A STUDY ON THE FEASIBILITY OF USING BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT: A CASE STUDY APPROACH.

Student name: Tsitsidzashe Goto

(Student number: 2280510)

School of Mechanical, Industrial and Aeronautical Engineering

University of the Witwatersrand

Johannesburg, South Africa.

Supervisor: Dr Joke Bührmann

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ABSTRACT

Supply Chain Management is continuously migrating towards digitalisation through the use of new technologies, and one such technology is Blockchain Technology. Several studies have highlighted the benefits of blockchain technology use in supply chain management, the problem however is that, a standard assessment framework to enable an organisation to decide whether the technology fits its organisation has not been developed. This project aimed at formulating an assessment framework that would work as a guide in assessing the feasibility of applying blockchain technology in an organisation's supply chain management system. A methodical triangulation was followed in the research (Thurmond, 2001), as the research data was acquired from a comprehensive literature review, questionnaires and an interview. The data acquired was analysed and from it, the framework was formulated. The formulated framework focused on three dimensions; internal analysis, external analysis and technical analysis. To test the capability of the framework, it was implemented and used on a fourth party logistics organisation identified as Company X in the research. Upon testing, it was concluded that it would be feasible for Company X to adopt blockchain technology as it would benefit both the company and its supply chain partners. The results upon framework implementation indicated that the framework performed the much-needed assessment with focus on operational and technical feasibility. A recommendation for future studies suggested that the feasibility assessment scope be expanded to cover aspects such as cultural feasibility.

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LIST OF ACRONYMS

3PL	Third party logistics
4PL	Fourth party logistics
API	Application programming interface
BT	Blockchain Technology
IoT	Internet of Things
PoW	Proof of work
PoS	Proof of Stake
PBFT	Practical Byzantine Fault Tolerance
SAP	Systems, Applications, Products in Data Processing
SC	Supply Chain
SCM	Supply Chain Management

CHAPTER 1. INTRODUCTORY CHAPTER

1.1 Research Background

Supply Chain Management integrates supply and demand management within and across companies. The Council of Supply Chain Management Professionals (CSCMP) defines Supply Chain Management as the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities (Stock, 2011). It believed that effective management of the chains of supply can be considered as a key element in achieving a competitive advantage for a company of any size. There are a lot of examples throughout supply chain history where Supply Chain Management (SCM) has become one of the main reasons for the great success of a company. An example is Walmart (an American multinational retail company) whose successful management of the chains of supply has been the main reason for its success and has become the world's largest retailer (Galvin, 2017).

Today's supply chain companies are becoming more complex and the visibility of key information, events and collaboration across organisational boundaries is increasingly viewed as an essential criterion for the long-term competitiveness of a supply chain network. The disadvantages of the current supply chain models are that the relationships between the members of the supply chain are not transparent and there is lack of information for the consumer about the origin of the products. There has been a proposition that suggests blockchain technology (BT) application in supply chain management as a means of addressing these disadvantages (Kuhi *et al.*, 2018). However, making decisions that concern supply chain improvements without an adequate cross disciplinary view may lead to regrettable decisions, resulting in waste of time, money, and market position. There is therefore need for an in-depth analysis on the implementation of blockchain technology before entirely embracing that avenue in a specific organisation.

The supply chain today is a series of largely discrete, isolated steps taken through marketing, product development, manufacturing, and distribution, and finally into the hands of the customer (Casino, 2019). Managers in many industries are trying to better manage supply chains by putting together roadmaps of digitalising supply chains. Digitisation overcomes these barriers and the supply chain becomes a completely integrated ecosystem that is fully transparent to all the players.

Amongst the numerous tools proposed for digitalisation in supply chains exists blockchain technology (Schrauf and Berttram, 2016).

The vision of Industry 4.0 (the fourth industrial revolution) is to have most enterprise processes become more digitised. From Industry 4.0 has merged the concept of Logistics 4.0 which encourages the use of technical solutions like cyber physical systems, wireless networks, the Internet of Things (IoT), cloud computing, blockchain technology and many other technologies for supply chain (Alicke *et al.*, 2016). A critical element of Industry 4.0 is said to be the evolution of traditional supply chains toward a connected, smart, and highly efficient digital supply chain ecosystem. These digital supply chains will dissolve silos and enable visibility and better management and performance. These changing supply chains will open new possibilities to changes in business processes. Recent strides towards digitalisation have brought about a proposition of a new model of supply chain via blockchain technology. This new model is believed to enable the concept of circular economy supply chains (other than the linear ones) and eliminates many of the disadvantages of the current supply chains (Masi *et al.*, 2017).

Blockchain Technology (BT) finds itself aligning or coming under the Industry 4.0 or more specifically under Supply chain 4.0, which aims at bringing in new technologies as a means of increasing the efficiency of systems, whilst maintaining reasonable or meaningful cost. Blockchain is therefore being explored because it fits into the global focus and can be associated with supply chain growth and acceleration. Blockchain technology is currently gaining the interest of a wide variety of industries; from finance, healthcare, utilities and even the government sector amongst many other sectors. The reason for this growing interest is the inherent characteristics of blockchain architecture and design is that it is believed to provides properties like transparency, robustness, auditability, and security (Casado-Vara *et al.*, 2018).

A blockchain can be considered a distributed database that is organised as a list of ordered blocks, where the committed blocks are immutable (Min, 2019). The impact that blockchain technology is said to bear on the supply chain management objectives such as cost, quality, speed, dependability, risk reduction, sustainability and flexibility makes it worth the exploration (Kshetri, 2018). The use of blockchain technology in supply chain activities to increase efficiency, transparency and accountability will be of interest as case studies of diverse blockchain applications are discussed and a framework for the feasibility assessment is created for the case study organisation.

1.2 Problem Statement and motivation

Supply chain systems are constantly migrating towards full integration, which implies seamlessly connecting suppliers, manufacturing, logistics, warehousing, and consumers. This has therefore brought about exploration on the implementation of blockchain technology in Supply Chain Management (SCM). The problem however is that there has not been a holistic assessment regarding the feasibility of such an application of blockchain and therefore practitioners come across extreme difficulty when faced with the decision of taking up blockchain technology. This difficulty has been associated with limited product data and or a reliable technology adoption framework to assess the suitability of blockchains in a specific organisation.

1.3 Research Question

The primary research question can be expressed as:

What factors must be included in a framework that is meant to assess the suitability of blockchain technology in the supply chain industry?

The primary question will be further classified into the following sub-question:
How does Company X measure up against these factors?

1.4 Research Objectives

The objectives of this research are to:

a. Perform a holistic study of the Company X's supply chain management system.
b. Develop a framework to assess the feasibility of blockchain technology adoption in an organisation.
c. Test the framework against Company X.
d. Conclude on the feasibility of adopting blockchain technology in Company X's SCM system.

1.5 Project Scope

The project will focus entirely on blockchain technology and the qualities it possesses that make it desirable for implementation in supply chain management. The study will be conducted at a

logistics organisation in Johannesburg whose primary profitability relies on the effectiveness of their supply chain management abilities, the organisation will be referred to as Company X throughout the study. The developed assessment framework will be tested on Company X and a conclusion given.

In terms of feasibility the research aims at measuring how beneficial or practical the use of blockchain will be to the organization. The research will only focus on the technical and operational feasibility of adopting the technology. The technical feasibility will consider the technical requirements of BT and whether an organisation can meet those. The operational feasibility will consider how well BT will fit into an organisation's SCM systems and satisfy the requirements of the system.

1.6 Project timeline

The research followed the timeline shown on the Gantt chart in Figure 1.1.

ID	Task Name	Start	Finish	Duration
1	Project Proposal preparation	2/14/2019	3/20/2019	25d
2	Literature Review	3/21/2019	4/17/2019	20d
3	Organisational Survey	4/10/2019	5/8/2019	21d
4	Delphi Method and Development of Framework	4/24/2019	6/18/2019	40d
5	Implementation of Framework	6/18/2019	7/9/2019	16d
6	Results and Conclusion	7/9/2019	8/5/2019	20d
7	Submit first draft of report	8/12/2019	8/12/2019	1d
8	Review and correct	8/26/2019	9/23/2019	21d
9	Final Report Submissionn	9/24/2019	9/25/2019	2d

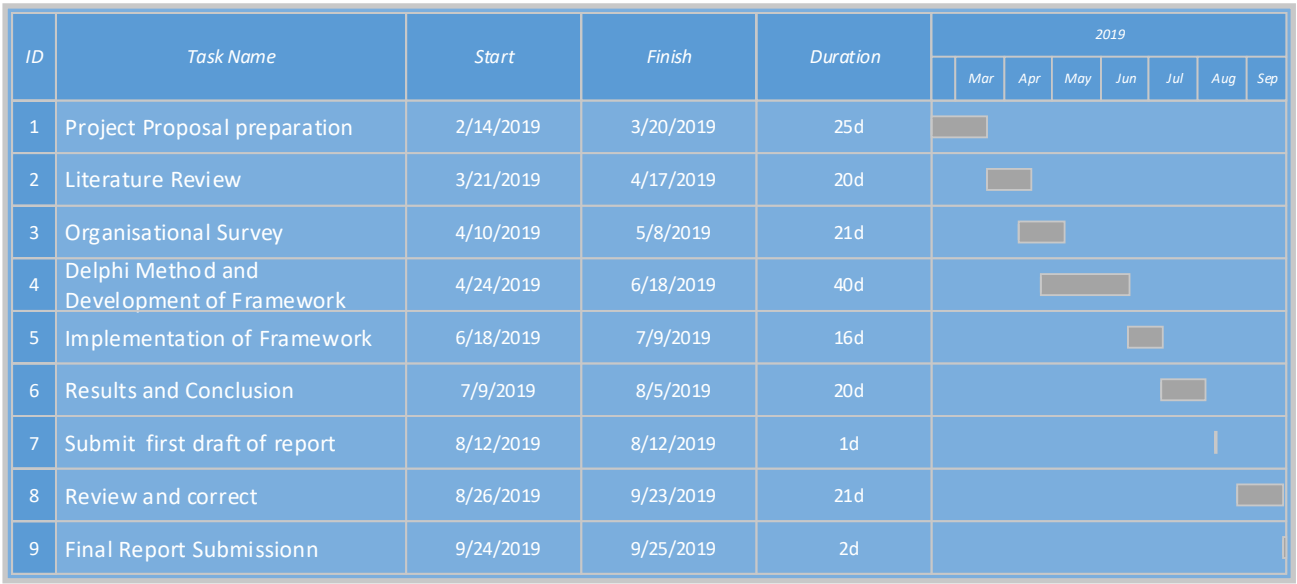

Figure 1.1 Project timelines.

1.7 Chapter Summary

This chapter introduced the project, identified the problems being addressed by the project and also outlined the means by which the problem will be addressed through the objectives. The timeline that the project followed was also highlighted in this Chapter.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

In this section, focus will initially be on understanding supply chain management and blockchain technology independently and later collaboratively. Supply chain objectives, models, its functionality and strides towards digitalisation will be explored. On the other hand, under blockchain technology, focus will be on its functionality, desirable qualities and applications. The formulation of the research hypotheses will also be done in this chapter.

2.2 Supply Chain Management

According to Stock (2011), supply chain management is the management of a network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse of materials, services, finances and information from the original producer to final customer, with the benefits of value addition, achievement of customer satisfaction, and profitability maximisation through efficiencies (Stock, 2011).

2.2.1 The aspects of a supply chain.

Supply chain management covers a very wide range of business processes and activities. These activities are divided into five basic areas and are called the five drivers of a supply chain, which are production, inventory, location, transportation and information (Koksharov, 2016).

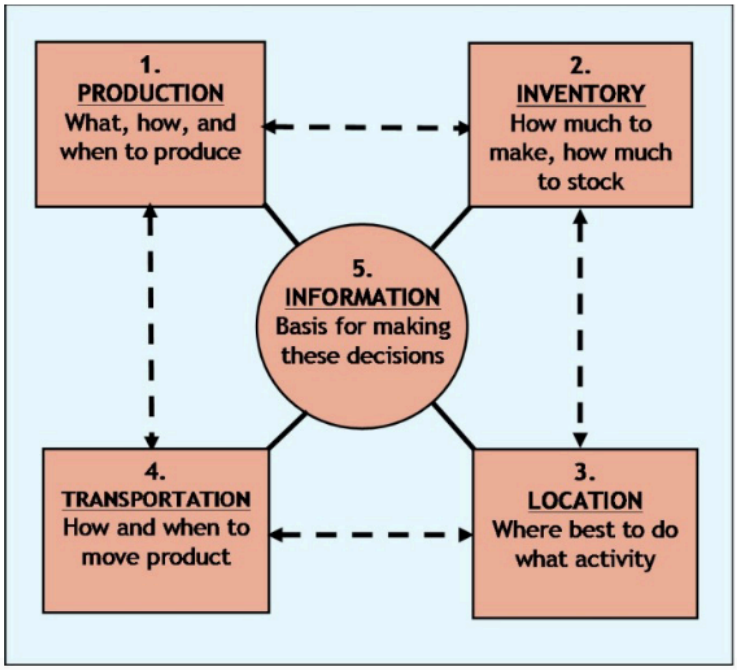

Figure 2.1 The five drivers of a supply chain (Koksharov, 2016)

Each of the drivers answers specific questions and relates to a particular element of the business process. Production covers most of the issues regarding the product itself. The typical questions in this area include questions about the product itself and the quantities to be produced. Furthermore, production refers to the aspect of storing the product therefore factories and warehouses are recognized as the main facilities of production (Koksharov, 2016).

Inventory describes how much of a product should be stocked at each stage and how much of the products should be held fully assembled or as raw materials. When making decisions regarding the inventory issues, there are three adjustments to be made. Firstly, the cycle inventory, which is the inventory required to cover the demand of the product. Second decision is safety inventory. Safety inventory is a defence against unforeseeable circumstances which allows the company to continue sales in case of break up in production. Finally, seasonal inventory requires changes in inventory level depending on demand fluctuations affected by certain periods of the year. The very basic example is winter and summer tyres for delivery vehicles required in some countries (Bhatnagar, 2009).

Location answers the question “Where?”. In more detail, it refers to the geo-location of supply chain facilities (Bhatnagar, 2009).

Transportation is the delivery of inventory during each stage of the supply chain. The most important decision to make at this stage is the kind of transport. There are five basic options in the modern world which are rail, pipelines, trucks, airplanes and electronic transport (Koksharov, 2016).

Information addresses issues to do with determining the data that is essential and how much of it must be collected. The main targets of information flow are to coordinate daily activities and forecasting. In order to build a successful supply chain strategy, all these drivers are to integrated with each other to achieve the strategic goals of the supply chain (Koksharov, 2016).

2.2.2 The parties in a supply chain system

Fundamentally, a supply chain can be formed with only three parties, which are suppliers, producers and customers. However, in any given supply chain, there is a set of companies having various functions. There might be suppliers of suppliers or customers of customers or in case of business-to-business operations, the final customer. Further, there are a lot of companies which are service providers at any given step of supply chain activities (Bhatnagar, 2009). The various parties and how they may interact is shown in Figure 2.2.

