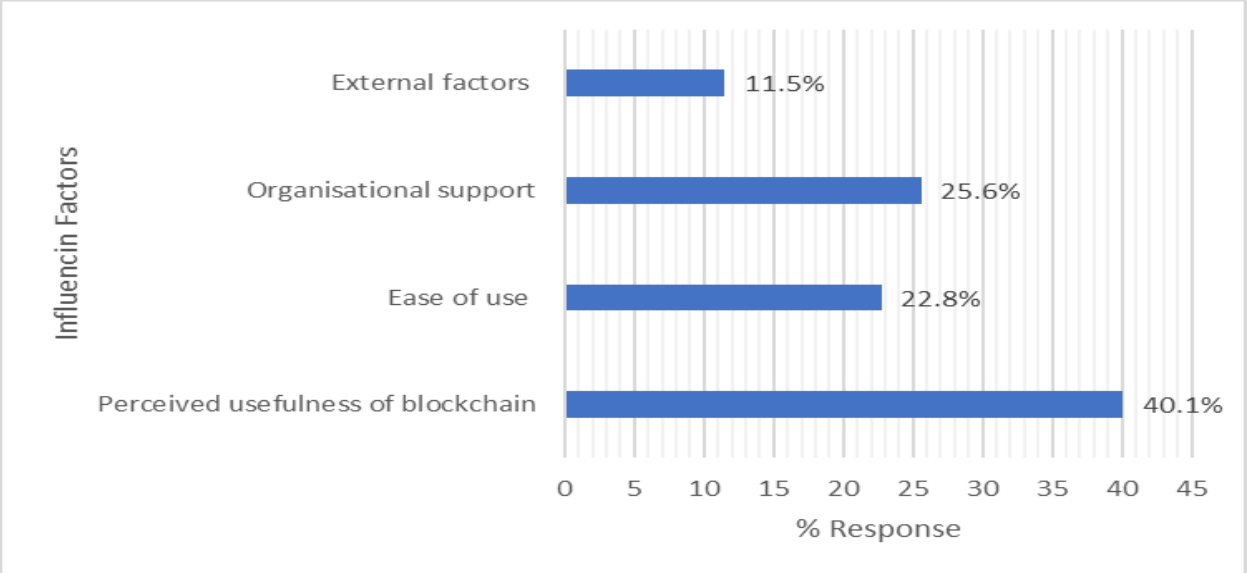

Figure 14. Influencing Factors

Source: Survey Data (2023)

As shown in Figure 14, a majority of respondents attributed their respective likelihoods of adoption to perceived usefulness of blockchain (40.1%), organisational support (25.6%), ease of use (22.8%), and external factors (11.5%).

4.4.5 Attitude Towards Using, Technical Enablers and Barriers

Respondents were asked to indicate how well they understood the technical enablers of blockchain technology, such as hyperledger fabrics and their ability to address confidentiality, integrity, and authentication of data in the supply chain. Findings are presented in Figure 4.6.

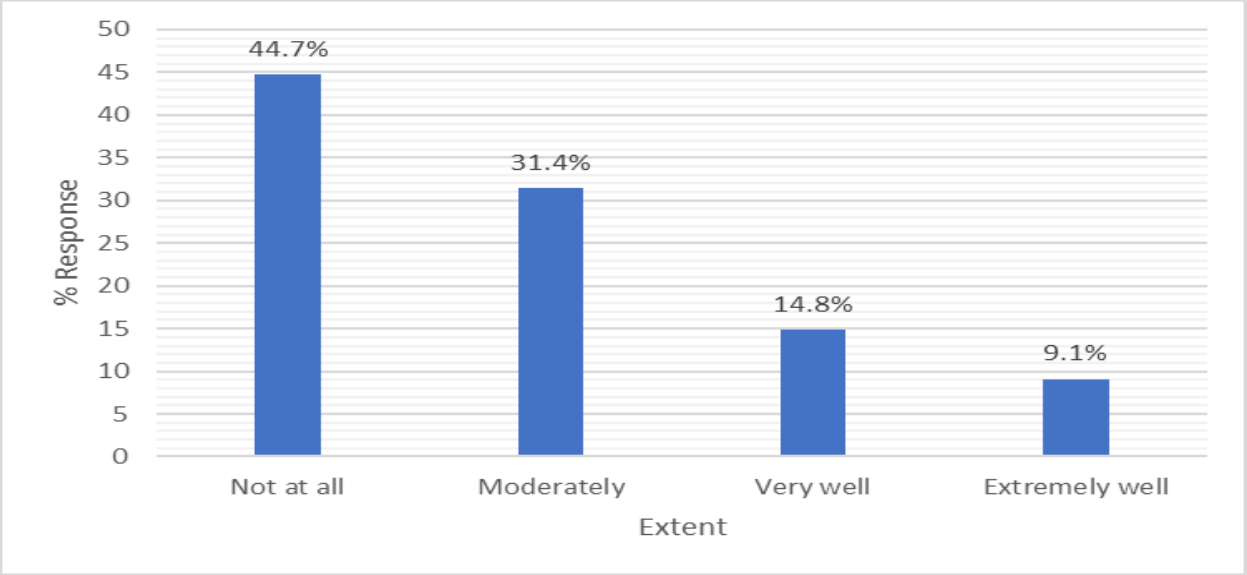

Figure 15. Understanding of Technical Enablers

Source: Survey Data (2023)

As shown in Figure 15, a majority of respondents do not understand the technical enablers of blockchain technology (44.7%), followed by 31.4% who understand the barriers moderately. Only 14.8% understand the technical enablers of blockchain technology very well, while 9.1% understand the technical enablers extremely well.

Of those that understood, the study sought to find out what in their opinion were the potential technical barriers to adopting blockchain technology in the pharmaceutical supply chain.

Findings are presented in Figure 4.7.

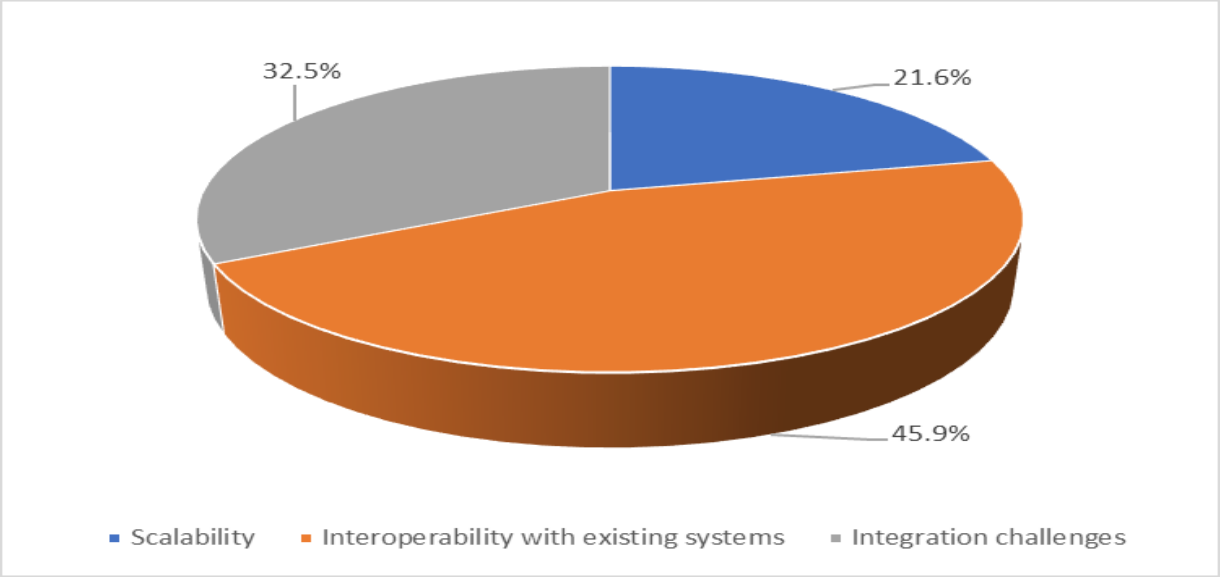

Figure 16. Technical Enablers

Source: Survey Data (2023)

As figure 16 illustrates, a majority of respondents (45.9%) cited interoperability with other existing systems as the main challenge. This was followed by 32.5% citing integration challenges while 21.6% indicated scalability.

Respondents were further asked to indicate the impact they believed blockchain adoption would have on the pharmaceutical industry in Nairobi. Findings are presented in Figure 4.8.

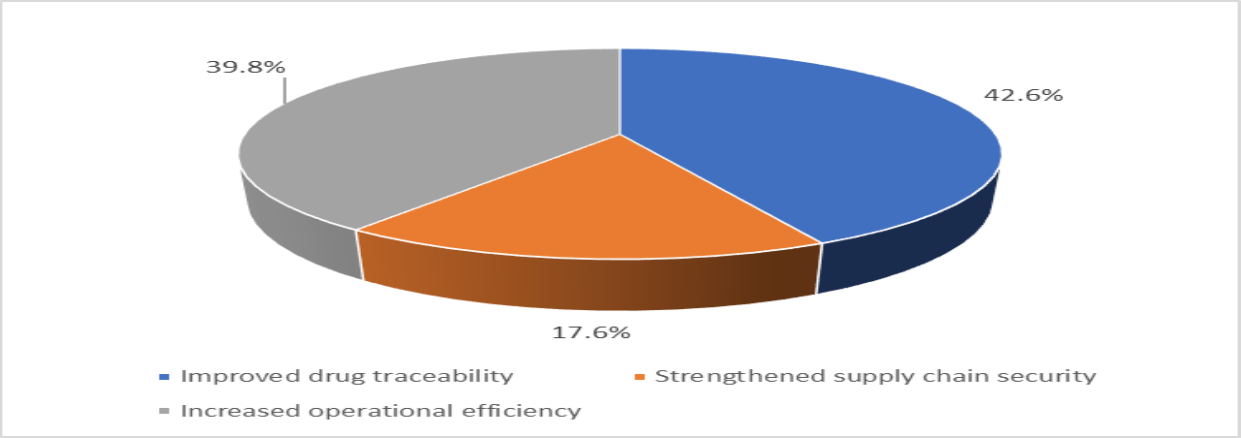

Figure 17. Impact of Blockchain Adoption

Source: Survey Data (2023)

As illustrated in Figure 17, a majority of respondents indicated that blockchain adoption would improve drug traceability in the pharmaceutical industry in Nairobi (42.6%); increased operational efficiency (9.8) and strengthen supply chain security (17.6%).