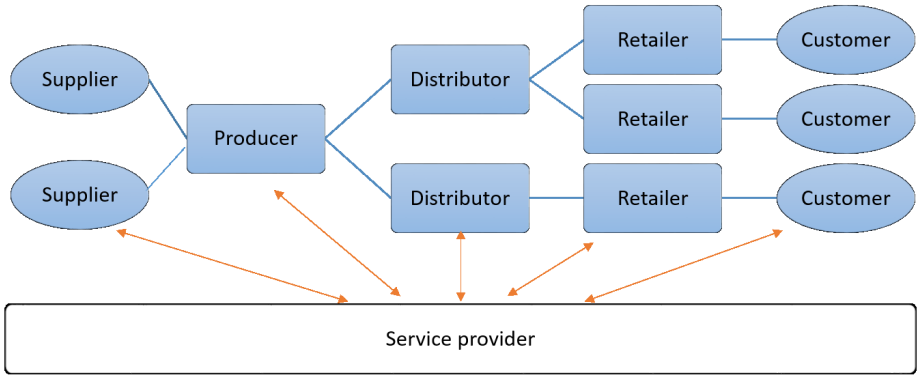

Figure 2.2 : The parties in a supply chain system (Koksharov, 2016)

2.2.3 Migration towards digitalisation of supply chains

Behind the great potential of the digital supply chain lies Industry 4.0, the fourth industrial revolution. A transformation in production and automation was brought on first by steam and waterpower (Industry 1.0), then by electrification (2.0), and more recently by the digital computer (3.0). Industry 4.0, digitization, is about companies orienting themselves to the customers through e-commerce, digital marketing, social media, and the customer experience. Ultimately, every aspect of business will be transformed through the vertical integration of research and development, manufacturing, marketing and sales, and other internal operations, and new business models will be based on these advances (Schrauf *et al.*, 2016). In effect, there is evolution toward a complete digital ecosystem. The next generation of performance management systems provides real-time, end-to-end transparency throughout the supply chain such as the exact position of trucks in the network at a given time during transportation. The digitisation of the supply chain enables companies to address the requirements of the customers promptly, address the challenges on the supply side as well as improve efficiency (Alicke *et al.*, 2016).

According to Alicke (2016), digitalisation is believed to bring about Supply Chain 4.0 which in turn will bring about the following benefits in line with supply chains:

- More flexibility
- More granular systems
- More accurate systems
- More efficient and transparent systems

2.2.4 The strategic supply chain objectives

As a crucial component of an organisation the supply chain ought to have strategic objectives that the organisation consistently aims at improving. The strategic objectives of a supply chain include cost, quality, speed, dependability, risk reduction, sustainability and flexibility (Kshetri, 2018). It is these objectives that necessitate the need for continuous improvement within the supply chain of an organisation.

2.3 Blockchain technology

A blockchain is a shared and distributed ledger that enables the process of recording transactions and tracking assets within a business network. An asset can be tangible (for example a house, a car, cash, land) or intangible like intellectual property, such as patents, copyrights, or branding. Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved (Gupta, 2018).

Blockchain technology is based on a distributed ledger system and can be seen as a verification system for digital transactions where data about a transaction, between members of the network, can be stored (Casino *et al.*, 2019). A blockchain can allow different levels of access; private, public or consortium and be outlined in different kinds of distribution architectures such as centralized, decentralized or distributed as visualised in Figure 2.3.

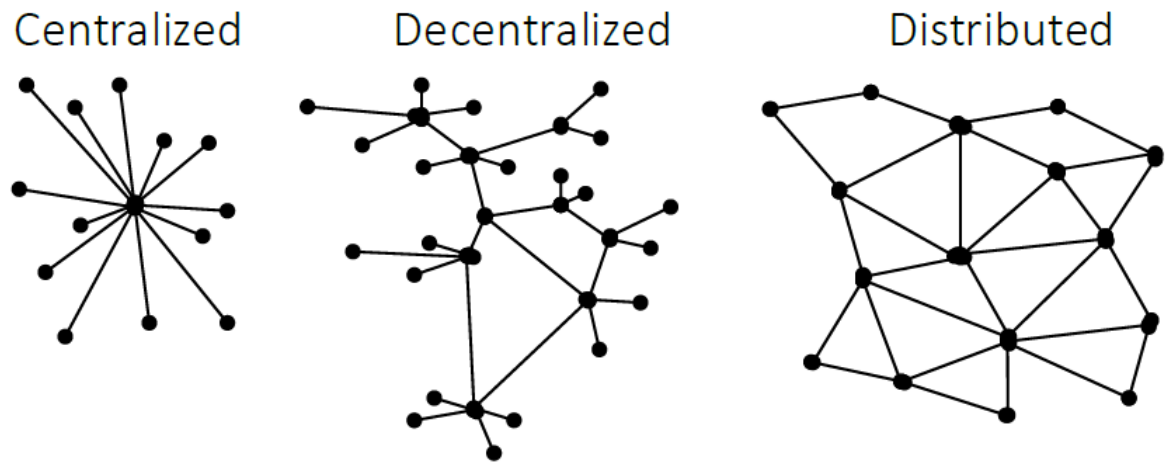

Figure 2.3 : Different network structures (Holmberg, 2018).

A member of a blockchain network is often called a node. A block contains of a hash and the hash from the previous block, which is how the blocks are connected and data will be chronologically stored, forming a chain of blocks within a network. Each of the blocks can be identified as an encrypted piece of information where all transactions are encrypted by hashing. A hash is the result from a hash function of all the content inside a block. A hash function is an algorithm that encrypts data and is almost impossible to reverse (Holmberg, 2018) .

The hash function is performed within some kind of consensus protocol which can be described as a specific procedure to confirm a transaction on a blockchain. The confirmation of transactions is an important function on the blockchain due to the risk of hacking attacks. A famous theory addressing the risks of attacks is called the Byzantine fault theory (Holmberg, 2018). The Byzantine fault theory originates from Byzantine generals' problem where several different armies together could defeat a city only if they all communicate at one specific moment and decide on the attack at the same time (Holmberg, 2018). According to Holmberg (2018), this problem can be applied in the digital world, saying that one single node will fail with a hacking attack, but if a network of nodes collaborates at the same time, they will be able to resist the hack of a database There are different approaches to deal with this problem, such as Proof of Work (PoW), Proof of Stake (PoS) and Practical Byzantine Fault Tolerance (PBFT) and each of these will be further studied in the project (Holmberg, 2018).

An important aspect to the blockchain technology is that it is designed to store information in a way that makes it impossible to change, delete or add information or blocks without being detected by other users. This ensures the origin and authenticity of a transaction is maintained and also increases the overall transparency and trust when linked to a specific product (Holmberg, 2018).

2.3.1 Exploring a blockchain application

Leasing a vehicle is not as easy as car companies make it look. One noteworthy challenge faced by car leasing networks is that the supporting systems are often fragmented even though the physical supply chain maybe integrated. Each party within the network maintains its own ledger, which can take days or weeks to synchronize as shown in Figure 2.4.

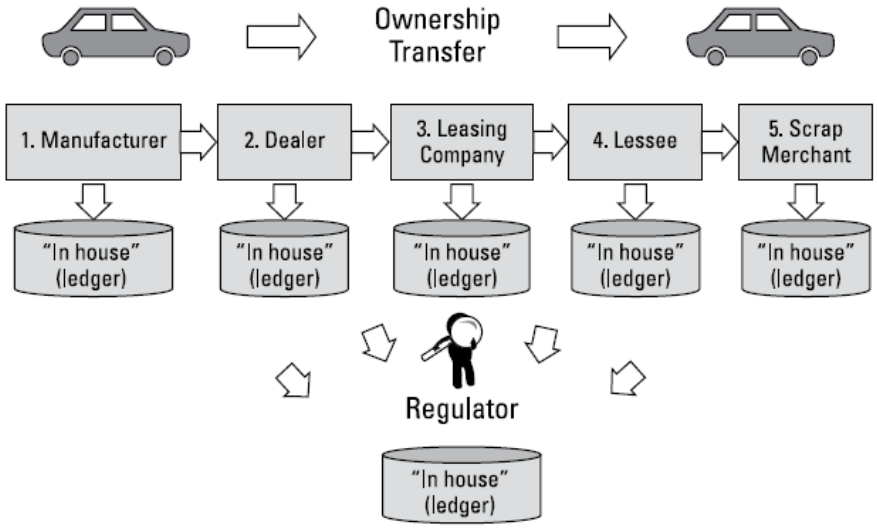

Figure 2.4: Tracking vehicle ownership without blockchain (Gupta, 2017).

With blockchain, network participants can interact as follows, the government regulator creates and populates the registration for the new vehicle on the blockchain and transfers the ownership of the vehicle to the manufacturer and the manufacturer adds the make, model, and vehicle identification number to the vehicle template within the parameters allowed by the smart contract (a digital agreement or set of rules that govern a transaction). The dealer is able to see if there is new stock and the ownership can be transferred to the dealership from the manufacturer, and the smart contract is the one that performs sale validation (Gupta, 2018). The leasing company can see the dealer's inventory. After a smart contract is executed to validate the transfer, ownership of the vehicle can be transferred from the dealer to the leasing company. The lessee can see the cars available for lease and complete any form required to execute the lease agreement (Gupta, 2018). The leasing process continues between various lessees and the leasing company until the leasing company is ready to retire the vehicle. At this point, ownership of the asset is transferred to the scrap merchant, who, according to another smart contract, has permission to dispose of the vehicle (Gupta, 2018). The new network that includes blockchain technology is shown in Figure 2.5.

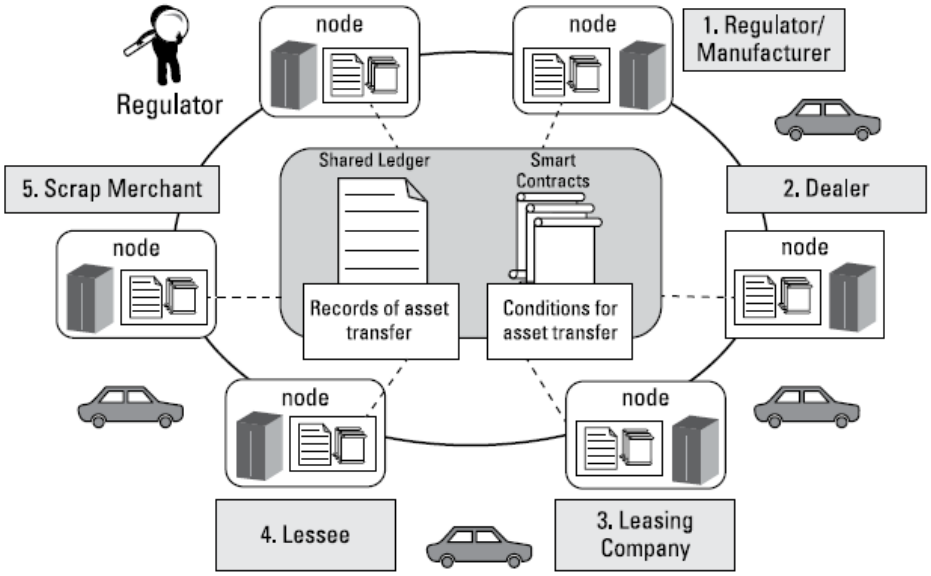

Figure 2.5: Tracking vehicle ownership with blockchain (Gupta, 2017).

2.3.2 Building trust with blockchain

Blockchain enhances trust across a business network. Blockchain is significantly valuable at increasing the level of trust among network members. Since every transaction builds on every other transaction, any corruption is readily apparent, and everyone is made aware of it (Scriber, 2018). This self-policing can mitigate the need to depend on the current level of legal or government safeguards and sanctions to monitor and control the flow of business transactions. The community of participants does that. Where a third-part is required to oversee a process, blockchain reduces the burden on the regulatory system by making it easier for the auditors and regulators to review relevant transaction details and verify compliance (Tian, 2017).

According to Gupta (2017) blockchain technology builds trust through the following five attributes:

i. Distributed and sustainable**:** The ledger is shared, updated with every transaction, and selectively replicated among participants in near real time. The blockchain platform's continued existence isn't dependent on any individual entity because it is not owned or controlled by any single organization.

ii. Secure, private, and indelible: Permissions and cryptography prevent unauthorized access to the network and ensure that participants are who they claim to be. Cryptographic techniques and other data partitioning techniques are used to give participants selective visibility into the ledger, hence achieving privacy. After conditions are agreed to, participants cannot tamper with a record of the transaction.

iii. Transparent and auditable: Since participants in a transaction have access to the same records, they can validate transactions and verify identities or ownership without the need for third-party intermediaries. Transactions are time-stamped, and their verification is in near real time.

iv. Consensus-based and transactional: All relevant network participants must agree that a transaction is valid. This is achieved through the use of consensus algorithms. The conditions under which a transaction or asset exchange can occur can be established by each blockchain network.

v. Orchestrated and flexible: Since business rules and smart contracts can be built into the platform, blockchain business networks can evolve as they expand to support end-to-end business processes and other several activities.

2.3.3 What Makes a Blockchain Suitable for Business?

Instead of having a blockchain that relies on the exchange of crypto-currencies with anonymous users on a public network (as is the case with bitcoin), a blockchain for business is a private, permissioned network with known identities and without the need for crypto-currencies. To further understand how a blockchain for business works, and to appreciate its potential for revolutionizing business networks, the four key concepts of blockchain (as shown on Figure 2.6) for business must be understood (Gupta, 2018).

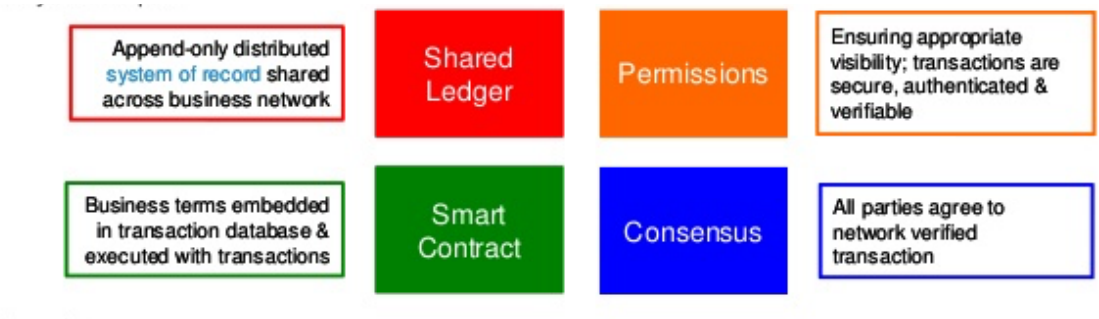

Figure 2.6: The four key concepts of blockchain (Gupta, 2018).

2.3.3.1 Shared ledger

Ledgers have been used in double-entry bookkeeping since the 13th century. However, the concept of a shared, distributed ledger which is an immutable record of all transactions on the network and a record that all network participants can access is new (Leng *et al.*, 2018). With a shared ledger, transactions are recorded only once, eliminating the duplication of effort that's typical of traditional business networks. According to Gupta (2017), the shared ledger has the following characteristics:

- Records all transactions across a business network since the distributed ledger is the system of record.
- Is shared among all network participants.
- Is permissioned, therefore participants see only those transactions they are authorized to view.