4.5 Setting up the Blockchain Network

In the present study, the network consisted of one peer organisation and one order. The developer first installed the required prerequisites, including Git, cURL, Docker, Docker Compose, Hyperledger Samples, Binaries, and Docker Images. The Hyperledger fabric was then downloaded and installed. The developer then clearly defined the objectives of the Hyperledger Fabric network and identified the specific use case it aimed to address. The developer then determined the desired outcomes, such as enhanced supply chain transparency or improved data sharing between organisations; and ensured that the chosen use case aligns with the capabilities and strengths of Hyperledger fabric.

4.5.1 Plan Network Components and Architecture

This step involved designing the network components and architecture based on the requirements of the use case. The developer then determined the number and roles of network participants, known as organisations, and their respective peers. The consensus mechanism was then decided upon, where the Practical Byzantine Fault Tolerance (PBFT) was adopted. The channels that will enable private communication and data sharing between specific participants were then defined.

4.5.2 Set up Network Infrastructure

The necessary infrastructure was then prepared to support the Hyperledger Fabric network. The developer then set up the required physical or virtual machines for each organisation's peers and orderers. The operating system, docker and docker compose on each machine were then installed and configured.

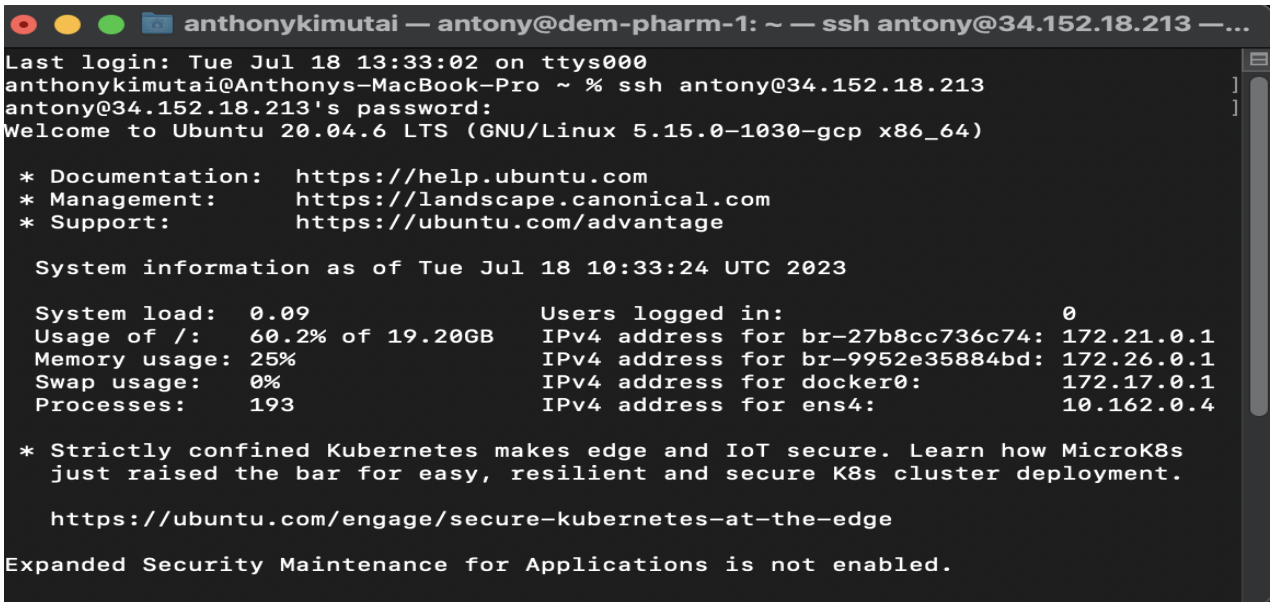

Figure 19. Components created during the process of setting up the network

4.5.3 Create Network Components and Configuration

This step involved creating cryptographic material, such as digital certificates, for network participants using the Fabric Certificate Authority (CA) tool. Channel artefacts were then generated, including channel configuration transaction files and anchor peer updates, to define the network's structure and policies. The Hyperledger Fabric network was then configured by specifying the organisations, peers, orderers, and channels in the configuration files.

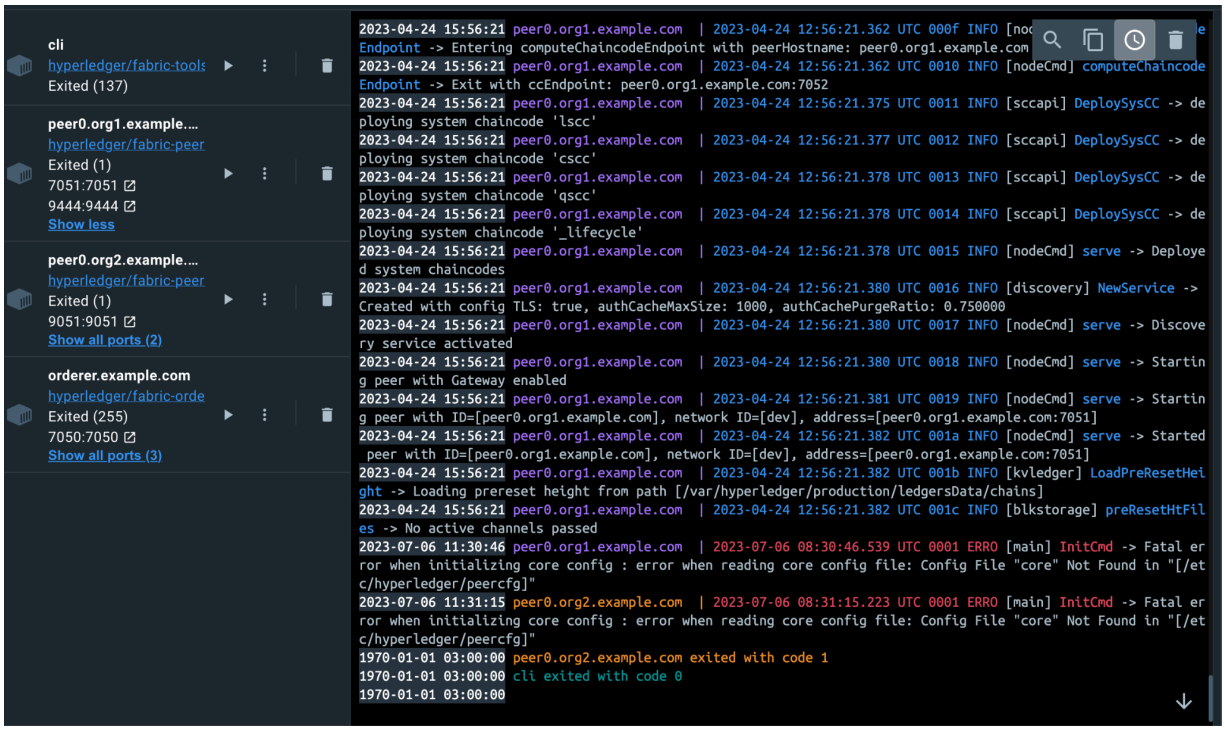

Figure 20. Configuring docker composer

4.5.4 Develop Chaincode

The chaincode was developed, which represents the smart contracts or business logic of the network. Chaincode was implemented using the JavaScript programming language. The developer then defined the functions and rules that govern the behaviour of the chaincode and interact with the ledger. Hyperledger Fabric's programming libraries and APIs were then utilised

to integrate the chaincode with the network.

4.5.5 Deploy and Start the Network

The Docker Compose file was used to deploy the network on the prepared infrastructure. The Docker Compose file defines the services, containers, and configurations required for the network components. The network was then started by executing the appropriate commands, which created and launched the peers, orders, and other necessary components. The developer then verified that the network is successfully running and connected.

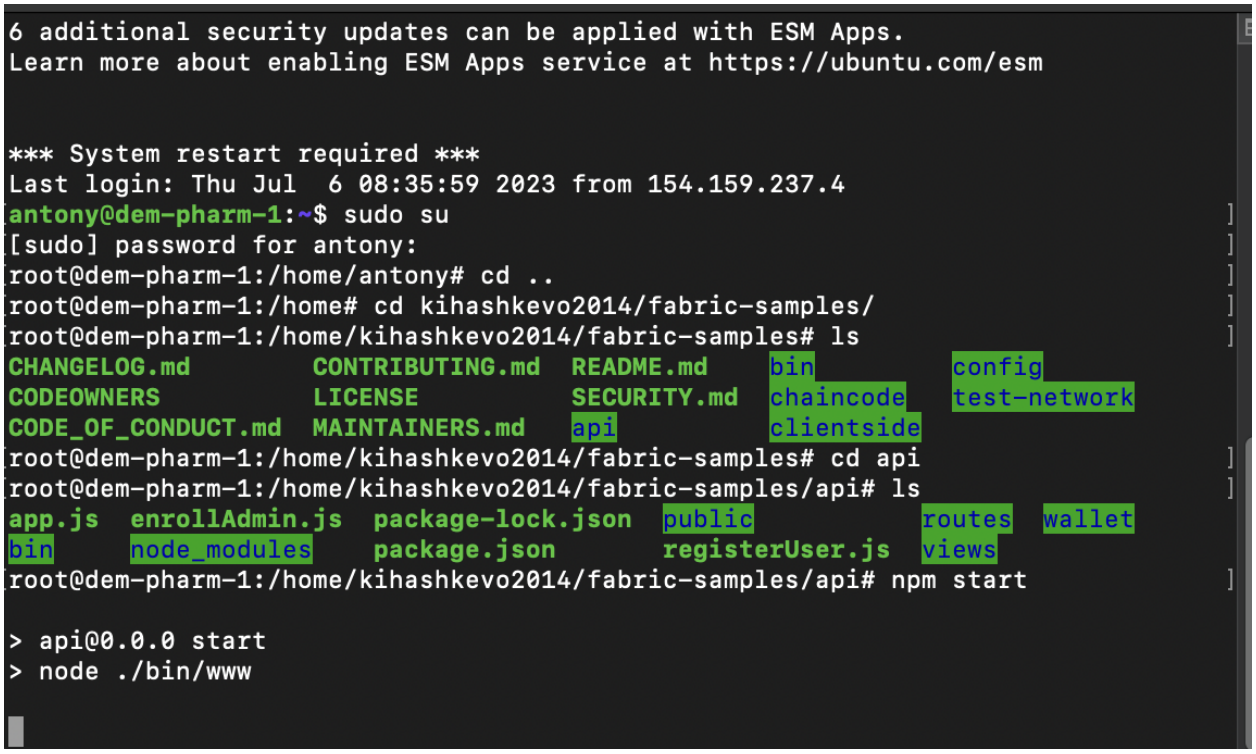

Figure 21. Starting the blockchain api configuration

i. **Join Organisations and Create Channels**

Organisations were then invited to join the network by distributing their cryptographic material and connection details. Each organisation's administrators used the provided material to join their peers to the network. Channels were created to facilitate private communication between specific

organisations. Channel policies and anchor peers were defined for each organisation.

ii. Install and Instantiate Chaincode

The chaincode was installed on the peers of the participating organisations. The chaincode was then instantiated on the desired channel, specifying the initial parameters and endorsing peers. This step deployed the chaincode on the network and made it available for execution and endorsement by the designated peers.

iii. Test and Validate the Network

Thorough testing of the Hyperledger Fabric network was conducted to ensure its functionality and validate the use case. Various scenarios and interactions were tested between participants, transactions were simulated, and the behaviour of the chaincode was verified. The developer then validated that the network meets the defined objectives and produces the expected results.

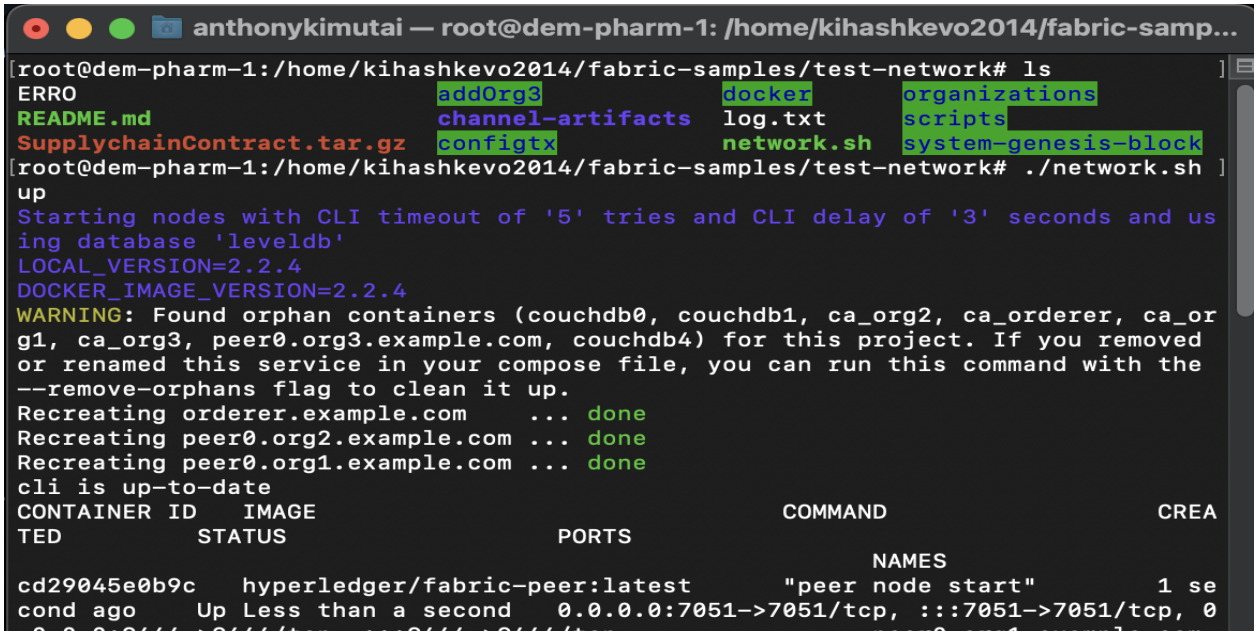

Figure 22. Switching on the blockchain network

iv. **Monitor and Maintain the Network**

The researcher continuously monitored the performance and health of the Hyperledger Fabric network. The nodes, channels, and transactions were particularly monitored to identify any issues or anomalies. The network was maintained by applying updates, addressing security vulnerabilities, and incorporating new features or enhancements. The researcher collaborated with network participants to address concerns, perform regular audits, and ensure the smooth operation of the network.

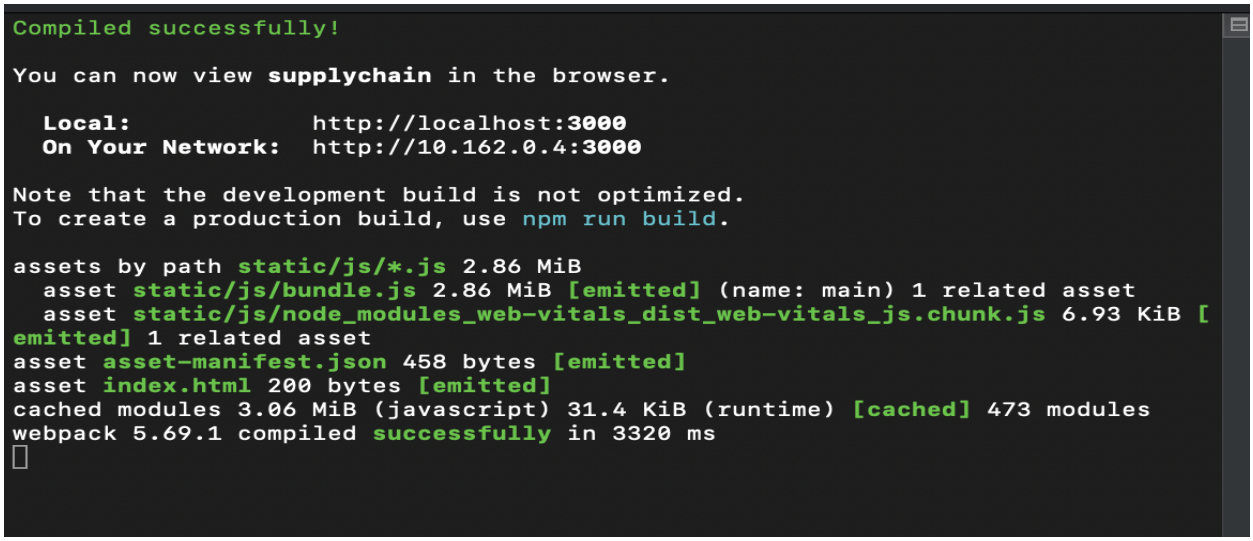

Figure 23.Firing up the client side

4.6 Web Application Features

4.6.1 Network users login page

The users login using their username and password. Users can login in the public blockchain network by indicating their login credentials and organisation they belong to as shown below.