2.3.3.2 Permissions

Blockchains can be permissioned or permissionless. In a permissioned blockchain, each participant has a unique identity which enables the use of policies to constrain network participation and access to transaction details. With the ability to constrain network participation, organizations can more easily comply with data protection regulations. Permissioned blockchains are also more effective at controlling the consistency of the data that gets appended to the blockchain (Gupta, 2018). More transaction detail can be stored in the blockchain due to the ability to restrict access to transaction details and participants can specify the transaction information they're willing to

allow others to view. In addition, some participants may be authorized to view only certain transactions, while others, such as auditors, may be given access to a broader range of transactions (Wust and Gervais, 2018)**.**

2.3.3.3 Consensus

According to Mao et al., (2018), in a business network where participants are known and trusted, transactions can be verified and committed to the ledger through various means of consensus (agreement), including the following:

- Proof of stake: Validators must hold a certain percentage of the network's total value to validate transactions. It may provide increased protection from a malicious attack on the network through the reduction of incentives for attack and making it very expensive to execute the attacks.
- Multi-signature: A majority of validators in the network must agree that a transaction is valid (for example, five out of seven)
- Practical Byzantine Fault Tolerance (PBFT): An algorithm designed to settle disputes among computing nodes (network participants) when one node in a set of nodes generates different output from the others in the set (Mao *et al.*, 2018).

2.3.3.4 Smart contracts

A smart contract is a set of rules or an agreement that governs a business's transactions. A smart contract is stored on the blockchain and is executed automatically as part of a transaction. They may have many contractual clauses that could be partially or fully self-executing, self-enforcing, or both depending on the participants' preferences. Their purpose is to provide security superior to traditional contract law while reducing the costs and delays associated with traditional contracts (Casado-Vara *et al.*, 2018).

For example, a smart contract may define contractual conditions under which a corporate bond transfer occurs, or it may encapsulate the terms and conditions of travel insurance, which may be executed automatically when, for example, a flight is delayed by more than six hours.

2.4 Blockchain Technology (BT) types, their characteristics and technical aspects

It is important when considering the use of a technology to analyse the characteristics of the technology so as to identify its applicability in a certain organisation. With a blockchain, you create rules for what information is shared and who gets to see it (Stanton, 2016). A blockchain system can be categorised into three types: public blockchain, private blockchain, and federated or hybrid blockchains.

2.4.1 Public blockchains

In public blockchains, anyone can transact in the blockchain network, and if valid, can see the stored blocks. In addition, anyone can read the transactions listed on the blockchain. Typically, these transactions are anonymous or pseudo-anonymous (Olsen *et al.*, 2019)**.** Bitcoin and Ethereum are examples of public blockchains.

2.4.2 Private blockchains

A private blockchain is regarded as a centralised network since it is entirely controlled by a single organization. With private blockchains, write permission to the blockchain is commonly kept centralised to one organisation(Olsen *et al.*, 2019). Reading the blockchain may be (partly) public or restricted to a selected few. In public blockchains, members who control the blockchain are at risk of security breaches (Olsen *et al.*, 2019).

2.4.3 Hybrid or federated blockchains

Hybrid or federated blockchains (also known as Consortium blockchains) are typically managed by a group of people, entities, or trusted authorities. In essence, joining the blockchain network is restricted and it is only granted to a selected set of nodes. This is one of the main differences when comparing it to a public blockchain, where any person with access to the Internet can participate in the process of verifying transactions and creating new blocks (Olsen *et al.*, 2019).

Hybrid blockchains offer higher scalability (they are faster) and provide more transaction privacy. The consensus process is controlled by a pre-selected set of nodes and the right to read the blockchain may be public or restricted to the participants (Olsen *et al.*, 2019).

Examples of successful applications of this hybrid blockchain are the Energy Web Foundation (EWF), which is considered the world's largest energy blockchain ecosystem and B3i which is an organisation that is improving efficiency across the insurance and reinsurance sector through

blockchain. Successful implementations of hybrid blockchains can reduce transaction costs, reduce data redundancies, replace legacy systems, simplify document handling, and create full compliance mechanisms (Olsen *et al.*, 2019).

In assessing the suitability of blockchain in the supply chain industry it is necessary to also have an overview of the qualities that each of the BT types contributes as these will affect an organisation's decision on which to adopt. Figure 2.7 compares the three types of blockchains based on six criteria: consensus determination, read permission, immutability, efficiency, centralisation, and consensus process which will also be used in determining the type of BT to employ. Each of the criteria is looked at in depth.

2.4.4 Consensus determination

The validation of a new chain block is known as consensus determination and it demonstrates to the blockchain network that some form of block validation has been established. In a public blockchain, each node could take part in the consensus process as there is no entry requirement. In a hybrid blockchain, only a selected set of nodes are responsible for validating new blocks. For the private blockchains, one organisation or trusted authority is entirely responsible for validation and consensus mechanism (Olsen *et al.*, 2019).

2.4.5 Read permission

Read permission is the visibility of transactions within the blockchain network. Within a public blockchain, there is no restriction in terms of reading the transactions as anyone can view all the transactions. The read permissions for private or hybrid blockchains are regulated and can be constructed in a variety of ways (Olsen *et al.*, 2019).

2.4.6 Immutability

The public BT usually has a high degree of immutability since transactions are stored in different nodes in the distributed network, which makes it nearly impossible to tamper with a public blockchain (Olsen *et al.*, 2019). For private and hybrid blockchains, immutability is low since the majority of block validators may tamper with the blockchain if they so desire but a predefined degree of consensus is still required (Olsen *et al.*, 2019).

2.4.7 Efficiency

Efficiency relates to the handling of transactions and how the flow of data propagates throughout the network. In a public blockchain, the propagation or broadcasting of transactions and blocks takes more time, and this is caused by the numerous nodes in the network. In terms of safety, restrictions on public blockchain would be stricter hence limiting the throughput of transactions. The fewer validators within hybrid and private blockchains may make the propagation of data more efficient (Olsen *et al.*, 2019).

2.4.8 Degree of centralisation

A centralised network relates to control that is carried out by a single entity in the BT system. According to Olsen *et al.*, (2019), the main difference between the three types of blockchain types is that a public blockchain is fully decentralised, meaning that no single authority handles or controls the blockchain network. The hybrid blockchain is partially centralised and the private blockchain is fully centralised as it is controlled by a single entity (Olsen *et al.*, 2019).

	Public	Consortium/Federated	Private
Consensus determination	everyone	selected (few)	single authority
Read permission	public	public, partly public, restricted	public, partly public, restricted
Immutability	nearly impossible	possible with majority of validators	possible
Efficiency	low	high	high
Centralised	no	partially	yes
Consensus process	permissionless	permissioned	permissioned

Figure 2.7 Types of blockchains and their characteristics (Olsen *et al.*, 2019).

2.4.9 Consensus mechanism

In blockchain, a consensus mechanism is required to enable the nodes in the blockchain network to decide on which new transactions to add to the blockchain (Olsen *et al.*, 2019).

Proof of work (PoW) provides a way to ensure that some computational work has been performed to validate transactions and to allow the new block to be appended to the blockchain. The computational work involves the solving of a cryptographic puzzle which takes time and computing power to solve. However, once it is solved, other nodes within the network can easily

verify the answer. PoW consensus mechanism uses huge amount of energy in computers when solving the cryptographic puzzle and it takes time to validate and append new blocks to the blockchain (Olsen *et al.*, 2019).

Proof of Stake (PoS) eliminates the need to buy expensive and powerful computer hardware to solve cryptographic puzzles in a short amount of time. The blockchain network selects, based on the amount of stake a member is willing to put into the system, an individual to confirm the validity of the transactions and the creation of the new block (Olsen *et al.*, 2019). Validators who place (proportionally) more stake are more likely to be chosen to create and append the new block to the blockchain. This is one of the main differences compared to the PoW mechanism (Mao *et al.*, 2018).

The Practical Byzantine Fault Tolerance (PBFT) algorithm is a mechanism to solve the problem traditionally known as the Byzantine Generals, which is fundamentally found in distributed systems with trust-less participants. According to Olsen et al (2019), each 'general' maintains an internal state. When a 'general' receives a message, they use the message in conjunction with their internal state to run a computation or an operation. This computation, in turn, tells that individual 'general' what to think about the message in question (Olsen *et al.*, 2019). Then, after reaching an individual decision about the new message, the 'general' shares that decision with all the other 'generals' in the system. A consensus decision is determined based on the total decisions submitted by all generals (Olsen *et al.*, 2019). Three examples of blockchains that rely on the PBFT for consensus are Hyperledger, Stellar, and Ripple. One of the advantages of a PBFT consensus mechanism is that it requires less effort in terms of computational work (Olsen *et al.*, 2019).

2.4.10 Comparison between permissioned and permissionless blockchain types.

The comparison between permissioned and permissionless blockchain types in relation to trust and the anonymity of validators is depicted in Figure 2.8

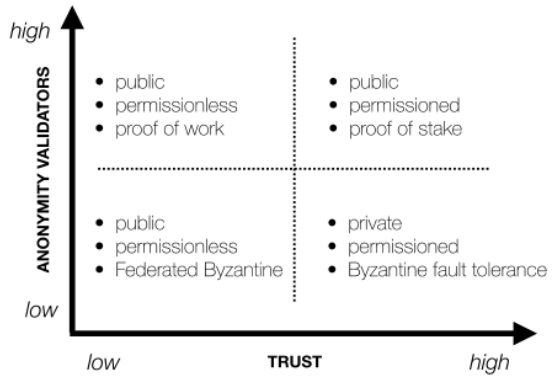

Figure 2.8 Overview of trust levels vs. anonymity of validators within permissioned and permissionless blockchains (Olsen *et al.*, 2019).

A permissionless blockchain when combined with a public blockchain has a high degree of anonymity of the validators with a low degree of trust in the validators. The consensus mechanism in this instance could be a proof of work-based implementation. Such blockchain types are suitable for full anonymous systems that have no control mechanism of one single entity or person such as Bitcoin (Olsen *et al.*, 2019).

A permissioned blockchain combined with a public blockchain has a high degree of anonymity of the validators while having a high degree of trust in those validators. The consensus mechanism implementation can be proof of stake based. Such types are typically more scalable but have a moderate degree of immutability an example is Ethereum (with proof of stake implementation) (Olsen *et al.*, 2019).

A permissioned blockchain combined with a private blockchain will possess a low degree of anonymity of the validators, but they will have a high degree of trust. When a consensus mechanism is PBFT based, the need for computation power and energy resources are reduced. Such blockchains are applicable to banking, fast payment infrastructure, corporate usage and are generally used for traceability, flexibility, and efficient governance of digital assets (Olsen *et al.*, 2019). Figure 2.8 shows a comparison between public and private blockchains and permissionless and permissioned. It may also help an organisation in determining the best combination of BT characteristics before making the decision to adopt it.

2.4.11 Blockchain infrastructure

Besides the investments made into setting up or developing the blockchain system, Olsen *et al.* (2019) believe that there are very few additional hardware investments to make so as to enable

information to be stored onto the blockchain. Where an organisation would have stored the information in a digital database, ledger, or supply chain system, it can store the information directly (for example in application programming interfaces) or indirectly (e.g. web interface) on the blockchain. Besides manually entering data into the system, scanners or other electronic reading devices can be used (Olsen et al., 2019).

Data connector application programming interfaces (APIs) allow companies to efficiently upload supply chain data from existing data stores (such as SAP) to their blockchain system for seamless integration of data from enterprise systems to blockchain solutions. Organisations that do not work with an enterprise software can enter data through web interfaces (Olsen et al., 2019).

According to Moura and Santos (2019), the adoption of BT will mean the organisation must be willing to embrace the IoT as this is a critical aspect of BT performance. IoT use in the SC industry, with technology such as sensors, barcode readers, and QR codes, is at the heart of this solution, and IoT integrated with blockchain can not only mitigate a lot of issues but can transform the industry (Moura and Santos, 2019). Internet-enabled sensors fastened onto equipment provide critical insights into maintenance and product safety issues, which includes real-time system-generated alerts and notifications (Moura and Santos, 2019). An organisation that is considering the use of BT must there for be willing to also invest in the necessary IoT devices as they are critical for the performance of blockchain technology in supply chain management.

2.5 Blockchain technology applications.

Blockchains introduced serious disruptions to the traditional business processes since the applications and transactions, which needed centralised architectures or trusted third parties to verify them, can now operate in a decentralised way with the same level of certainty. The inherent characteristics of blockchain architecture and design provide properties like transparency, robustness, auditability, and security (Casino, 2019). Blockchain technology can mitigate risks associated with intermediaries' interventions, including hacking, compromised privacy, vulnerability to political turmoil, costly compliance with government rules and regulation, instability of financial institutions, and contractual disputes (Min, 2019).

One of their main advantages is the lack of infrastructure costs: the network is self-sustained and capable of maintaining itself, drastically reducing management overheads (Casino, 2019). Blockchain application has gained attention from various fields such as education, health,

governance, data management, industry and business, as well as in other fields as shown in Figure 2.9.

Figure 2.9: Blockchain applications (Casino, 2019).

According to Galvin (2017) the benefits of blockchain technology in supply chain within the food industry include:

i. Improved track & trace capabilities which in turn result in decreased response time to product recalls.
ii. Enhanced food flow which has an impact on shelf life management
iii. Lower compliance costs.

2.5.1 Blockchain Technology use cases in Supply Chain Management

ConsenSys is a market leading blockchain technology company that recently presented and showed some use cases of BT in SCM. The organisation is currently proving the authenticity of luxury items to battle fraud and counterfeiting. The luxury goods industry is dealing with the growing challenges like imitations and intellectual property (IP) when it comes to protecting brand value and authentic relationships between customers and brands. ConsenSys, in partnership with LVMH and Microsoft, recently announced AURA, a platform that makes it possible for consumers to access the product history and proof of authenticity of luxury goods. This platform traces from raw materials to the point of sale, all the way to second-hand markets (Consensys, 2019).

Treum is a blockchain-based trust platform focused on traceability, transparency, and tradability in supply chains. Treum (which is a ConsenSys platform) has a traceability feature which seamlessly records an asset's end-to-end source information. It is its transparency capability that allows manufacturers to verify that their supply chain meets product objectives. Altogether, Treum is able to give both companies and consumers the full product story. In the pharmaceutical industry a transparent supply chain management system can help to better ensure products are protected. Treum partnered with GlaxoSmithKline to use blockchain to track intellectual property (IP) licenses used by scientists as well as ensure that products are produced, transported, and stored in proper conditions (Consensys, 2019).

2.6 Questionnaire Design

When a questionnaire is used for research, it is necessary to ensure that it is constructed and designed in a way that allows for the gathering of the necessary data effectively. The types of questions that can be used, what the question content must be, and the placement of the question is critical.

2.6.1 Types of questions

According to William Trochim (2006), there are chiefly three types of structured questions that can be used when constructing a questionnaire. These are dichotomous questions, questions based on level of measurement and contingency (or filter) questions.

The Dichotomous Questions have two possible responses. An example of such questions is those that ask for a Yes/No or Agree/Disagree response. Questions can also be classified in terms of their level of measurement and an example is survey questions that attempt to measure on an interval level. The Likert response scale is the most common of these types. The Likert response scale is the traditional 1-to-5 rating and in some cases 1-to-7 or 1-to-9. An example is shown in Figure 2.10 (Trochim, 2016).