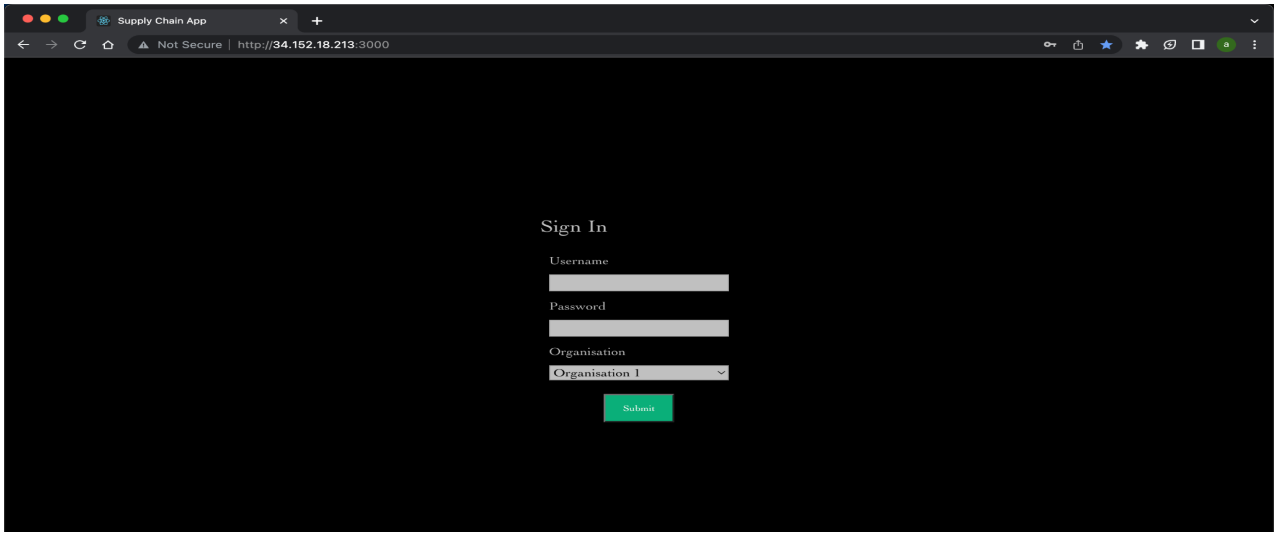

Figure 24. Public blockchain login page

4.6.2 View order page

Information on every product (asset) that is registered in the blockchain can be accessed here as shown in the figure below.

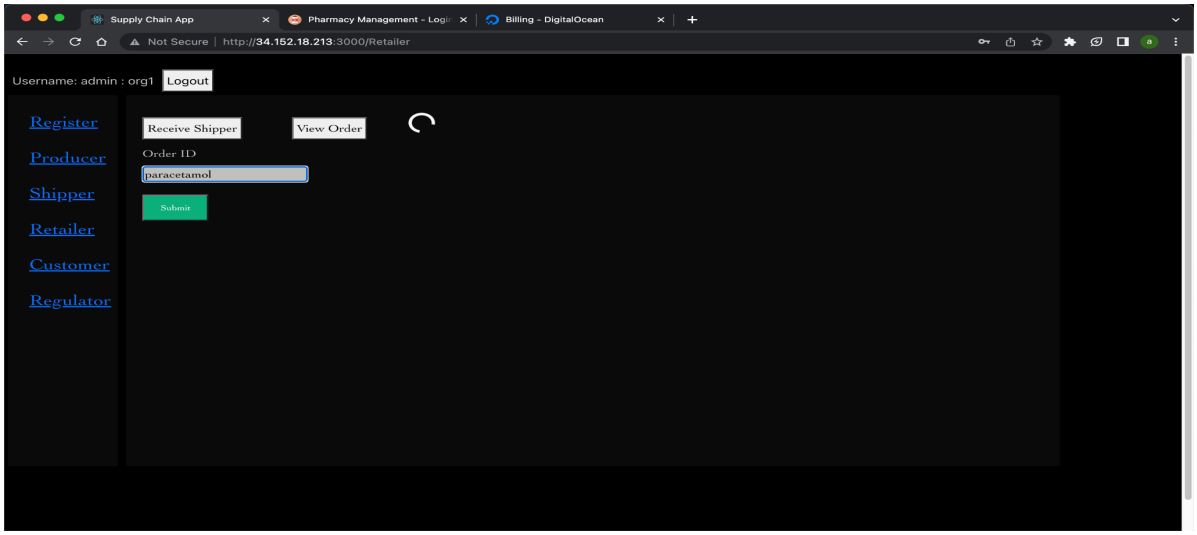

Figure 25. Product search order page

4.6.3 Product registration

The producer can register various pharmaceutical products in the blockchain network. The manufacturers on the blockchain are able to create and register new items on the blockchain. The product id and other information are added using a form as shown below.

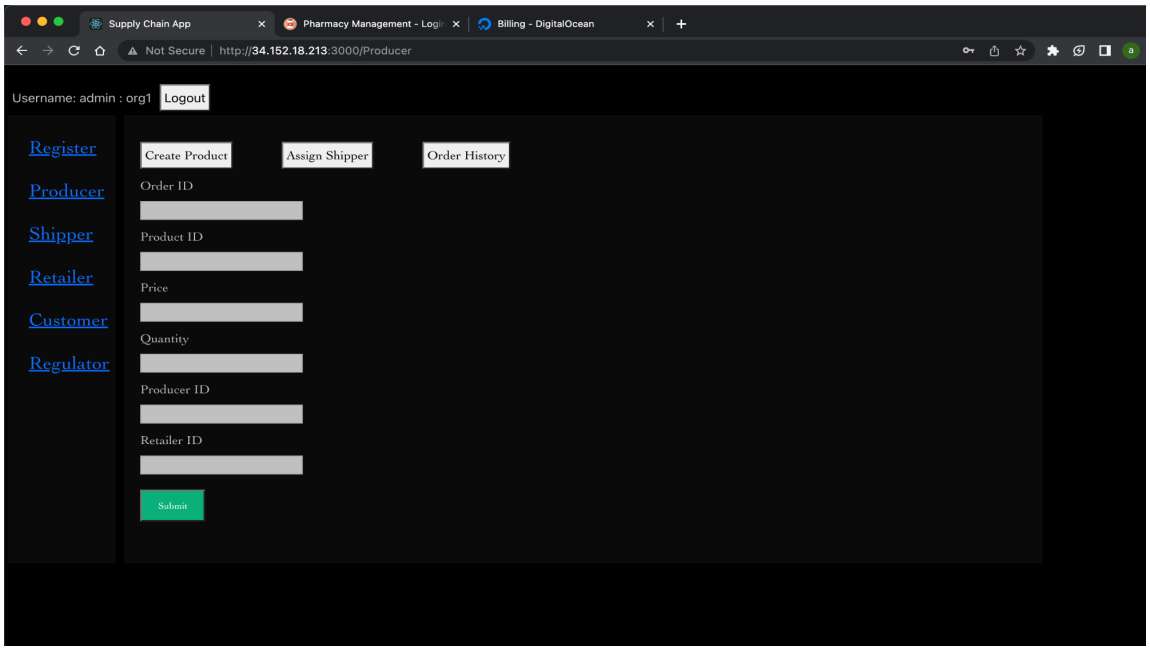

Figure 26. Product registration page

4.6.4 Tracing a product

As a product moves along the supply chain, it changes ownership between the parties involved. When the end consumer purchases the product and scans the smart label attached to it, this is the page that displays the results.

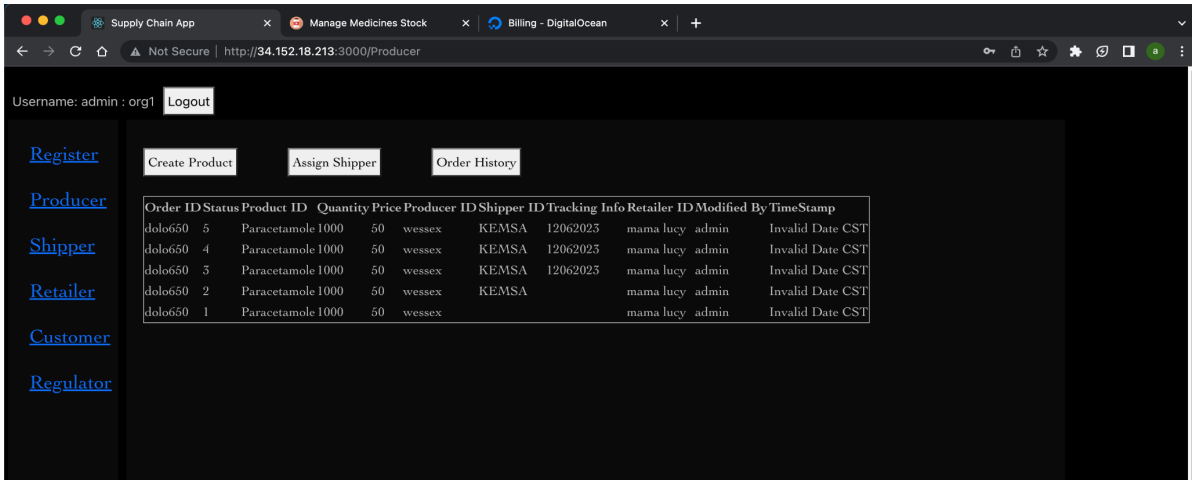

Figure 27. Audit trail of drugs in the pharmaceutical supply chain.

4.6.7 Managing pharmaceutical suppliers

Manufacturers can manage the pool of active and verified suppliers within the pharmaceutical supply chain.

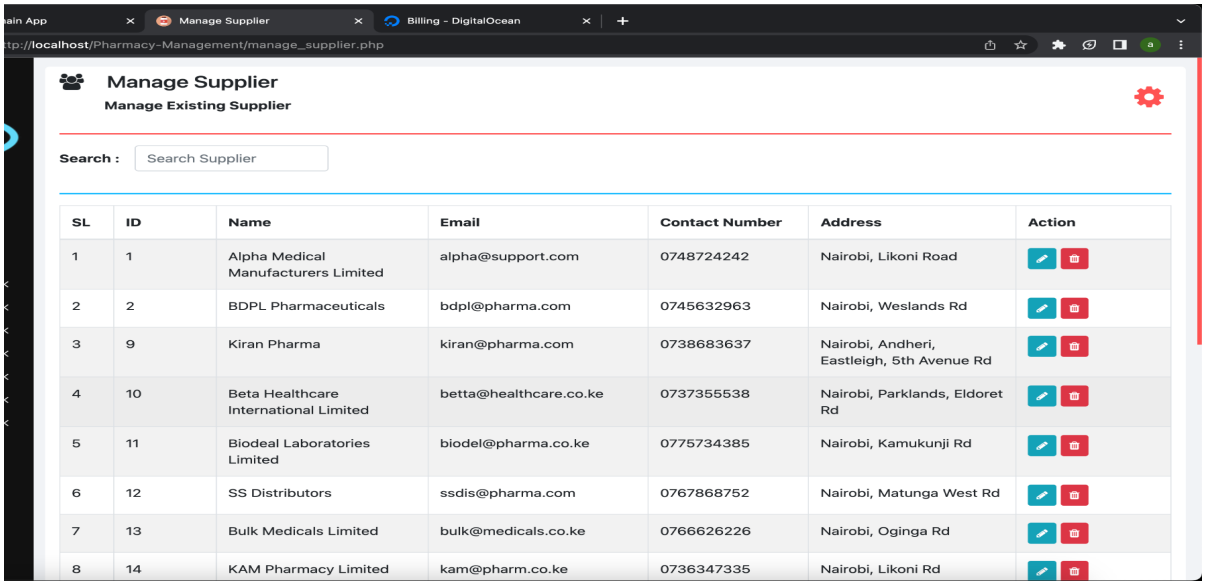

Figure 29. Illustration of managing pharmaceutical suppliers

4.6.8 Managing pharmaceutical drugs

Manufacturers can manage the stock of drugs in store and flag them as either expired or out of stock.

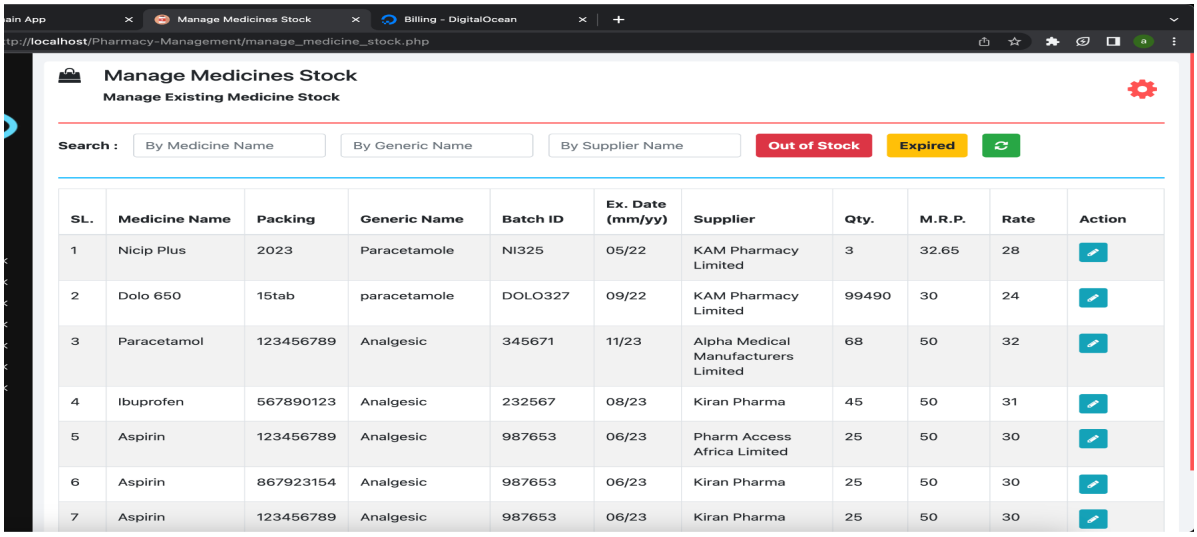

Figure 30. Managing pharmaceutical supply stock

4.7 Focus Group Discussion

A focus group qualitative research technique involved bringing together a small group of individuals who took part in the survey. There were 7 participants who took part in the focus group discussion on reviewing the specific key findings related to the research study. A virtual meeting was conducted where the key finding of the study was presented to the focus group participants.

The focus group discussion provided valuable insights into the ease of use, awareness, and perception of blockchain technology in the pharmaceutical supply chain. The participants expressed a positive attitude towards blockchain technology, emphasising its usefulness in increasing transparency, accountability, traceability, and reducing fraud. However, several challenges were identified that could hinder the adoption of blockchain in the industry. The high cost associated with implementation, including initial investment, infrastructure development, and ongoing maintenance, emerged as a significant barrier. Additionally, the technical complexity of blockchain, such as complex algorithms and distributed networks, may require specialised skills and expertise that organisations in the pharmaceutical supply chain might lack. Regulatory issues, particularly compliance with existing regulations and data privacy concerns pose less challenges in adoption.

4.6.1 Challenges in Adopting Blockchain Technology

The descriptive statistics for challenges in adopting blockchain technology depict an overall mean of **3.525** and a standard deviation of **0.535**. The discussion by the focus group was shared and captured in the table below.

	Mean	Std.Dev	Focus Group Discussion
Cost	**4.127**	**0.542**	The high cost associated with implementing blockchain technology, including initial investment, infrastructure development, and ongoing maintenance, can act as a barrier for adoption in the pharmaceutical supply chain. It requires significant financial resources that organisations may not be willing or able to allocate.
Technical Complexity	**3.885**	**0.527**	Blockchain technology often involves setting up distributed ledgers, smart contracts, and distributed networks, which may require specialised skills and expertise to implement and maintain. The technical complexity associated with blockchain can pose challenges for organisations in the pharmaceutical supply chain that may not have the necessary technical knowledge or resources.
Regulatory Issues	**2.212**	**0.422**	Regulatory issues, such as compliance with existing regulations, data privacy, and security concerns, can pose challenges to the adoption of blockchain technology in the pharmaceutical supply chain. The decentralised and immutable nature of blockchain may require organisations to navigate complex regulatory frameworks and ensure compliance, which can slow down or impede the adoption process.
	3.875	**0.649**	Implementing blockchain technology requires a significant shift in processes, workflows, and organisational culture.

	Mean	Std.Dev	Focus Group Discussion
Resistance to Change			Resistance to change among stakeholders, including pharmaceutical companies, supply chain participants, and regulators, can hinder the adoption of blockchain. Resistance may arise due to fear of the unknown, concerns about job security, or scepticism about the cost benefits and effectiveness of blockchain technology.
Overall	**3.525**	**0.535**	

Table 6. Discussed challenges in adopting blockchain technology

4.6.2 Attitude Towards Using, Technical Enablers and Barriers

The focus group discussed that interoperability with other existing systems had exposed the majority of the respondents to legacy technologies. Respondents were asked to indicate how well they understood the technical enablers of blockchain technology, such as hyperledger fabrics and their ability to address confidentiality, integrity, and authentication of data in the supply chain. It was noted that the majority of the respondents do at least moderately understand the technical enablers of blockchain technology (55.3%), while (44.7%) of respondents do not understand the technical enablers of blockchain technology as shown in the figure below.

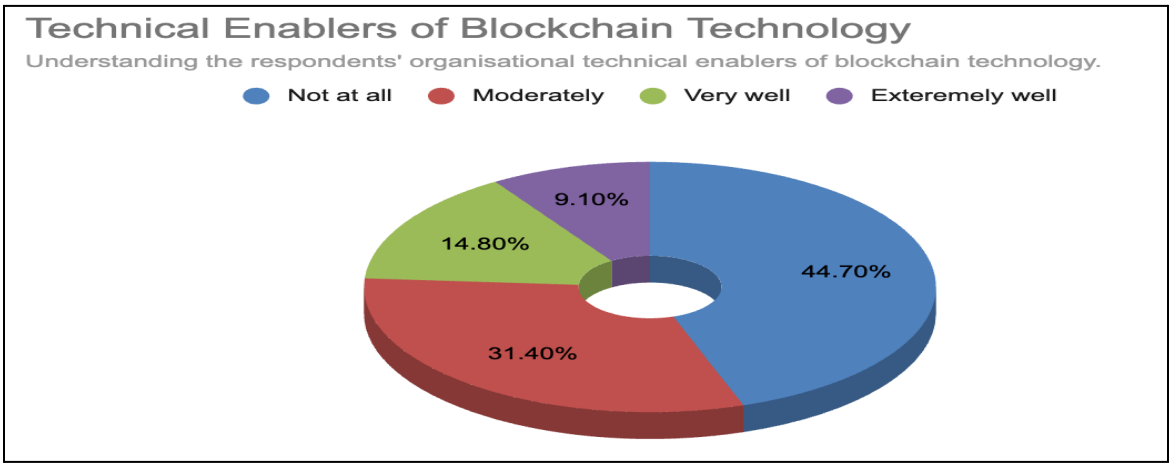

Figure 31. Technical enablers of blockchain technology

Source: Survey Data (2023

This shows that nearly 45% of the respondents do not understand the technical enablers of

blockchain technology in their organisation. This explains why the respondents perception on the ease of use of blockchain technology (3.667); is low in their organisation. However, the respondents had a higher perception on the ease of usefulness of blockchain technology (4.168);.