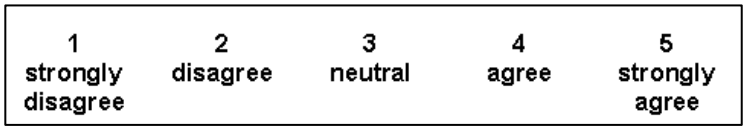

Figure 2.10 Likert response scale (Trochim, 2016).

The third type of questions are the filter or contingency questions. According to William Trochim (2006), these are used when one has to ask the respondent one question in order to determine if they are qualified or experienced enough to answer a subsequent one.

2.6.2 Question content

For each question in the survey, the researcher should ask how well it addresses the content they are trying to get at and this usually in line with the research question or objective. The critical part of a questionnaire design is ensuring that the content being investigated is addressed well. It is necessary for the researcher to examine each question to see if they need to ask it at all. Caution must also be taken to avoid the problem double-barrelled questions as these may touch on more than one issue, hence complicating the study. Each question in the survey must be assessed to see whether the respondent is likely to have the necessary information to be able to answer the question. The questions need to be specific and clearly defined to avoid any misinterpretation by the respondents. It is also critical to ensure that the questions are not biased or loaded so as to allow for the respondents to express their uninfluenced opinion (Trochim, 2016).

2.6.3 Question Placement

The ordering of questions is among the most difficult tasks faced by a survey designer. According to William Trochim (2006), when performing question placement, the following must be noted:

- Start with the easy and nonthreatening questions.

- The more difficult and threatening questions must be near end.
- A mail/online survey must not start with an open-ended question.
- Only one topic should be asked at a time.
- A transition must be used when switching topics.
- The response set (the tendency of respondent to just keep checking the same response) must be reduced.

2.7 Triangulation Methodology

Triangulation is an approach which enables the checking of findings by the use of different data collection methods, sources and theoretical constructs (Williamson and Johanson, 2017). According to Yeasmin and Rahman (2012), triangulation is a process of study verification that increases validity by incorporating several viewpoints and methods. It refers to the combination of two or more theories, data sources, methods or investigators in a single study of a particular phenomenon and can be employed in both quantitative and qualitative studies (Yeasmin and Rahman, 2012). Triangulation is an effective tool that may overcome the weakness or intrinsic biases and the problems that come from single method, single-observer, single-theory studies (Yeasmin and Rahman, 2012).

2.7.1 Methodologic Triangulation

Methodologic triangulation is also called multimethod, mixed-method, or methods triangulation. According to Thurmond (2001), some authors have discussed methodologic triangulation in reference to qualitative and quantitative methods, indicating a paradigmatic connection. Methodical triangulation may therefore refer to either research designs or data collection methods (Thurmond, 2001). Thurmond (2001) also observes that methodical triangulation decreases the deficiencies and biases that stem from any single method hence creating the potential for counterbalancing the flaws or the weaknesses of one method with the strengths of another (Thurmond, 2001).

The two types of methodologic triangulation are within-method triangulation and between- or across-method triangulation. Researchers using within- method triangulation use two or more data collection procedures that are from the same design approach. The procedures could consist of administering survey questionnaires and using pre-existing data from databases for quantitative

approaches. In qualitative approaches, nonparticipant observations could be combined with interviews. This highlights that in this approach the methods are either qualitative or quantitative, but not both. (Thurmond, 2001). Researchers using across-method (between-method) triangulation employ both qualitative and quantitative data collection methods in the same study. An example highlighted by Thurmond (2001) is the combination of participant interviews and questionnaires in the same study (Thurmond, 2001).

2.7.2 Benefits of Triangulation

The benefits of methodologic triangulation include increased confidence in research data, revealing unique and interesting findings, challenging theories, providing a clearer understanding of the problem and creating new ways of understanding a subject (Thurmond, 2001).

This approach also minimises the inadequacies of single-source research as already highlighted. The fact that two sources complement and verify one another reduces the impact of bias (Yeasmin and Rahman, 2012). Methodical triangulation can increase credibility of scientific knowledge by improving both internal consistency and generalizability, through combining both quantitative and qualitative methods in a single study (Yeasmin and Rahman, 2012).

2.8 The suitability assessment frameworks and criteria suggested by other experts

In an article on the Forbes website, Jai Menon (2018) highlighted some questions that an organisation needs to ask and answer before making a decision on using blockchain technology (Menon, 2018). Amongst the question highlighted were the following:

i. Might you have a need to remove a record in the blockchain or correct a mistake?

As stated earlier, blockchains are append-only, so they will not allow for that. Organisation that will not need to edit their supply chain and logistics records will likely find the use of blockchain technology more beneficial.

ii. Are there multiple entities involved, or are you trying to solve a problem inside one organization?

Since trust usually already exists within a single organization, blockchain will be irrelevant as it works better in situations where there are several partners or organisation involved in an ecosystem.

iii. If multiple independent entities are involved, do the entities trust each other?

Blockchain eliminates the need for trust between different entities and if such trust already exists, blockchain may be overkill (Menon, 2018). In this regard, blockchain may then be of benefit to the smaller or newer organisations that may not be trusted by major organisations.

iv. Do you need the transparency provided by the blockchain, where all participants can see the chain?

This quality is by far one of the most crucial decisions an organisation must make as the transparency in systems has the potential of making a SC system more efficient.

v. Is it important to know the humans or systems involved in a transaction to be able to ensure that transactions cannot be counterfeited or compromised?

Blockchains are useful where knowledge on the identity of participants in a transaction is desired, an example of such a scenario in medicine would be knowing which doctor prescribed medication to a patient. In an ecosystem where anonymity is desired, the blockchain system will still want to be able to prevent party A from performing a transaction and making it look like Y did it. An organisation must not use blockchain if this is not important to it (Menon, 2018).

vi. How important is it for the system to be distributed? Can a centralized system meet your needs?

Since the distributed ledger concept is what blockchain technology is built on, an organisation that decides to take up BT must find value in a distributed system.

vii. What are your organisation's barriers, if any, to greater investment in blockchain technology?

Many a times the greatest barriers towards technology adoption lie within the organisation ad it is important to look at the organisational cultures and strategies as they affect such crucial decisions. According to Moura and Santos (2019), these are questions that must be asked when identifying the best case for BT application:

i. Is there a business network? If the answer is a yes, then BT may be applicable. In organisations that may have a wide global scope, this technology may prove extremely beneficial. Global or national operation require the greatest amount of transparency and visibility.

ii. Is there a transaction that needs validation or consensus? If the transactions being processed require that validation the BT will be of help.

iii. Are audit trails important (showing provenance)? If the answer is yes, then BT may be applicable in the organisation. Audit trails maybe important for customer requests and regulatory agency requirements.

iv. Is there any need to track data changes (data immutability and finality)? (Moura and Santos, 2019).

v. What is the organisation's technology adoption strategy? The timing of technology adoption is one critical strategy an organisation may have. Another strategy could be that of determining if an they develop the BT themselves or the attain it as a service organisation. Their strategy is a critical part of their decision to adopt the technology.

2.9 Hypothesis formulation

2.9.1 Integration in the Supply Chain ecosystem

The need for seamless integration within SCs is one that will continue to be pursued until the desired integration is achieved. Integration is an important quality for each of the parties in a supply chain and also for the 3LP and 4LP organisations. Blockchain will bring about integration in SC, as it allows for seamless connection between SC parties.

We have moved from an age of physical space to cyberspace, beyond the barriers of current technologies such the internet and telecommunications towards an era of convergence and collaboration. As technologies converge and firms collaborate, better opportunities for firms' performance are created (Siriram, 2011). Successful SCM requires the effective management of strategic alliances, extensive data management capabilities and advanced interorganisational information management (Patterson et al., 2003).

Figure 2.11 illustrates the difference between a traditional SC model and one that has an integrated SC ecosystem. The advantages of an integrated SC according to Schrauf and Berttram (2016) include:

- A complete view of supply chain,
- Information availability to all supply chain members simultaneously,
- Rapid assessment of end customer demand changes and,

- Real-time response on planning and execution (Schrauf and Berttram, 2016).

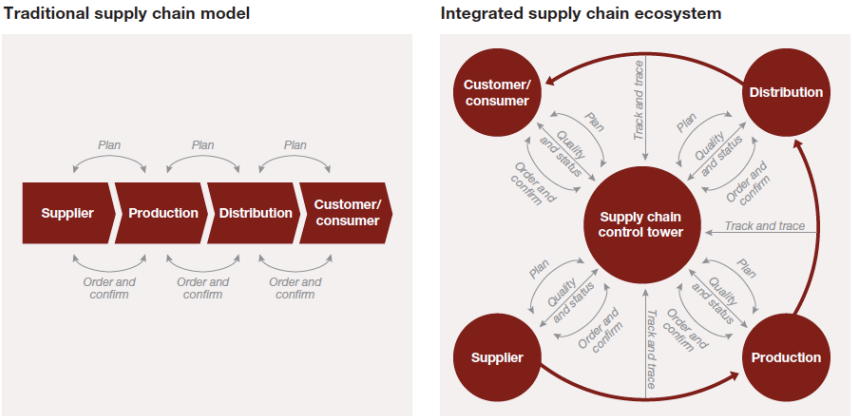

Figure 2.11 Traditional supply chain model vs Integrated supply chain ecosystem (Schrauf and Berttram, 2016).

Supply chain partners have a significant influence on an organisation's decision to take up a new SC technology. In the advent of strategic alliances, firms coerce members of their supply chains to adopt new technologies to satisfy the need for fast and accurate information transmission within the systems (Patterson *et al.*, 2003). Usually organisation want to plunge into technologies that easily integrate with already available technologies.

According to Patterson *et al.*, (2003), organizations facing greater uncertainty employ supply chain technology to improve information management and exchange in order to be able to better respond to changing environmental conditions. As suggested, information technologies allow firms to more quickly and accurately share demand data, sales projections and production schedules which provides adopting organizations greater flexibility and responsiveness in the face of a constantly changing environment (Patterson *et al.*, 2003). An organisation will therefore likely adopt a technology if it easily integrates all the SC parties and also collaborates well with the other already existing technologies. The then lead to the formulation Hypothesis one (H1):

H1:The ease of technology integration has a positive impact on BT adoption.

2.9.2 Effect of BT on the Value Chain

A value chain may be viewed as a set of activities that an organization carries out to create value for its clients. The way in which value chain activities are performed determines costs and affects

profits, therefore it is necessary to assess all activities and see if they feed into value addition (Smartsheet, 2018) Factors that can influence the value you provide include finding and utilizing the right people, motivating the team, adoption of a technology, and acting on feedback from customers (Smartsheet, 2018). An organisation will likely adopt a technology that adds value to its core activities which in-turn usually translates to giving the organisation a competitive advantage and meeting its customers' requirements.

BT provides secure data exchange and a temper proof repository for documents and other logistics of SCM data. BT may bring about significant reduction in delays and fraud hence saving organisations huge sums of money. According to the World Trade Organisation (WTO), the reduction of barriers within the International supply chain could increase worldwide GDP by almost 5% and the total volume by 15% (Lieber, 2017). In corporate relationships, the gains and incentives are mutual to all parties. Incentives in the blockchain business networks may not necessarily be monetary, but might be instead visibility, access, share, and exchange rights (Arun *et al.*, 2019). According to Stanton (2017) information sharing in digital supply chains is often constrained because of three problems. The problems being, systems mismatch, data reliability and trust in partners, however, BT may serve as a tool for removing these constraints (Stanton, 2016).

Since a blockchain is distributed, to make a change in the database, such as adding information, a new block of data must be added to the chain. Prior to the addition that block, all the nodes need to agree to add that block. After a block is added to the blockchain, it can never be changed, meaning it is immutable. BT is useful for SCM because it allows for the sharing of information in a way that is difficult to change or hack (Stanton, 2016). Blockchain implementations normally show auditability characteristics. This characteristic of the blockchain improves traceability and transparency of the data stored in the blockchain by ensuring that information once recorded is never overwritten or lost (Olsen *et al.*, 2019). Due to the depth of the value that BT adoption may bring to an organisation there is need for an organisation to then invest in the necessary skill and personnel so as to harness these benefits fully. The investment in skill may include training or even hiring or contracting new personnel within the organisation. Based on this, the following hypotheses were formulated:

H2:The availability of human resources (skill) is critical to the adoption of BT.

H3: An organisation's perceived need for the immutability of records has a positive relationship with the adoption of BT.

H4: If BT carries benefits that directly influence an organisation's value chain, it will willingly adopt the technology.

2.9.3 Trust in interorganisational relationships

In answering a question as to whether there is a need for a new technology like blockchain in supply chain, Petersen (2017) stated it would seem so. He justified his answer by stating that today's current systems cannot yet deliver the proper solution, since fraudulent behaviour or adulteration/tampering of products in supply chains is still taking place. He stated that blockchain might be perceived as the technology that holds somewhat quasi-magical powers, in this pursuit to influence or reinforce trust, strengthen information quality and automate documentation flows in interorganizational relationships (Petersen, 2017). Based on this it was gathered that the major reasons for taking up BT in SCs may be based upon the three facets identified.

According to Petersen (2017), many researchers have identified certain critical success factors for interorganizational relationships. He highlights that trust facilitates more open communication, information sharing and conflict management. Trust is hard to measure and define but focusing on certain aspects of trust will help to narrow the scope and specify the possible contribution made by blockchain. In that regard Petersen (2017) focuses on contract trust, predictability and dependability in his study. Petersen (2017) is therefore among the authors that highlight how BT will benefit a SCM system that is highly dependent on trust. The need for trust in an SC is likely to increase with the size of the organisation's SC ecosystem.

Blockchain can minimise errors and increase trust through the reconciling of each transaction with a supplier. Blockchain can also implement business rules, smart contracts, which means a transaction only takes place only if two or more participants endorse them, or if another transaction has been completed first, due to the hashing method (Petersen, 2017). The following hypotheses were formulated:

H5: Trust amongst SC parties must be of high priority for an organisation to adopt BT.

H6: An organisation will likely adopt BT if it operates in an ecosystem that has many parties.

2.9.4 The roles of blockchain in achieving various strategic supply chain objectives

Kshetri (2018), identifies the various strategic SCM objects and then shows the role of BT in achieving them. It is important to ensure that a technology can achieve the key SC objectives before its adoption. Organisations do not venture into technological investments that do not benefit their systems' main objectives. The objectives include cost, speed, dependability, risk reduction and flexibility (Kshetri, 2018).

The cost aspect in the adoption of BT may be viewed two way, firstly the cost faced by the organisations through adoption and secondly, the costs that are reduced or eliminated because of the adoption. In the industries where traceability matters, issues involving defective products can be easily identified at the source and strategic decision may be made. Kshetri (2018) also suggests that the allocation of just the right amount of resources to perform shipping and other activities is one of the cost cutting measures brought about by blockchain in SC. There will also be elimination of paper records as digitally signed documents can be securely stored and each of the identities of individuals and assets can be validated. Regulatory compliance costs can be reduced as auditable data can be provided to satisfy regulators (Kshetri, 2018).

Speed can be increased by digitizing physical process and reducing interactions and communications. Speed may also be increased through the elimination of redundant processes at each steps of the SC as parties trust each other well enough. According to Kshetri (2018), the digitally signed documents' secure storage and transmission can validate the identities of individuals and assets and hence minimise the needs of physical interactions and communications (Kshetri, 2018).

Blockchain technology will exert pressure on supply chain partners to be more responsible and accountable for their actions hence leading to dependability. Blockchain will be beneficial to smaller organisations that are new in the industry as these are rarely contracted because the validation of their certifications is too much of a burden to organisation. Blockchain-based digital certification is therefore a means of increasing dependability for all parties and will chiefly be of help to the smaller and newer organisations. These supply chain certification processes may also verify provenance. Blockchain's super-audit trail can address challenges associated with self-reported data that is provided by supply chain partners (Kshetri, 2018).

One of the unique qualities that come with blockchain technology is its ability to validate identities as this quality can verify the provenance of items such as rough-cut diamonds and fine wines. In

the BT systems, only parties mutually accepted in the network can engage in transactions in specific touchpoints and in such cases the foolproof method for confirmed identity can reduce cyber security related risks (Kshetri, 2018).

Verification of organisational sustainability is made possible by BT adoption as it makes it possible to make indicators related to sustainability more quantifiable and more meaningful. Most organisation are drifting towards engaging with SC partners that observe the environment and their effect on it. However, most organisations are not willing to part with the resources and effort needed to monitor how sustainable their partner is and blockchain will bring about this aspect to a business (Kshetri, 2018).

BT adoption will bring about supply chains which have a great flexibility to adapt to changing customer demands and shorter lead times. The visibility within the SC system would then make it easier to notice any adjustments that may need to be made within the supply chain systems (Kshetri, 2018). The following hypotheses were therefore formulated:

H7:An organisation will adopt BT if it grants it a competitive advantage.

H8:The projected ROI has an influence on the adoption.

Table 2.1 List of the formulated hypotheses

Hypothesis Number	Hypothesis formulated
H1	The ease of technology integration has a positive impact on BT adoption.
H2	The availability of human resources (skill) is critical to the adoption of BT.
H3	An organisation's perceived need for the immutability of records has a positive relationship with the adoption of BT.
H4	If BT carries benefits that directly influence an organisation's value chain, it will willingly adopt the technology.
H5	Trust amongst SC parties must be of high priority for BT to adopted.
H6	An organisation will likely adopt BT if it operates in an ecosystem that has many parties.
H7	An organisation will adopt BT if it grants it a competitive advantage.
H8	The projected ROI has an influence on the adoption.

2.10 Chapter Summary

This chapter focused on defining and making SCM and BT clear. The SCM ecosystem and the migration of supply chains towards digitalisation were reviewed. The BT architecture was looked into and the various case uses of BT in SC were also reviewed. Some literature on methodologic triangulation was reviewed and the formulation of hypotheses was performed in this chapter. The following chapter will focus on clearly outlining the methodology that the research followed.

CHAPTER 3. METHODOLOGY

3.1 Introduction

This chapter provides a detailed description of the research method followed in the study. The research instruments used in the study are also discussed in greater detail. The formulated hypotheses are further investigated through the questionnaire and a detailed company study on Company X is carried out.

3.2 Research Design

The research followed a methodologic triangulation (as discussed in section 2.7), as more than one kind of method was used in the study. As stated in section 2.7, this approach minimises the inadequacies of a single-source research and the impact of bias is reduced through the use of three research instruments that complement and verify one another. A summary of the research flow is shown in Figure 3.1 where the reviewed literature, questionnaire and interview fed into the methodology which in turn sought to address the research question. Each of the methods had a unique contribution, the literature from other scholars was used to formulate the hypotheses (shown in Table 2.1) which were then tested across the opinion of identified experts in the questionnaire and lastly an analysis of Company X's SCM with the objective of understanding the system design and network (through an interview). The research question's domain was company X and it was grounded on the theory of BT and SCM. Upon carrying out the study using the highlighted methods and with focus on addressing the research question, the data collected was analysed and the results obtained. The last step in the research was the discussion of the results and from there conclusions were drawn.

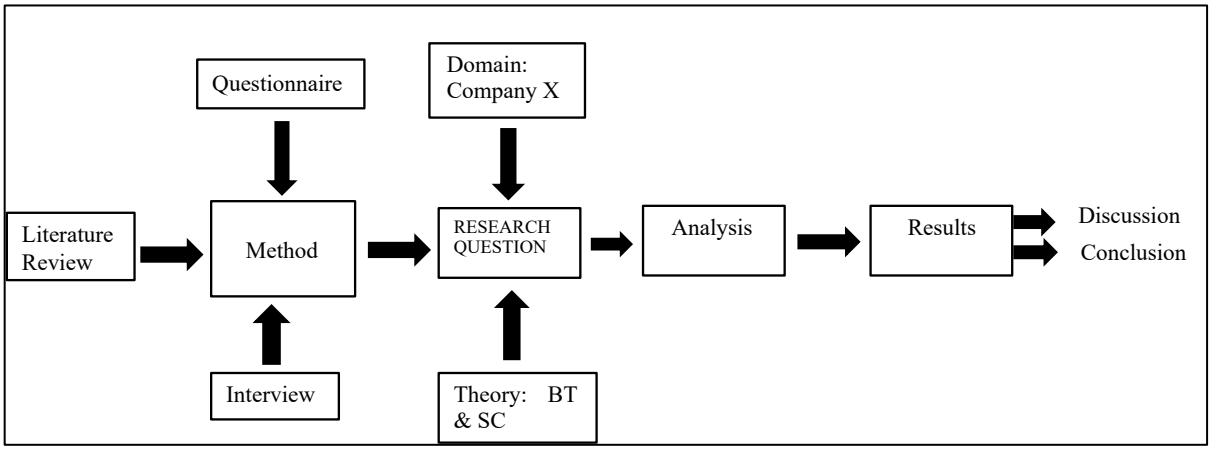

Figure 3.1 Research flow and structure.

The research followed both a primary and secondary data analysis approach with the primary data being gathered from an interview with Company X personnel and questionnaires from professionals (experts) that possess knowledge in BT and SC. The questionnaires were used to attain the perspective of experts in the fields of blockchain technology and supply chain management. An in-depth organisational study was carried in a bid to understand Company X (the case study organisation) and its position in SCM. The study was performed through interviews with an employee who was highly recommend and also possessed knowledge in both SC and BT. The organisational study was used to gather information on the organisation and the factors that influence its decision to adopt a technology.

The secondary data analysis approach was based on the literature and previous work of other scholars around the subject of use of blockchain technology in the supply chain industry. The criteria for choosing the literature to be reviewed was based on the quality of it being focused on either blockchain technology, supply chain management or both. Various studies, literature and research articles on blockchain technology and its application in supply chain management were analysed. The process of filtering and selecting the final literature is shown in the flow chart in Figure 3.2. The literature review brought insight on the critical variables and factors that may be included in a BT adoption framework and some hypotheses were formulated from the literature. Based on the data gathered from the experts, Company X personnel and literature reviews, a framework to assess the feasibility of implementing blockchain was created and the proposed framework was tested against Company X.

3.2.1 Sampling

The population under study includes the organisations that have adopted blockchain technology for use before and individuals that possess knowledge in BT use in SCM. Six professionals that have shown knowledge and expertise in both blockchain and supply chain responded to the questionnaires. Afterwards a stakeholder from Company X who possess knowledge on the company's strategy, SCM and BT was interviewed. For the literature review, the sampling method used was purposive researching meaning the author selected the material that best suited the study based on relevance.

3.2.2 Instrumentation

Journals, articles, books and publications were the source of the relevant literature for the framework formulation. An interview and questionnaires were used to gather information from the organisation stakeholder and the experts respectively. The questionnaire followed the Likert-type scale and had a few open-ended opinion questions. The interview on the other end was semi-structured so as to allow focus on the prepared topics without constraining the interview to a particular format hence creating an allowance for an element of flexibility. The one-to-one interview allowed for the gathering of information and data directly from the respondent.

3.2.3 Data Collection and Analysis Procedures

The data and information acquired from the literature review, field experts and case study organisation were assessed and used to develop a framework for the feasibility assessment. A letter of participation was sent to each of the individual prior to the acquisition of any information from them. The interviewee also signed a consent form prior to the interviews and a letter of permission was acquired from Company X prior to data collection of any sort.

3.3 Ethical Issues/Clearance

The author received ethics clearance approval to carry out the study from the School of Mechanical, Industrial and Aeronautical Engineering ethics board. The ethics clearance number for this research report is MIAEC 045/19.

3.4 Literature analysis

The protocol for identifying papers to be included in the analysis was based on the research question to be addressed and the method employed by Risius and Spohrer (2017) for research paper selection was followed (Risius and Spohrer, 2017). The main goal was for the literature to be based on both BT and SCM. In line with the decision to limit the scope, the author aimed for a comprehensive overview of prior work relevant to the research question and willingly excluded even high-quality papers on blockchain technology if they did not help answer the research question. The research material was searched for through the databases of the ScienceDirect, IEEE Xplore, ResearchGate and through the articles published by organisations' research centres. In particular, search terms ''blockchain in supply chain'' and ''blockchain technology and supply chain management'' were used in the mentioned databases. A qualitative content analysis was conducted for a final set of 24 papers. Figure 3.2 depicts the numbers of papers that emerged from each of the steps of this process and the selected articles and papers that were the input to the content analysis which eventually led to the hypothesis formulation, identification of important BT technical aspects and the suitability assessment criteria suggested by other experts.

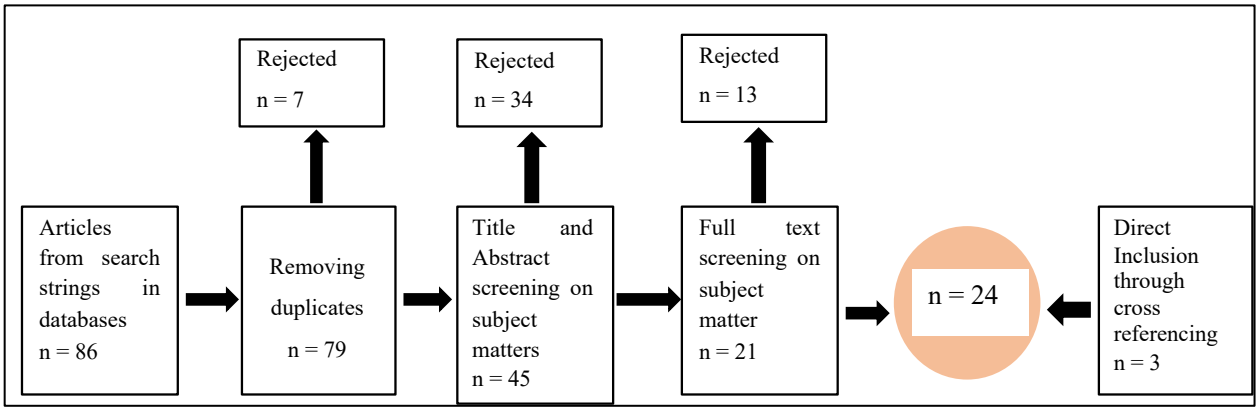

Figure 3.2 Research literature screening.

3.5 Questionnaire study methodology

The method followed in the questionnaire study is shown in Figure 3.3. The entire methodology entails two major stages, namely; Development of instrument and Data collection and analysis. At the initial stage, a questionnaire was developed and sent to two experts in the fields of both SC and BT for pre-testing. The number was limited to two experts due to limitations set by how few the experts in both fields are. The recommendations given by the experts were taken into consideration and the final questionnaire was developed. The questionnaire was developed to investigate the

eight formulated hypotheses (shown in Table 2.1), hence all the questions in the questionnaire addressed a specific hypothesis.

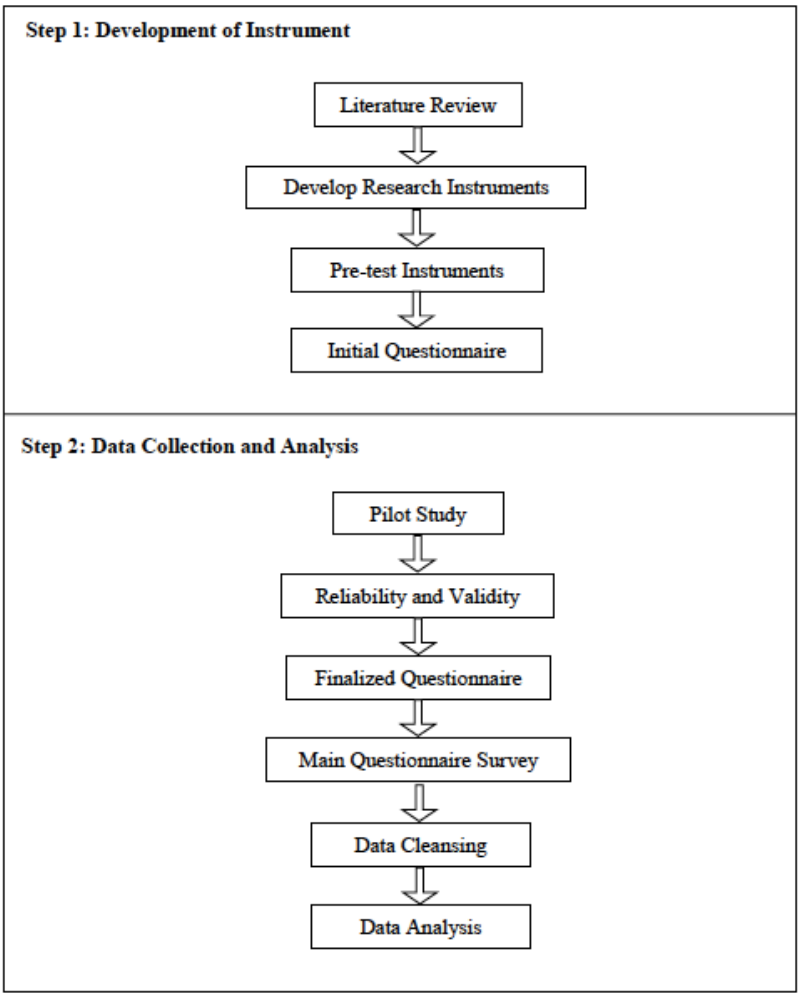

Figure 3.3 Questionnaire study flow (Boon, 2013)

3.5.1 Questionnaire Pretesting

The main purpose of the pre-testing was to ensure that all questions are easy to understand and relevant as highlighted in section 2.6. According to Boon (2013), the pre-test serves as the foundation for correction of the language structure in a particular question when needed. Through the pre-test, the author was able to check the appropriateness of the language structure, the length and logical flow of the questionnaire and whether the time allocated to complete the questionnaire is realistic (Boon, 2013). The expert that performed the pre-test of the questionnaire was knowledgeable in the field of SCM and BT and was considered fit for the evaluation of the content validity of the survey questionnaire. The expert was asked to assess the quality of the questionnaire

in terms of its wording, clarity and relevance. Upon assessment the questionnaire was concluded to be measuring the constructs that it intended to measure (content validity) with a few changes that were recommended.