4.8 Discussion

Respondents were asked to rate their respective opinions regarding the ease of use, awareness, and perception of blockchain technology in the pharmaceutical supply chain. An overall mean of 3.667 and a standard deviation of 0.325 was established, implying that a majority of the respondents highly affirm the ease of use, awareness and perception of blockchain technology. Respondents were also asked to rate their respective opinions regarding the perceived usefulness of blockchain technology in the pharmaceutical supply chain. An overall mean of 4.180 and a standard deviation of 0.397 was established, which implies that a majority of the respondents highly affirm the perceived usefulness of blockchain technology. Respondents were further asked to rate their respective opinions regarding the perceived usefulness of blockchain technology in the pharmaceutical supply chain. The study found an overall mean of 3.525 and a standard deviation of 0.535. This means that a majority of the respondents highly affirm the perceived usefulness of blockchain technology in the pharmaceutical supply chain.

It can be deduced from the findings that a majority of users within the pharmaceutical industry consider blockchain technology easy to use, are aware of it and positively perceive it. Some potential users however believe that implementing blockchain technology in the pharmaceutical supply chain can be technically challenging, and that it requires expertise in blockchain development and integration, which may pose a barrier for adoption. It is thus important that user-friendly blockchain platforms and tools are developed to simplify the implementation

process. As these tools evolve, the ease of use is expected to improve, making it more accessible to pharmaceutical companies. It can also be deduced that while challenges and limitations exist in implementing blockchain technology, its perceived usefulness in the pharmaceutical supply chain stems from its potential to address critical issues such as drug counterfeiting, supply chain inefficiencies, patient safety concerns, and regulatory compliance. As the technology continues to mature and gain wider adoption, its benefits are likely to become more apparent. The findings agree with Viriyasitavat and Hoonsopon (2019) who found that blockchain technology offers unique advantages in the setting of visibility systems since its autonomous and decentralised digital library can ensure the veracity of information. The features of technology tracking and data tamper susceptibility can efficiently control the supply chain problem, as can access to information and total reliability of data flow; faking and substandard problems; anti-tampering and time stamps of blockchain application data.

Respondents were further asked to rate their readiness to adopt blockchain technology in the pharmaceutical supply chain, as whether not ready at all, somewhat ready and moderately ready. A majority of respondents (41.4%) indicated that they are moderately ready to adopt blockchain technology in the pharmaceutical supply chain. A majority of respondents are also somewhat likely (49.6%) to adopt blockchain technology in the pharmaceutical supply chain. Asked on factors influencing their adoption readiness, a majority cited perceived usefulness of blockchain, organisational support, ease of use and external factors.

The study thus deduces that the readiness to adopt blockchain technology in the pharmaceutical supply chain varies across different stakeholders and regions. The readiness to adopt blockchain first depends on the extent to which blockchain technology in the pharmaceutical supply chain will enhance traceability, improve supply chain efficiency, and reduce counterfeit drugs. It also

depends on existing technological infrastructure within the pharmaceutical industry. Companies with advanced digital capabilities and robust IT systems may find it easier to integrate blockchain solutions into their existing operations. However, organisations with limited technological resources may face challenges in implementing and maintaining blockchain technology. The regulatory landscape plays a crucial role in the adoption of blockchain technology. Clear regulatory frameworks and guidelines can provide confidence and clarity for pharmaceutical companies, encouraging them to adopt blockchain solutions. The findings are consistent with Viriyasitavat and Hoonsopon (2019) who report that this technology may be a crucial facilitator for creating private blockchain system settings where regulatory bodies and participants will enrol, administer, and regulate pharmaceutical companies and their end consumers under the supervision of the administration or a group of regulatory bodies.

The study further found that a majority of respondents do not understand the technical enablers of blockchain technology (44.7%), followed by 31.4% who understand the enablers moderately. Of those that understood, the study sought to find out what in their opinion were the potential technical barriers to adopting blockchain technology in the pharmaceutical supply chain. A majority of respondents (45.9%) cited interoperability with other existing systems as the main challenge. Interoperability is crucial for blockchain technology to effectively integrate with existing systems and share data across different platforms. The development of interoperability standards allows seamless communication and data exchange between blockchain networks, electronic health records, supply chain management systems, and other relevant healthcare IT systems. Blockchain technology has faced challenges in terms of scalability and performance, particularly in handling a high volume of transactions. However, various technical advancements, such as the development of second-layer solutions (e.g., off-chain transactions)

and consensus algorithm improvements, aim to address these limitations and enhance the scalability and performance of blockchain in the pharmaceutical industry.

Respondents were further asked to indicate the impact they believed blockchain adoption would have on the pharmaceutical industry in Nairobi. A majority of respondents indicated that blockchain adoption would improve drug traceability in the pharmaceutical industry in Nairobi (42.6%). It can thus be deduced that blockchain creates a decentralised and immutable ledger where each transaction related to a drug's journey is recorded. This includes information about the drug's origin, manufacturing, transportation, and distribution. Once recorded on the blockchain, this information cannot be altered, ensuring the integrity and reliability of the data. All stakeholders, including manufacturers, distributors, pharmacies, and regulators, have access to the same transparent and tamper-proof information. Counterfeit drugs are a significant concern in the pharmaceutical industry. Blockchain technology enables the verification of drug authenticity by tracking its movement on the blockchain. Each time a drug changes hands or location, the transaction is recorded, creating an auditable trail. Stakeholders can verify the legitimacy of a drug by checking its history on the blockchain, ensuring it has not been tampered with or replaced. This is in agreement with Figorilli et al. (2018) who found that the creation of a decentralised shared information platform for an unchangeable, reliable, responsible, and comprehensive system in the drug supply chain is possible with the help of blockchain-based medication tracing.

4.8.1 Hypothesis Testing

To determine whether there is a relationship between Perceived Usefulness (PU), Perceived Ease of Use (PEU) and the Attitude to Adopt (ATA) blockchain technology, a correlation

analysis was conducted. The analysis assessed the strength and direction of the relationship between the variables, whereby;

	Denotation
H1	There is a relationship between Perceived Usefulness (PU) and the Attitude to Adopt (Attitude to Adopt) blockchain technology in the pharmaceutical supply chain.
H2	There is a relationship between Perceived Usefulness (PU) and the Perceived Ease of Use (PEU) of adopting blockchain technology in the pharmaceutical supply chain.
H3	There is a relationship between Perceived Ease of Use (PEU) and Attitude to Adopt (ATA) blockchain technology in the pharmaceutical supply chain.

Table 7. Research hypotheses

To justify the hypotheses using the regression equation $Y = \beta 0 + \beta X + \varepsilon$, the variables in the equation were related to the constructs mentioned in the hypotheses. To evaluate the hypothesis, the p-value associated with the beta coefficient was compared to a predetermined significance level (< 0.05). If the p-value is less than the significance level, the relationship between the predictor variable and the dependent variable is considered statistically significant, and the hypothesis is accepted. If the p-value is greater than the significance level, the relationship is considered statistically insignificant, and the hypothesis is rejected. The beta coefficients $\beta 0$, provide insights into what direction the predictor variable affects the outcome of interest (ATA). It quantifies and compares the effects of different variables (PU, PUE) helping in understanding the relationships between variables. The beta sign (positive or negative) and magnitude of the beta coefficient, determines the direction and strength of the relationship.

The variables were assigned as follows: $ATA = \beta 0 + \beta 1PU + \beta 2PEU + \varepsilon$, where; Y = Attitude to Adopt (ATA), X1 = Perceived Usefulness (PU) and, X2 = Perceived Ease of Use (PEU). A multiple regression analysis was conducted with the aid of SPSS version 27 that yielded the following results: $ATA = 0.85 + 0.32PU + 0.47PEU + \varepsilon$.

	Beta Coefficients (β)	Standard Error	t-value	p-value
Constant (β0)	0.85	0.12	7.08	<0.001
Perceived Usefulness (PU) (β1)	0.32	0.09	3.56	0.002
Perceived Ease of Use (PEU) (β2)	0.47	0.11	4.27	<0.001

Table 8. Regression analysis results

Source: Survey Data (2023

This showed that the Attitude to Adopt (ATA) blockchain technology in the pharmaceutical supply chain is predicted by three factors: perceived usefulness (PU), perceived ease of use (PEU), and an error term (ε). The constant beta term of 0.85 represents the expected value of ATA when both PU and PEU are zero. The beta coefficient 0.32 attached to PU suggests that for every unit increase in perceived usefulness, the predicted attitude to adopt increases by 0.32 units, assuming all other variables remain constant. Similarly, the coefficient 0.47 attached to PEU indicates that for every unit increase in perceived ease of use, the predicted attitude to adopt increases by 0.47 units, assuming all other variables remain constant. The error term (ε) represents the variability in ATA that cannot be explained by PU and PEU. The coefficients associated with PU and PEU provide information on the strength and direction of these relationships. Higher values of perceived usefulness and perceived ease of use result in a more positive attitude toward adopting blockchain technology in the pharmaceutical supply chain, while the error term represents the unpredictable factors that can affect the attitude to adopt.

4.8.2 Regression Analysis Results and Hypothesis Evaluation

The remarks tables below indicates whether each hypothesis based on the beta coefficient should be accepted or rejected.