3.5.2 Pilot Test

Due to the small size of the sample size, a pilot study was carried out by two experts before the collection of the primary research data. The data was collected through an online questionnaire that made use of Google forms. The initial findings from the pilot study were subjected to various types of reliability and validity tests.

3.5.3 Questionnaire Design

The questionnaire design followed the recommendations highlighted in section 2.6. Care was taken in the questionnaire design to ensure that it was simple, and the use of negative statements avoided. The questions were designed to be self-explanatory in nature and any terms thought of as new were defined in the questionnaire. In order to make the questionnaire easily accessible it was created and filled-in through Google forms which means a responded upon agreeing to take up in the research had the link sent to them and they filled in the form. The decision on which experts to ask to take part in the research was based mostly on the professionals that showed through their LinkedIn profiles that they possessed knowledge in both SCM and BT. Recommendations on the best professional to request were also received from the several of the individuals that were approached.

3.5.4 Questionnaire Scaling

During pretesting, the questionnaire was examined to firstly reduce the length needed to measure all the factors adequately and secondly, to adjust any items that may have made the survey difficult to the respondents. The majority of the items in the questionnaire were given in the form of statements via Likert-type scales as they are relatively easy to establish, analyse and also answer for the respondents.

The five-point scale was used to ensure an odd number is used and also the limit was left at 5 because too many points may lead to the respondents responding randomly to the questions without putting much thought into their response. On the scale range 5 stood for Strongly agree and 1, strongly disagree or 5- Very Important and 1- Not at all important. A consistent scoring

procedure was therefore retained throughout the questionnaire. Purposeful sampling was used in identify and approaching the respondents. Some of the respondents were then recommended by the other experts that had responded.

3.5.5 Questionnaire Structure

The purpose of this questionnaire was to collect the opinion of the experts with regards to the adoption of BT in SCM with special focus on the initially formulated hypotheses. The questionnaire comprised of four sections. The first section comprised of an introductory note addressed to a responded which gave them details on the author, research purpose and the detailed objectives of the study. Clear and precise instructions were given prior to each section in order to reduce confusion. Within the first section, the participants were required to consent that their participation was voluntary, and they were allowed to choose if they would want to remain anonymous in the study. The respondents were also requested to give a summary of their professional background. The last part of the first section investigated the field that a person was knowledgeable in and based on the response the respondent was directed to a specific section that was in relation to the chosen option.

The second section was for SCM related questions and comprised of five-point Likert-scale questions only and a total of 13 questions were in this section, of which all of them required an answer. If a responded had answered they possess knowledge in SCM alone or both SCM and BT then they would answer this section. The third section was for BT related questions and comprised of five-point Likert type, option and open-ended questions. This section has a total of 14 questions. If a responded had answered they possess knowledge in BT alone or both SCM and BT then they would answer this section. The fourth section of the questionnaire was for both SCM and BT related question meaning a responded that possessed knowledge in both answered questions from all sections. This section was comprised of five-point Likert type, option and open-ended questions. There were 13 questions in this section. The final questionnaire is presented in Appendix A below.

3.5.6 Methods of data analysis

The data was initially filtered based on the need for the respondents to possess knowledge in both SCM and BT. After that, each of the questions were then factored into the various hypotheses they

were feeding into. Due to the sample size and number of questions the size was manageable, and the author performed the factoring. The procedures applied to analyse the data statistically with the objective of tackling and answering research questions and testing the hypotheses in this study include means, standard deviations, correlations and variance analysis. All of the data analysis was done in IBM's SPSS.

3.5.7 Refinement and validation of questionnaire

Various forms of reliability and validity can serve as a criterion for assessing the soundness of a questionnaire. In this study Cronbach's alpha and construct validity were used along with ensuring a purposive sampling method was employed.

The reliability of internal consistency of the constructs was examined using the Cronbach's alpha. According to Boon (2013) a cut-off point of 0.70 in the alpha value indicates an acceptable degree of reliability of the construct (Boon, 2013). The internal consistency method was therefore used in assessing the reliability of the questionnaire instruments in this study.

Validity refers to the degree to which any instrument measures what it is intended to measure (Zhang et al., 2000). The convergent construct validity was used as a means of evaluation of the validity of each of the questions that were feeding into a single construct (or formulated hypothesis). The item correlation was used to assess the convergent validity. According to Cristobal et al. (2007), the items with item correlation lower than 0.30 are not acceptable. However, for an exploratory study like this one, 0.20 is an acceptable value for inter item and item-total correlation (Cristobal et al., 2007). Correlation values greater than 0.7 are too high and may indicate the factors feeding into a construct were just the same question phrased differently. Purposive sampling was used to identify the respondents, the responds had to possess knowledge in both SCM and BT. This helped increase the quality of the responses received.

3.6 Interview

The main aim of the interview was to understand how Company X's supply chain systems function. The interview was held at the company premises and the template followed when asking the questions is shown in Appendix C. The interview was recorded and later transcribed by the author.

3.6.1 Organisational Background

Company X is a fourth party logistics (4LP) company, in this arrangement a firm outsources its logistical operations to two or more specialist firms (the third-party logistics) and hires another specialist firm (the fourth party) to coordinate the activities of the third parties. Company X has two division, one which focuses on Supply Chain technology and consulting and on data analytics and optimization. On the Data Analytics and optimisation side, they use a system from the United States of America called the Enterprise Optimiser. This system allows the organisation to build a model of a business and helps solve optimisation problems with respect to a specific objective function. It builds models of both the operational and the financial side of the business. This division of the organisation also does some forecasting and planning in the banking sector.

The second division of the organisation, which was of major interest in the report, uses a Transportation Management System (TMS) called BluJay TMS. This TMS allows for planning of primary transportation which includes aspects such as point to point transportation. The company with the help of the system handles the outsourcing of a carrier, the planning, movement of products and also the facilitation of payment between the carriers and the client. It merges planning, payments and all other logistics components.

Company X also offers consultancy services in which it goes out to a business, assesses its Supply Chain Management (SCM) model and then recommends areas of improvement which may include recommendation on technologies to employ. Additionally, they handle the operation of a control tower that runs the South African primary distribution of one of the leading FMCG companies in the country. Company X does all the planning, execution, management of PODs (Proof of delivery) notes. Company X manages the whole logistics process and hands the client an invoice upon completion of a service. Company X does not get involved in brokering the carriers, they charge purely a management fee and their client pays off the carriers themselves.

The organisation's strategy is purely service based meaning they aim to keep their capital expenditure at minimum and provide a service. For example, the company does not own any carriers, but they do manage the efficient flow of the logistics for a client. Due to the nature of the organisation, their technology adoption is purely backed by market research as the interest of clients on the product or package is of importance. The systems or technologies the organisation usually adopts usually involve risk taking although the adoption is backed by thorough market research.

The company's core competencies lie on the efficient and effective management of its clients' SCs. It is critical for Company X to ensure that it consistently meets the needs of its customers and more than ever the needs of customers are consistently evolving. Company X's ability to smoothly manage its client's logistics and also bring about continuous improvement is critical in ensuring it maintains a competitive advantage.

3.6.2 Identified operational problem/inefficiencies

Within the current systems Company X manages, one major problem is that of PODs. These are a huge problem because when goods are delivered to a retailer the delivery must be accompanied by an invoice and that invoice must be checked by the personnel at the Distribution Centre (DC) to ensure everything is delivered as specified on the delivery note. If something is missing it has to be crossed off and a background process to get a rebate for the goods that were not delivered correctly should be run. There is possibility of an organisation dragging the process on, in an effort to evade the immediate payment of rebate. The main reason behind this behaviour could be the fact that holding the money for longer means it will accrue the interest that is tied to it.

Another dimension of the problem is that the industry also requires a physical piece of paper (invoice) to go back to the suppliers so that they use it as a reference to see if they have been paid the right amount by their customer. This process takes time and the longer it takes for the invoice to do back to a supplier the longer it takes for that supplier to be able to invoice their client for the actual stock that would have been delivered. The shorter and faster that process can be, the faster the suppliers get their money and the less they'll lose out on interest accrued on pending payments. The longer this process drags on the more it costs a supplier. There are ePOD solutions now which are a way people can sign for the receipt of orders (for example signing on glass/phone screens). Despite the use of ePOD the companies still require the physical pieces of paper to facilitate those transaction and this is because of the system requirements in general and lack of inter-organisational trust.

When the PODs are brought back from the clients, they numerous considering the various deliveries of products that would have been done. They then need to be scanned and put into a system, to ensure copies are sent across to the clients and supplier for their own records. The physical PODs are then sent to a storage area and must be kept for about 5 years before being disposed. This therefore shows the magnitude of the cost of handling and storing PODs. There is

a lot of human resource and time associated with the POD handling process, this means if BT can tackle this inefficiency it would positively impact the SCM.

3.6.3 Interview Sampling

The specific type of purposive sampling employed to identifying an interviewee was expert sampling. The interviewee had to be a person that possesses knowledge in both BT and SCM. Beyond knowledge in these two areas the interviewee had to have an extensive understanding of how the organisation's SCM systems work. The interviewed expert was identified throughout the research report as the 'interviewee'. The interviewee is an employee in Company X.

3.6.4 Interview Structure and Design

The interview with the organisation stakeholder was semi-structured so as to allow focus on the prepared topics without constraining the interview to a particular format hence creating an allowance for an element of flexibility. The one-to-one interview allowed for the gathering of information and data directly from the respondent**.** The first part of the interview involved introductions and also a briefing on the purpose of the interview. That was followed by some background information about the Company X, after which the in-depth questions were then asked. The interview structure is shown in Appendix C below.

3.6.5 Interview analysis

The analysis of the interview data followed a framework analysis methodology as suggested by Ritchie and Spencer (1994). The qualitative data that is utilized in framework analysis is usually gathered in the form of participant observation, focus groups or interviews (Srivastava and Thomson, 2009). According to Srivastava and Thomson (2019), upon data collection the data is sifted, charted and sorted in accordance with key issues and themes. This involves a five-step process of:

1) Familiarization

Familiarization refers to the process during which the researcher becomes familiarized with the transcripts of the data collected and gains an overview of the collected data (Srivastava and Thomson, 2009). In other words, the researcher becomes immersed in the data by listening to audiotapes, studying the field or reading the transcripts. Throughout this process the researcher becomes aware of key ideas and recurrent themes and takes note of them.

2) Identifying a thematic framework

At this stage, the researcher recognizes emerging themes or issues in the data. The basis of the thematic framework from the key issues, concepts and themes that have been expressed by the participants. involves both logical and intuitive thinking. It also includes the making of judgments about meaning, importance of issues and their relevance.

3) Indexing

At this stage the researcher identifies portions or sections of the data that correspond to a particular theme.

4) Charting

At this stage, the specific pieces of data that were indexed in the previous stage are now arranged in charts of the themes. The data is transfers from being purely textual and is placed in charts that consist of the headings and subheadings that were drawn during the thematic framework.

5) Mapping and interpretation

Mapping and interpretation involve the analysis of the key characteristics as laid out in the charts and the researcher gives their analysis.

3.7 Chapter Summary

This chapter elaborated on the main issues of the research methodology and strategies adopted in the study. The general methods that the research followed were first discussed in brief and then each of the methodology instruments used in the study were looked into in depth. The questionnaire instrument and all the constructs surrounding it were also looked into. Lastly a section looked into the interview instrument and the methodology of analysis it followed. The previous chapters and this one focused on making the research background, theoretical basis for the research, hypotheses and methodology clear. The following chapters will present and discuss the results of the study which will lead to the formulation of the BT assessment framework and its use on Company X.

CHAPTER 4. RESULTS AND ANALYSIS

4.1 Introduction

The chapter discusses the results obtained by the researcher while carrying out the research as documented in Chapter 3. The responses to the questionnaires were analysed, followed by the synthesis of the literature reviewed previously and the findings from the organisational study were also discussed. In conclusion, based on the findings, the framework was created making reference to the hypotheses formulated.

4.2 Questionnaire analysis

The eight hypotheses that were formed (as shown in Table 2.1) were tested through the questionnaire responses and the perspectives of the scholars reviewed in Chapter 2. Each of the two sources of data will be analysed with respect to the hypothesis they are linked to. The questionnaires were distributed to professionals in the field of SCM and BT and eight responses were received out of fifteen requests that were sent out, hence a response rate of 0.53 was achieved. As shown in Figure 4.1, of the responses received, one was from a SC expert alone, one from a BT expert alone and six from professionals that had an understanding of both SC and BT. For the purposes of accomplishing the desired objectives of the project, it was preferred that the experts possess knowledge in both fields and not just one so as to allow for consistency in the objective tackling of the questionnaire. To accommodate the need for the objective consistency in the research, the data from experts that possessed knowledge in both fields was considered.

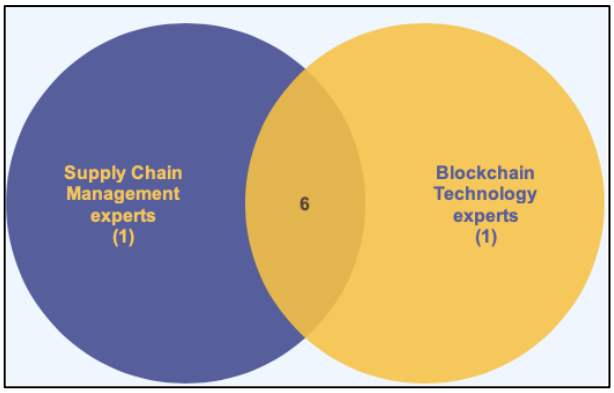

Figure 4.1 Classification of the questionnaire responses

The qualifications and expertise of the 6 people from whose responses the analysis was performed are summarised in Table 4.1. Each of the experts will be identified as Expert 1, Expert 2, ……and Expert 6.

Table 4.1 Professional profiles of Experts

Expert ID	**Professional Experience**
Expert 1	Holds a Doctor of Technology degree in Industrial Engineering, is currently a lecturer and has also worked in production and operations management prior to joining academia.
Expert 2	Holds a BSc in Economics and management and possess 10 years of international experience in operations and supply chain management.
Expert 3	Holds a master's degree in production management and has worked in Supply Chain Management for 4 years.
Expert 4	Holds an MBA, MSc in Supply Chain, and holds Chartered Institute of Procurement and Supply (CIPS) Level 6 certification, Chartered Institute of Logistics and Transport (CILT) Level 6 certification.
Expert 5	Possess 4 years working experience in software development, working in the e-commerce space specializing in development of payment systems, integrations and building web and mobile apps. Holds a BTech (Hons) in E-Commerce and is certified in the Ethereum blockchain.
Expert 6	Holds a BEng degree in Industrial Engineering and has been working in Supply Chain and Logistics for 7 years.

Each of the questions in the questionnaire were investigating at least one of the hypotheses formulated. The author grouped the question responses based on the respective hypothesis they were investigating, each of the questions and the hypothesis they fell under are shown in Appendix B below. Table 4.3 however, shows the value name that was given to the questions on the statistical tool used for the data analysis. The tool used was IBM's SPSS (Statistical Package for the Social Science) package. A total of 35 question followed the Likert-type of scale and each of the

responses were tested for the mean, standard deviation and the internal reliability of each of the grouped responses was tested using the Cronbach's Alpha. In general, a Cronbach's Alpha value of >0.7 was considered as acceptable as this showed the reliability of the data acquired.

4.2.1 Statistical Data Analysis

A minimum Cronbach's alpha value of 0.7 is recommended when testing the internal consistency of a study and this was threshold used in this study (Briggs and Cheek, 1986). In the study the Cronbach alpha value ranged between 0.683 and 0.842 for the 8 constructs. 7 out of the 8 constructs have a Cronbach alpha that is >0.70 which indicates a high internal consistency.

All the average standard deviations extracted range from 0.423 to 0.825. The item correlation examines whether the two or more measures of constructs (questions) that theoretically should be related, are in fact related. According to Cristobal et al. (2007), the items with item correlation lower than 0.30 are not acceptable. However, for an exploratory study like this one, 0.20 is an acceptable value for inter item and item-total correlation (Cristobal *et al.*, 2007). Table 4.2 shows the standards that each variable should meet and also an interpretation of what a value may mean.

Table 4.2 Interpretation of each variable's measures

Mean	**Standard deviation**	**Inter Item correlation** **(measures whether the questions measured the intended hypothesis and are related)**	**Cronbach's Alpha**
Range 1 to 5 1= Strongly Disagree 2= Disagree 3= Neutral 4= Agree 5=Strongly Agree	0 to 0.5 – Acceptable >0.5 – Shows High dispersion as number increases	0 to 1.9 Too Low and Rejected 0.2 to 0.6 Acceptable-06 >0.7 – Too High and may indicate the factors feeding into a construct were just the same question phrased differently.	>=0.70 – Desired and Accepted <0.70 – Rejected

A summary of the reliability testing, central tendency, variability and item correlation analysis are shown in Table 4.3.

Table 4.3 Summary of statistical data analysis

Hypothesis	Allocated question on questionnaire	Mean	Mean Standard Deviation	Item Correlation	Cronbach's Alpha
H1:The ease of technology integration has a positive impact on BT adoption.	3, 25	3.250	0.462	0.632	0.683
H2:The availability of human resources (skill) is critical to the adoption of BT.	14, 16	3.75	0.816	0.302	0.842
H3:An organisation's perceived need for the immutability of records has a positive relationship with the adoption of BT.	1, 2, 18, 33	4.389	0.521	0.452	0.742
H4:If BT carries benefits that directly influence an organisation's value chain it will willingly adopt the technology.	1, 5, 6, 7, 8, 9, 10, 11, 12, 18, 19, 23, 26,27 ,28, 29, 30, 31	4.033	0.435	0.388	0.775
H5:Trust amongst SC parties must be of high priority.	1, 2, 12, 4, 5, 7, 9, 13, 25,	4.524	0.423	0.272	0.711
H6:An organisation will likely adopt BT if it operates in an ecosystem that has many parties.	8, 10, 12, 13, 25, 26, 29, 31,33	4.333	0.511	0.281	0.750
H7:An organisation will adopt BT if it grants it a competitive advantage.	4, 5, 6, 7, 8, 9, 11, 12, 13, 18, 19, 23, 26, 27, 28, 29, 30, 31, 32,33,34,35	4.071	0.431	0.283	0.826
H8:The projected ROI has an influence on the adoption.	20, 21, 22, 10	3.389	0.825	0.673	0.745

H1: Based on the statistical analysis, the mean is at 3.25. A central tendency of 3.250 shows that the most common opinion of the experts regarding the need for a technology to be easy to integrate into a system for it to be adopted was just above neutral. Neutral in this study is considered an undesirable response as it neither shows agreement of disagreement, therefore based on the mean the hypothesis is unsatisfactory. The standard deviation however shows how closely clustered the responses of the experts were at a value of 0.462 meaning the mean is a true reflection of the expert's opinions on this matter. On the other hand, Cronbach's Alpha was 0.683 which is less than the threshold value of 0.70. This already shows that there was no internal consistency and since this then means this maybe unreliable.

The author draws from this analysis that it is not a requirement for a technology to be easy to integrate with other technologies as this has no bearing on the value that the technology carries. Whether the integration is easy, moderate or hard, an organisation that is working on harnessing the value brought by BT cannot stop the pursuit based on the presence of significant effort or difficulty. Every new technology that an organisation may adopt requires that effort be made in ensuring it is in sync with the other technologies or systems already in place. Organisations that make a decision to plunge in BT must therefore embrace it with the difficulty or need for effort that will come with its implementation. Based on these premises, hypothesis one (H1) will be rejected.

H2: The central tendency of the responses was found to be 3.75 which may be considered to be skewed towards the experts agreeing with the hypothesis. The relatively high standard deviation of 0.816 shows that the responses were slightly scattered. The reliability of the questionnaire is greater than the threshold of 0.7 and this shows that the internal consistency in the responses was acceptable. The inter-item correlation on the other hand was 0.302 which according to correlations specifications is considered a moderate correlation hence ascertaining that convergent construct validity exists in this hypothesis.

This hypothesis satisfied the statistical standards, this shows that the opinion of the experts is that skill is a relatively important determinant as to whether an organisation should take up BT. The author however believes there was a high dispersion in the opinion of these experts because skill and expertise in a new technology are developed with time and cannot necessarily be considered a barrier. In an adoption framework an internal audit of the type to expertise and human resource

an organisation has will aid in deciding whether it may be feasible for an organisation to adopt BT. The organisation if skill is available in house, may develop the BT themselves or if they lack the necessary human resources they may first invest in training (long term) or contract personnel with expertise (short term). The need and assessment of the human resources would be necessary if an organisation is to consider adopting BT. In conclusion, hypothesis number two (H2) holds in this study.

H3: Hypothesis three was investigating how an organisation's need for immutability of records may affect its decision to adopt BT. The mean achieved from the responses was 4.389 and this shows that the experts explicitly agreed to the idea of an organisation's need for immutability being a factor in its decision to adopt BT. The dispersion shown by the responses was slightly above 0.5 and although this was noted, the responses were relatively clustered meaning the mean represents the responses of most of the experts. An item correlation of 0.452 was noted and this shows how each of the measures actually examined the constructs that they are meant to examine. This hypothesis meets all the statistical requirements and it hold.

As shown in chapter 2, immutability of records is one of major qualities that BT possess. Based on the opinion of experts it can therefore be concluded that the organisations that will adopt BT are those that need this immutability quality. Immutability of records in SCs is necessary as this has an impact on the future interorganisational relationships and it also assists with the auditability of the records at a later date. An organisation must therefore first decide if this quality is desirable for its SCM systems before it makes the decision to adopt BT.

H4: Hypothesis 4, highlights that an organisation will likely take up BT if the benefits it brings feed into the organisation's value chain. The mean for response was 4.033 which translates to the experts agreeing with this notion. The dispersion as indicated by a standard deviation of 0.435 was within the acceptable range. The reliability of the measurement tool was also acceptable as it scored a relatively high Cronbach's Alpha of 0.775.

There is therefore need for an analysis of the benefits that BT brings to an organisation's SC so as to ensure they actually feed into the value stream. The ultimate goal must be for the benefits to be seen throughout the value chain. Based on this, it can be concluded that there is a need for a

thorough analysis of how far down the value stream a BT adoption benefit goes and hence this hypothesis holds and was accepted.

H5: This hypothesis received the highest mean in the study at a mean of 4.524 which shows that the experts strongly agree with the construct being analysed. Hypothesis five stated that trust within interorganisational relationships must be of high priority in order for an organisation to adopt BT. The standard deviation of 0.423 indicated how closely clustered the responses were. This means that most of the experts believed strongly that trust must be a priority for an organisation to consider BT adoption. An acceptable inter- item correlation of 0.272 was achieved whilst the reliability of the questionnaire responses was also valid with a Cronbach's Alpha value of 0.711. Based on the satisfaction of each of these statistical parameters, hypothesis 5 was seen as acceptable.

The nature of transactions in SC is that they carry risk along with them. BT will then reduce the risk associated with dealing with several partners in a SC ecosystem. Trust between SC partners must be of priority in an ecosystem for an organisation to adopt BT. The need for trust in an ecosystem must there for assessed before deciding to adopt BT.

H6: A relatively high mean was observed for this hypothesis as it stood at 4.33 and a relatively low standard deviation in the experts' responses was noted and seen to be 0.511(slightly above the desirable range).The inter-item correlation was noted as 0.281 which remains an acceptable measure showing the validity of these factors to measure this construct. The internal consistency of the responses as measured by Cronbach's Alpha was 0.75 which is an acceptable value and based on the fulfilment of these necessary metrics this hypothesis holds.

The nature of BT and its inherent characteristics as shown in chapter 2 are based on its distributed nature which means and shows that it will work better in an ecosystem that has many parties. Usually these parties are external parties because mistrust exists mostly in an organisation's external relationships. It is therefore critical for an organisation to analyse the nature of its supply chain and assess if its ecosystem consists of several external parties. If the ecosystem does consist of several partners, BT will be of benefit. Based on this, the aspect of an organisation's ecosystem must be analysed when looking into adopting BT in SCM.

H7: Hypothesis seven brings up the aspect of competitive advantage and suggests that an organisation will likely take up BT if it will give it a competitive advantage. The mean indicated that the experts were in agreement with this view and the standard deviation of 0.431 showed that this view was well clustered around the mean. The inter-item correlation also demonstrated it was acceptable at a value of 0.283, hence showing the factors measured the construct. Lastly the Cronbach's Alpha value was the highest recorded in the study at 0.826 showing a high reliability in the measurement. Based on this statistical analysis hypothesis seven (H7) holds.

In a society that is consistently advancing, it is important for organisations to ensure their SCM systems remain relevant to their customers and hence creating a competitive advantage for them. Depending on the type of competitive advantage strategy an organisation employs, looking at the effect that BT may have on that competitive advantage will be of benefit. When considering the adoption of BT, it will be necessary for an organisation to assess the effect that the adoption will have on its competitive advantage and this involves aspects such as benchmarking their SCM systems across those of competitors.

H8: This hypothesis was measuring the influence of the perceived Return on Investment (ROI) on an organisation's decision to adopt BT. The responses of the experts showed a mean of 3.389 which falls under the neutral region. The dispersion of the responses was high at 0.825 and this means the responses where significantly dispersed. The Cronbach Alpha of the measurement was 0.745 which is acceptable.

Upon assessing these results and referring back to previously analysed literature, the author notes that the ROI from BT adoption may not necessarily be measured from monetary return perspective as the technology bring many returns that may be hard to quantify before setting up actual models. Arun *et al.* (2019) highlight that the return that BT may bring to an organisation is the kind that will translate in better services, competitiveness and also disruption in the company's competitive spaces. This therefore points out the need for the ROI to be analysed from a qualitative dimension initially since a quantitative analysis maybe be impracticable. The author however noted that the reason why the mean response from the experts may have been neutral is the fact that they assessed the aspect of ROI from a quantitative perspective. The conclusion on this hypothesis is that ROI has an influence on an organisation's decision to adopt BT but the most practical ROI assessment to be done at the initial stage is of a qualitative nature.

4.2.2 Summary of questionnaire analysis

Of the eight hypotheses that were formulated (shown in Table 2.1), only seven were accepted and hypothesis number one was rejected as shown in Table 4.4. The ones that were accepted highlight the constructs that must be included in a framework that organisations can use to assess the feasibility of adopting BT in their organisations. The seven constructs will therefore be included in the formulation of the assessment framework in chapter 5. These hypotheses will contribute towards the operational feasibility assessment of the study.

Table 4.4 List of accepted hypotheses.

Hypothesis Number	Accepted hypothesis
H2	The availability of human resources (skill) is critical to the adoption of BT.
H3	An organisation's perceived need for the immutability of records has a positive relationship with the adoption of BT.
H4	If BT carries benefits that directly influence an organisation's value chain, it will willingly adopt the technology.
H5	Trust amongst SC parties must be of high priority for BT to adopted.
H6	An organisation will likely adopt BT if it operates in an ecosystem that has many parties.
H7	An organisation will adopt BT if it grants it a competitive advantage.
H8	The projected ROI has an influence on the adoption.

4.2.3 Risks associated with BT adoption

Upon asking the experts to identify or highlight risks that they felt were associated with BT adoption in SCM, several risks were identified and those are discussed. The first was that the adoption costs may not guarantee the perceived return on investment that was addressed earlier. The fact that information on a BT is unalterable is a risk in itself as any mistake made cannot be reversed and all transaction data is permanently stored. The most important thing is also to build security into the BT system because there are many loopholes that can be exploited with a new

system within a growing market hence there is need for rigorous testing and care to be taken in the system design and development and not just adopt BT without necessary knowledge. An organisation may also lack the necessary resources to support the adoption, this may then be evaded by enduring that the adoption project receives enough support from the project sponsors to ensure sufficient funding.

The oversharing of some information that organisations might not want out to their supply chain partners was another risk that was identified. This can be dealt with by ensuring that the permissions are set out and controlled from the onset, this is therefore an implementation and setup issue. The last risk identified is associated with whether the SC parties involved will all be up to speed on what BT is. This risk is rooted also on whether the supply chain parties' knowledge will go beyond 'the blockchain hype'. The blockchain hype is the attention that BT has been receiving from technology enthusiasts and this hype does not substitute the need for an organisation to conduct a thorough research on the technology. It would be necessary to ensure that an extensive training and research is done throughout the supply chain of an organisation to ensure that all parties understand the technology and the benefits it will bring to their businesses.

4.3 Literature Analysis

The literature that was reviewed in section 2.4 focused on types of blockchains available, the characteristics of BT that make it desirable, the role of the IoT in BT adoption and also some challenges associated with BT adoption. This section will draw the critical aspects from the literature review that the author believes must be included in the framework formulation for the technical feasibility assessment.

4.3.1 Types of blockchains

It is important in the earlier stages of considering BT adoption in SCM for an organisation to access if the already available types of BT can meet its needs. Olsen et al., (2019) highlighted how each of the various types of BT offer unique benefits and how best an organisation may assess the best combination for its system.

The matrix used to determine the best type of BT for an organisation will be adopted from Olsen et al., (2019) the decision will be made across the 6 metrics shown in Figure 2.7 namely, consensus determination, read permission, immutability, efficiency, centralisation and the consensus process. The consensus mechanism that an organisation decides to use is also important for the functionality

of the blockchain. In order to assess the best fitting consensus mechanism, it is necessary to look at the level of anonymity and trust desired in the network and the best mechanism may be determined using the metric in Figure 2.8.

4.3.2 Role of IoT in BT

Moura and Santos (2019) highlight that IoT devices are an enabler in BT use. The adoption of BT will mean the organisation must be willing to embrace the IoT as this is a critical aspect of BT performance. Before implementing BT an organisation must analyse if they have the necessary devices throughout the SC so as to ensure the benefits of BT are fully embraced. Since BT dwells on the construct of system integration and digitality, IoT devices are a chief enabler in the successful use of BT. If the SCM system does not have the necessary IoT devices, an organisation must there for be willing to also invest in the necessary IoT devices as they are critical for the performance of blockchain technology in supply chain management. BT also requires good connectivity and with the digital world continually exploring networks with better speeds, BT is definitely bound to find a network support. Recent strides in the fifth generation of mobile telecommunication (5G) shows how connection and network speed are continuously evolving in the positive direction. An organisation that is considering the adoption of this technology must therefore analyse its SCM system with regards to the use of IoT devices in the system as they are critical to the successful implementation of BT.