	Beta Coefficient	Remarks
H1	β= 0.32 & P=<.05	Accept Hypothesis H1
H2	β= 0.47& P=<.05	Accept Hypothesis H2
H3	β= 0.47 & P=<.05	Accept Hypothesis H3

Table 9. Hypothesis remarks

Source: Survey Data (2023

These remarks indicate that the regression analysis results support all three hypotheses (H1, H2, and H3). The beta coefficient (β) determines the relationships between the predictor variables and the dependent variable. The coefficients provide evidence of a relationship between the variables mentioned in the hypotheses, reinforcing the validity of the stated relationships. For H1, the correlation coefficient is 0.32, suggesting a positive relationship between perceived usefulness (PU) and attitude to adopt (ATA) blockchain technology in the pharmaceutical supply chain. Since the correlation coefficient is not zero, we accept H1. For H2, the correlation coefficient is 0.47, indicating a positive relationship between perceived usefulness (PU) and perceived ease of use (PEU) of adopting blockchain technology. Since the correlation coefficient is not zero, we accept H2.For H3, the correlation coefficient is 0.47, suggesting a positive relationship between perceived ease of use (PEU) and attitude to adopt (ATA) blockchain technology. Since the correlation coefficient is not zero, we accept H3

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In the present chapter, a summary of the key findings of the study are presented, the consequential conclusion drawn and recommendations for policy, practice and research presented. The aim of the chapter is to tie the research objectives and stated research questions to the findings and deduce inferences based on the research findings. The chapter then culminates in suggestions for future research as a way of highlighting how the identified knowledge gaps and limitations can be bridged and addressed.

5.2 Summary of Key Findings

Respondents were asked to please rate their respective opinions regarding the ease of use, awareness, and perception of blockchain technology in the pharmaceutical supply chain. A majority of respondents highly agree that the integration of blockchain technology into existing processes and systems within the pharmaceutical supply chain is perceived as seamless (4.009); and that they find the user interface and functionality of blockchain technology in the pharmaceutical supply chain to be intuitive and easy to understand (3.924).

Respondents were also asked to rate their respective opinions regarding the perceived usefulness of blockchain technology in the pharmaceutical supply chain. Majority of respondents highly agree that blockchain technology has the potential to increase drug authenticity in the pharmaceutical supply chain (4.202); enhance supply chain visibility in the pharmaceutical supply chain (4.200); improve traceability in the pharmaceutical supply chain (4.183); reduce fraud in the pharmaceutical supply chain (4.173); increase accountability in the pharmaceutical supply chain (4.167); and increase transparency in the pharmaceutical supply chain (4.155).

Respondents were also asked to rate their respective opinions regarding the perceived usefulness of blockchain technology in the pharmaceutical supply chain. a majority of respondents highly affirmed cost (4.127); technical complexity (3.885); and resistance to change (3.875). a majority however dissented to regulatory issues (2.212). Respondents were further asked to rate their readiness to adopt blockchain technology in the pharmaceutical supply chain, as whether not ready at all, somewhat ready and moderately ready. a majority of respondents (41.4%) indicated that they are moderately ready to adopt blockchain technology in the pharmaceutical supply chain. Respondents were then asked to indicate how likely they were to adopt blockchain technology in the pharmaceutical supply chain. a majority of respondents are somewhat likely (49.6%) to adopt blockchain technology in the pharmaceutical supply chain. In this regard, the study further prompted to find out the factors that would influence their decision to adopt blockchain technology. A majority of respondents attributed their respective likelihoods of adoption to perceived usefulness of blockchain (40.1%), organisational support (25.6%), ease of use (22.8%), and external factors (11.5%).

Respondents were asked to indicate how well they understood the technical enablers of blockchain technology, such as hyperledger fabrics and their ability to address confidentiality, integrity, and authentication of data in the supply chain. a majority of respondents do not understand the technical enablers of blockchain technology (44.7%), followed by 31.4% who understand the barriers moderately. Only 14.8% understand the technical enablers of blockchain technology very well, while 9.1% understand the technical enablers extremely well.

Of those that understood, the study sought to find out what in their opinion were the potential technical barriers to adopting blockchain technology in the pharmaceutical supply chain. a

majority of respondents (45.9%) cited interoperability with other existing systems as the main challenge. This was followed by 32.5% citing integration challenges while 21.6% indicated scalability. Respondents were further asked to indicate the impact they believed blockchain adoption would have on the pharmaceutical industry in Nairobi. A majority of respondents indicated that blockchain adoption would improve drug traceability in the pharmaceutical industry in Nairobi (42.6%); increased operational efficiency (9.8%) and strengthen supply chain security (17.6%).

5.3 Conclusion

Based on the foregoing findings, it can be deduced that blockchain enhances traceability of drugs in the pharmaceutical supply chain in Kenya. Blockchain provides a tamper-proof and immutable ledger that records every transaction and movement of drugs throughout the supply chain. By capturing data at each stage, including manufacturing, distribution, and dispensing, blockchain enables transparent and auditable traceability. This ensures that the drug's journey can be verified and any unauthorised or fraudulent activities can be easily identified. Blockchain can assign unique serial numbers or identifiers to individual drug units or batches. These identifiers are recorded on the blockchain, allowing for precise tracking and traceability. In Kenya, implementing serialised product identification through blockchain can enable stakeholders to monitor the movement of drugs from manufacturers to pharmacies, clinics, and hospitals, ensuring that each unit can be identified and verified. Counterfeit drugs pose a significant challenge in Kenya and many other countries. Blockchain technology can help combat counterfeit drugs by verifying the authenticity of drugs at each stage of the supply chain. By recording and verifying the drug's history and origin on the blockchain, stakeholders can ensure that the drugs are genuine and have not been tampered with or replaced.

The study also concludes that the effectiveness of current technologies in facilitating traceability in the pharmaceutical supply chain in Kenya can vary. While some technologies are being utilised, there are still challenges and limitations that need to be addressed. Barcoding and RFID technologies are commonly used in the country's pharmaceutical industry to track and trace products. Barcodes and RFID tags can help identify and monitor the movement of drugs at different stages of the supply chain. However, the adoption of these technologies in Kenya's pharmaceutical supply chain might not be uniform across the industry due to factors such as cost, infrastructure limitations, and varying levels of implementation by different stakeholders. Assigning batch and lot numbers to pharmaceutical products is also a common practice to enable traceability in the country's pharmaceutical industry. These numbers help identify specific groups of products manufactured together and can be used for tracking and tracing purposes. However, manual data entry, inconsistent practices, and limited interoperability of information systems can hinder the effectiveness of batch and lot number-based traceability in Kenya's pharmaceutical supply chain.

The study further concludes that blockchain technology can be adopted in several ways to achieve efficiency along the pharmaceutical supply chain. Blockchain provides real-time visibility into the pharmaceutical supply chain by recording and sharing transactional data across all stakeholders. This transparency enables improved coordination, reduces delays, and enhances overall supply chain efficiency. Stakeholders can access accurate and up-to-date information about inventory levels, shipment status, and product movements, allowing for better planning and decision-making. Blockchain can also streamline documentation processes and automate manual tasks through the use of smart contracts. Smart contracts are self-executing contracts with predefined rules and conditions. They can automate tasks such as order processing, payment

settlements, and regulatory compliance, reducing paperwork, administrative burdens, and human errors.

It is also concluded that blockchain technology secures data handling along the pharmaceutical supply chain by addressing data manipulation and human error through the following mechanisms. Blockchain provides an immutable ledger, meaning that once data is recorded on the blockchain, it cannot be altered or tampered with. Each transaction is linked to the previous one through cryptographic hashes, creating a chain of blocks that ensures the integrity and immutability of data. This prevents unauthorised modifications or tampering, reducing the risk of data manipulation along the supply chain. Blockchain operates on a distributed and decentralised network, where multiple nodes or participants maintain copies of the blockchain. This distribution of data ensures redundancy and enhances security. If one node attempts to manipulate data or introduces errors, the other nodes in the network can identify the inconsistency and reject the invalid data. This decentralised structure reduces the reliance on a single point of failure and increases resilience against data manipulation or errors.

5.4 Recommendations

Based on the foregoing findings and conclusions, the study advances the following policy and practice recommendations for enhanced uptake of block chain in the Kenyan pharmaceutical industry. There is a need to develop clear and supportive regulatory frameworks that address the use of blockchain technology in the pharmaceutical industry. These frameworks should provide guidance on data privacy, security, interoperability, and legal aspects of blockchain implementation. They should also encourage collaboration between regulatory bodies, industry stakeholders, and technology providers to ensure compliance and standardisation.

There is also a need to facilitate collaboration among pharmaceutical companies, technology providers, healthcare institutions, and government agencies. Establish partnerships and consortiums to jointly explore and implement blockchain solutions. Collaborative efforts can help pool resources, share best practices, and accelerate the adoption of blockchain technology across the industry.

The study also recommends the introduction of financial incentives, such as grants, subsidies, or tax benefits, to encourage pharmaceutical companies and other stakeholders to invest in blockchain technology. Financial support can help mitigate the initial costs associated with implementation and incentivize organisations to adopt blockchain solutions for enhanced supply chain efficiency, traceability, and patient safety. There is also a need to conduct training programs, workshops, and awareness campaigns to educate stakeholders about blockchain technology and its potential benefits in the pharmaceutical industry. Offer specialised courses and certifications to build a skilled workforce capable of implementing, managing, and utilising blockchain solutions effectively.

The study further recommends the promotion of the standardisation of data formats, protocols, and interfaces to ensure interoperability between different blockchain systems and existing information systems in the pharmaceutical industry. Establish common standards for data exchange, serialisation, and identification to facilitate seamless integration of blockchain technology with existing infrastructure and enable data sharing among stakeholders. Foster public-private partnerships to drive blockchain adoption in the pharmaceutical industry. Collaborate with government agencies, industry associations, and technology providers to establish initiatives, research centres, or innovation hubs focused on blockchain technology. These partnerships can support knowledge exchange, resource sharing, and joint efforts to

overcome challenges and drive widespread adoption.

5.5 Suggestions for Future Studies

The purpose of this study was to assess the use of blockchain technology in the pharmaceutical supply chain with reference to Nairobi County. Based on the foregoing limitation faced, this study recommends that future research should replicate this study into different industries and supply chains with a view to see if there are any parallels or discrepancies with the current study's findings. Future studies could also explore other variables and methodologies.

Furthermore, the researcher recommends that the use of blockchain technology can be assessed using various existing adoption models which have been mentioned in this literature.

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APPENDICES

Appendix I: Questionnaire for Manufacturers, Distributors and Pharmacists

This form is aimed at collecting information regarding the adoption of blockchain in the pharmaceutical supply Chain in Nairobi County.

1. **Demographic Information**

   1.1 Please provide the following demographic information:

   Role: [Pharmaceutical manufacturer/Distributor/Pharmacist]

   Organization/Pharmacy name:

   Years of experience in the pharmaceutical industry:

2. **Perceived ease of use of blockchain technology:**

   2.1 On a scale from 1 to 5, where 1 represents 'Strongly Disagree' and 5 represents 'Strongly Agree,' please rate your opinion regarding the ease of use, awareness, and perception of blockchain technology in the pharmaceutical supply chain. Please consider the following statements:

   2.1.1 I find the functionality of blockchain technology in the pharmaceutical supply chain to be useful? (1:Strongly Disagree, 2:Disagree, 3:Neutral, 4: Agree, 5:Strongly Agree)

   - ☐ Strongly Disagree,
   - ☐ Disagree,
   - ☐ Neutral
   - ☐ Agree
   - ☐ Strongly Agree

   2.1.2 The integration of blockchain technology into existing processes and systems within the pharmaceutical supply chain is perceived as seamless?

- ☐ Strongly Disagree,
- ☐ Disagree,
- ☐ Neutral,
- ☐ Agree,
- ☐ Strongly Agree

2.2 How would you define blockchain technology in your own words?

2.3 On a scale of 1 to 5, please rate your perception of the potential of blockchain technology to increase transparency, accountability, and traceability in the pharmaceutical supply chain: (1:Strongly Disagree, 2:Disagree, 3:Neutral, 4: Agree, 5:Strongly Agree)

- ☐ Strongly Disagree,
- ☐ Disagree,
- ☐ Neutral,
- ☐ Agree,
- ☐ Strongly Agree

3. Perceived Usefulness :

3.1. What do you consider to be the potential benefits of adopting blockchain technology in the pharmaceutical supply chain? Select all that apply:

- ☐ Increased drug authenticity,
- ☐ Reduced Fraud,
- ☐ Enhanced supply chain visibility
- ☐ Improved traceability of drugs
- ☐ None of the above

3.2. What are the main challenges or concerns you foresee in adopting blockchain technology in the pharmaceutical supply chain? Select all that apply:

- ☐ Cost,

- ☐ Technical Complexity,
- ☐ Regulatory Issues
- ☐ Resistance to change
- ☐ None of the above

3.3 How easy do you think it is to use blockchain technology?

4. Intention to use and adoption readiness:

4.1. Please select your readiness to adopt blockchain technology in the pharmaceutical supply chain:

- ☐ Not ready at all,
- ☐ Somewhat ready,
- ☐ Moderately ready
- ☐ Improved traceability of drugs
- ☐ None of the above

4.2. How likely are you to adopt blockchain technology in the pharmaceutical supply chain? (1:Not likely at all, 2:Somewhat likely, 3:Very Likely, 4:Extremely Likely)

- ☐ Not likely at all,
- ☐ Somewhat likely,
- ☐ Very likely
- ☐ None of the above

4.3. What factors would influence your decision to adopt blockchain technology? (Select all that apply):

- ☐ Perceived usefulness of blockchain,
- ☐ Ease of use,
- ☐ Organisational support,
- ☐ External factors

☐ None of the above

5. Attitude Towards Using, Technical Enablers and Barriers:

5.1. How well do you understand the technical enablers of blockchain technology, such as hyperledger fabrics and their ability to address confidentiality, integrity, and authentication of data in the supply chain? (1:Not at all, 2:Moderately, 3:Very well, 5:Extremely well)

☐ Not at all,
☐ Moderately,
☐ Very well
☐ Extremely well

5.2. In your opinion, what are the potential technical barriers to adopting blockchain technology in the pharmaceutical supply chain? Please select all that apply:

☐ Not likely at all,
☐ Somewhat likely,
☐ Very likely
☐ None of the above

5.3. In your opinion, what are the potential technical barriers to adopting blockchain technology in the pharmaceutical supply chain? Please select all that apply:

☐ Scalability,
☐ Interoperability with existing systems,
☐ Integration challenges
☐ None of the above

5.4 What impact do you believe blockchain adoption would have on the pharmaceutical industry in Nairobi? Please select all that apply:

- ☐ Improved drug traceability,
- ☐ Strengthened supply chain security,
- ☐ Increased operational efficiency,
- ☐ None of the above

6. Suggestions and Recommendations:

6.1. Based on your experience and understanding, do you have any suggestions or recommendations for the use of blockchain technology in the pharmaceutical supply chain? Please share your insights.

6.2. Are there any specific areas or processes within the pharmaceutical supply chain where you believe blockchain implementation would be most beneficial? Please provide details.

6.3. Is there any additional information or comments you would like to share regarding the adoption of blockchain technology in the pharmaceutical supply chain?

6.4 In your opinion, could improved drug traceability minimize the cases of counterfeit drugs in the supply chain (Yes/No)?

Appendix II: Focus Group Questions and Research Participants

1. What are the main challenges or barriers you perceive in adopting blockchain technology in the pharmaceutical supply chain? Specifically, could you elaborate on the high cost associated with implementation and maintenance? How do these cost considerations impact decision-making within your organisations?
2. The survey report highlights the technical complexity of blockchain, including distributed ledgers, smart contracts, and distributed networks. In your opinion, how can organisations address these technical challenges? Are there opportunities for collaboration, training, or partnerships that could help overcome these obstacles?
3. The survey report mentions that a majority of respondents demonstrated understanding of the technical enablers of blockchain technology, but there were still knowledge gaps. In your opinion, what steps can be taken to bridge these knowledge gaps and improve the overall understanding of blockchain technology within the pharmaceutical industry?
4. Based on the findings presented, do you have any recommendations or suggestions for organisations interested in adopting blockchain technology in the pharmaceutical supply chain? Are there any specific considerations or best practices that you believe should be followed?
5. What are the main challenges or barriers you perceive in adopting blockchain technology in the pharmaceutical supply chain? Specifically, could you elaborate on the high cost associated with implementation and maintenance? How do these cost considerations impact decision-making within organisations?
6. Considering the technical complexity of blockchain, do you feel that organisations in the pharmaceutical supply chain possess the necessary skills and expertise to successfully implement and maintain this technology? Can you provide insights into the potential resource constraints or knowledge gaps that might hinder adoption?
7. How do regulatory issues, such as compliance with existing regulations and data privacy concerns, influence the adoption of blockchain technology in the pharmaceutical supply chain? Are there specific regulatory frameworks or requirements that pose challenges or uncertainties in implementing blockchain solutions?
8. The focus group report suggests that resistance to change can impede the adoption of blockchain technology. Can you provide insights into the reasons behind this resistance

among stakeholders in the pharmaceutical industry? Are there concerns related to job security, scepticism about cost benefits, or other factors that contribute to this resistance?

9. In terms of technical enablers, such as hyperledger fabrics, how well do you understand their functionality and their ability to address data confidentiality, integrity, and authentication in the supply chain? Do you think there is a discrepancy between the perceived ease of use and usefulness of blockchain technology and the understanding of its technical enablers?

The focus group consisted of 7 participants who were selected based on their involvement and expertise in the pharmaceutical supply chain. The participants represented a diverse range of stakeholders, including professionals from the pharmaceutical industry. Confidentiality and anonymity were ensured, and pseudonyms were used to conceal the participants' identities. The following table provides a summary of the research participants:

Participant ID	Pseudonym	Affiliation/Role
P01	Patricia	KEMSA, Logistics Officer
P02	Sarah	Mama Lucy Hospital, Pharmacist
P03	Mary	Mama Lucy Hospital, Pharmacist
P04	Patrick	Wessex Pharmaceuticals, Medical Representative
P05	David	KEMSA, Logistics Officer
P06	Samson	KAM Pharmacy, Pharmacist
P07	Jane	GSK Pharmaceuticals
P08	Anthony Ngetich	Moderator

Table 10. Focus group participants

Appendix III: Work Plan

The following is a schedule of activities indicating when each respective activity was due to occur:

Msc Work Plan 2023		MONTH																					
Task	Month / Week Number	February				March				April				May				June				July			
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Phase 1	**STATUS**																								
Define research topic	Complete																								
Formulate research questions	Complete																								
Define research objectives	Complete																								
Conduct literature review	Complete																								
Identify gaps in current research	Complete																								
Phase 2	**STATUS**																								
Draft the research proposal	Complete																								
Revise the research proposal	Complete																								
Present the research proposal M1	Complete																								
Phase 3	**STATUS**																								
Gather users and system requirements	Complete																								
Develop prototype	Complete																								
Develop a data collection plan	Complete																								
Obtain research permit from NACOSTI	Complete																								
Collect and analyze data	Complete																								
Validate results with the supervisor	Complete																								
Phase 4	**STATUS**																								
Submit the final thesis to the supervisor	Complete																								
Defend thesis during the M2	Complete																								
Review & Submit approved thesis M3	Complete																								
Submit publishable paper	Complete																								
Present the viva voce M3	Complete																								
Completion	100.00%																								

Figure 32. Work plan schedule