4.4 Interview data analysis

The author became aware of the key issues from the interview through listening to the audio recording of the interview and also transcribing the audio recording. The key issues, concepts and themes that were expressed by the participant, where noted and assessed to fall under the following themes:

- Organisation background (Systems in place, core competencies and nature of the organisation)
- Operational inefficiencies in existing system
- Potential application of BT within organisation

4.4.1 Potential use of BT as identified in Company X.

Through the analysis of data acquired through the interview, the author further identified potential uses if BT within the organisation. If BT were to facilitate the processing of PODs it would mean visibility for all SC parties, meaning both the suppliers and clients will have a single proof of the delivery that they know is immutable and cannot be tempered with. That would potentially give them the confidence to forgo the need for a physical POD. That would completely change how the PODs are managed.

Since SC is generally associated with risk, organisation rarely want to deal with smaller (not well known) organisations in a bid to avoid the risk of associating with companies that do not have a track record. For small and emerging organisation BT could help validate their trustworthiness and also validate their capabilities. This may then make it easier for Company X to handle the logistics of a client even when smaller 3LPs are contracted.

Organisations have not plunged into investigating the sustainability of their SC partners due to the belief that it is hard and complex to trace the environmental footprint an organisation possesses. The world however day by day continues place new requisites on suppliers especially when it comes to how well they value the environment. The traceability aspect of BT may make this possible hence forcing SC parties to comply to some sustainability aspects.

4.4.2 Overall view on Company X

Company X being a 4PL will likely benefit from BT adoption as it has the platform to use it across several SCs since it manages several clients. The researcher believes that BT adoption may possibly be more beneficial to Company X due to the nature of the organisation and the scope of SC systems it has the ability to handle. The logistics and SCM industry are consistently moving towards integration, digitality and greater speed and the researcher believes the first 4PL organisation that will fully embrace BT may have an opportunity to disrupt the SCM field in South Africa. The unique advantage that Company X possesses is that if it were to adopt BT it has the abilities of not only serving one supply chain but several as it works with various clients in the industry. Beyond the trust, visibility and immutability of records, Company X may then add to greater speed, smart contracts, sustainability traceability and even the efficient management of PODs amongst many other benefits.

4.5 Research reliability and validity

Methodical triangulation was employed in the study in a bid to improve the validity and reliability of the research findings. The study as stated made use of questionnaires (on which quantitative analysis was performed), an interview and literature review (on which qualitative analysis was performed). The combination of these methods led to a more reliable and valid study with reduced bias and increased generalizability.

The questionnaire reliability and construct (convergent) validity as discussed in section 3.5.7 were determined using the Cronbach's Alpha and the inter-item correlation respectively. The constructs that met the desired reliability and validity were used in the formulation of the framework in the next chapter.

4.6 Chapter Summary

The chapter examined in detail the data acquired in the research and critical factors that must be included in the BT adoption assessment framework were highlighted. Based on the results and analysis, the framework will be formulated and tested on Company X in the following chapter.

CHAPTER 5. FRAMEWORK DEVELOPMENT AND TESTING

5.1 Introduction

The framework was formulated and tested on Company X in this chapter and conclusions on the framework's effectiveness as a decision-making tool was also assessed. The steps that the assessment framework follows were highlighted and a schematic diagram showing how the assessment is carried out was also put together.

5.2 Framework formulation

After the analysis of the data acquired from each of the methodology instruments, the factors that may be included in the BT adoption assessment framework were emphasised. In this section, the synthesis of framework from the identified factors is carried out.

Based on previously developed frameworks (reviewed in section 2.8), it is necessary to access the need for SCM immutability, visibility and extent of anonymity when considering the use of BT. These metrics tie in with the conclusions from the questionnaire analysis. As highlighted by Jai Menon (2018), the aspect of BT implementation being more relevant to the external relationships and not the internal ones necessitate the need for the analysis of the organisation's SC ecosystem. The aspect of trust is also highlighted which then shows that it should be included in a framework as this is one of the major benefits that come with BT.

Moura and Santos (2019) introduce the aspect of provenance as they highlight that organisations that will need clear audit trails in their SCM will find BT more beneficial hence meaning the aspect of auditability will also be included in a framework that is used to assess the applicability of BT. They also highlight the need for the analysis of an organisation's technology adoption strategies, which speaks into an internal analysis. An organisation's strategy will therefore have a bearing on how far along a technology's life cycle they may choose to adopt it. Each of these aspects will therefore be included in the framework to be formulated. Each of the seven accepted hypotheses shown in Table 4.4 also contributed toward the framework formulation in the study.

Based on this analysis, the assessment framework was broadly classified into three phases, one focusing on an internal analysis, the other on an external analysis and the third one on the technical analysis. The framework assesses the operational and technical feasibility of an organisation to employ BT.

5.2.1 Phase One: Internal analysis

1. Conducting a needs and resources assessment: This initial step looks into assessing if there are any opportunities for BT within the organisation and why an organisation may want to use BT. Initial step is centred on the analysis of the organisation.
   The critical questions will be:
   What problems or conditions will blockchain technology address?
   In what ways will it address important perceived needs of the organization?

2. Conducting an appropriateness assessment: This evaluates whether the technology fits the setting. The questions that will be asked in this step typically examine the unique qualities that BT possesses and their appropriateness in an organisation. The question will be:
   Is there any need to track data changes (data immutability and finality)?
   Is there a transaction that needs validation or consensus?
   If multiple independent entities are involved, do the entities trust each other?
   Do you need the transparency provided by the blockchain, where all participants can see the chain?
   Do the BT benefits feed into the organisation's value stream?

3. Conducting a capacity and readiness assessment: At this stage the aim is to assess if the organisation is ready for the development. The questions may include the following:
   To what degree does the organization have the will and the means (i.e. adequate resources, skills and motivation) to implement the technology?
   What are the organisation's barriers, if any, to greater investment in blockchain technology?
   What infrastructure, skills, and motivation of the organization or SC ecosystem need enhancement in order to ensure the technology will be implemented with quality?

5.2.2 Phase Two: External audit

This phase focuses on the factors that are extrinsic to the organisation but still have a significant impact on the technology adoption.

1. Is there a business network? If the answer is a yes, then BT may be applicable. In organisations that may have a wide global scope, this technology may prove extremely beneficial. Global or national operation require the greatest amount of transparency and visibility.
2. Are audit trails important in the system (showing provenance)?
3. How will BT differentiate the company from its competitors?

5.2.3 Phase Three: The technical aspects

Identify from the information and knowledge gathered in the preceding phases whether the technical side of the technology implementation will address the identified needs.

1. Identify if there is a type of Blockchain that can meet the needs identified in phase 1. The types of blockchains were identified in section 4.3.1 and based on a general view of the characteristics of each type, an organisation must identify the likely applicable type for an organisation. If none of the types of the blockchains can meet the needs of the organisation, then maybe that limitation will affect the adoption of BT. The decision will be made across the 6 metrics shown in Figure 4.2 namely, consensus determination, read permission, immutability, efficiency, centralisation and the consensus process.
2. What is the organisation's technology adoption strategy?
3. Does the SC already embrace IoT? Are they willing to invest in it?

5.3 Framework Schematic.

The framework schematic was then designed based on the framework formulated in section 5.2 above. The schematic provides a summary of the framework and makes it easy to follow the framework steps. The developed framework requires that the assessment be done in each phase and in the prescribed order, the assessment will start at step one and move incrementally until step nine is reached (shown in Figure 5.1). A conclusion must be given upon the completion of the analysis at each phase. This conclusion must summarise the finding at each phase and based on the phase findings, an overall conclusion must be given. The overall conclusion assesses holistically the contribution that BT will bring internally and externally whilst focusing on the technicalities of the technology too.

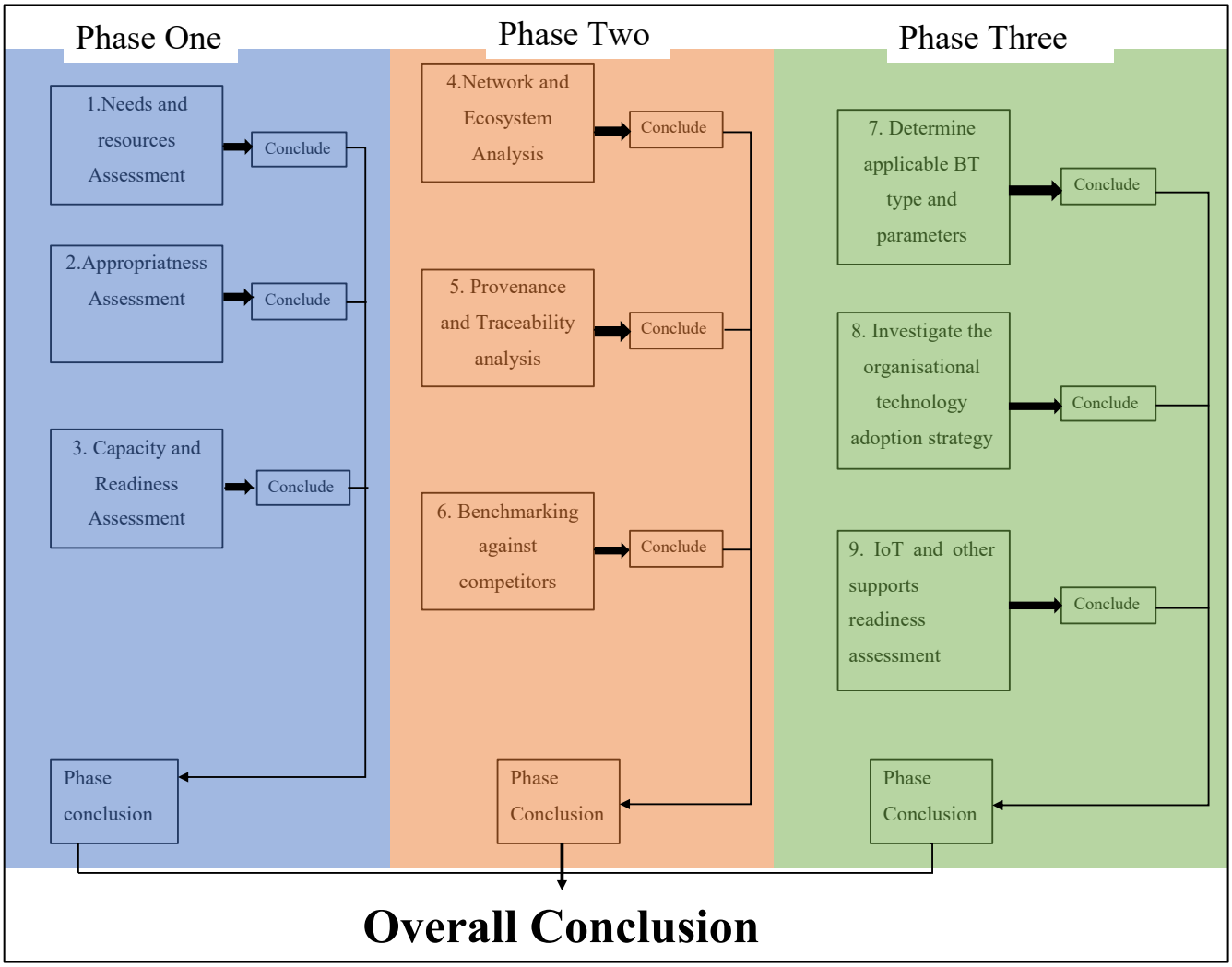

Figure 5.1 Blockchain adoption assessment framework schematic.

5.4 Framework Testing

The assessment framework formulated in section 5.2 is then used to test the applicability of BT in Company X's SCM. The framework formulation steps will be followed as shown in the developed framework schematic shown in Figure 5.1.

5.4.1 Phase One: Internal Analysis

Table 5.1 Internal analysis implementation

Step	Questions	Response
1. Needs and resources assessment	a. What problems or conditions will blockchain technology address?	a. The PODs will be handled efficiently. Reduction of paper trail. Speed up payment of suppliers. End customer demand changes are rapidly met (flexibility), Risk reduction between parties.
	b. In what ways will it address important perceived needs of the organization?	b. It will bring a complete view of supply chain. Information available to all supply chain members simultaneously. Reverse logistics become more efficient. Sustainability of parties verified. Dependability of SC partners.
2. Appropriate -ness Assessment	a. Is there any need to track data changes (data immutability and finality)?	a. Yes, it is important to track any changes of transaction details in an SC that Company X manages.
	b. Is there a transaction that needs validation or consensus?	b. Yes, in cases such as delivery of products parties must consent to the transaction.
	c. If multiple independent entities are involved, do the entities trust each other?	c. An element of trust does exist, but there is still need for an improvement so as to allow for better transacting conditions
	d. Do you need the transparency provided by the blockchain, where all participants can see the chain?	d. Yes, however, the permissions will need to be controlled so that only the necessary parties have access to specific data.
	e. Do these benefit feed into the organisation's value stream	e. Yes, considering Company X's value stream focuses on SC efficiency and creating a good transacting environment.
3. Capacity and readiness assessment	a. What are your organisation's barriers, if any, to greater investment in blockchain technology?	a. Not many organisations have adopted it hence there is high investment risk.
	b. What infrastructure, skills, and motivation of the organization or SC ecosystem need enhancement in order to ensure the technology will be implemented with quality?	b. There is need for investment is skill development in organisation and other SC partners will also need to enhance their knowledge and skills. The interoperability of BT will be important to its quality implementation.

5.4.1.1 Phase Conclusion

Based on the Internal analysis it can be concluded that Company X stands to benefit from BT adoption in its SCM systems as shown by the main identified benefits. The aspect of BT being a

technology that is not widely used in the SC industry yet (especially in South Africa) has been identified as one of the main barriers Company X will face when considering the adoption of BT. Of the few international use cases that were identified in the literature, BT seems to have provided the projected benefits. The belief is that as long as if the technology is implemented well and all the SC parties are willing to cooperate then Company X will likely benefit from BT adoption regardless of how new the technology is. The several dimensions of SCM related problems that BT can tackle within Company X show the value that the technology will bring to the organisation. Internally, Company X will benefit from BT adoption, however there is need to ensure the necessary skills and personnel are invested in (possibly through training) as those will be crucial for a successful adoption and implementation of BT.

5.4.2 Phase Two

Table 5.2 External analysis implementation

Step	Question	Response
4.Network and Ecosystem analysis	a. Is there a business network? b. If yes, what is the network scope? c. Will the organisation get buy-in from SC partners?	a. Yes, Company X does exist within a business network as it manages the SCM for its clients. b. Company X handles a national business network for a leading FMCG and that may even translate to the international scope. c. Because the SC parties also stand to benefit from BT, Company X will likely get by in. However, the fact that the SC parties will also need to invest in some necessary support devices shows how the concept selling has to be well presented and thought out
5.Provenance and Traceability analysis	a. Are audit trails important in the system (showing provenance)? b. Is trust crucial for the success of interorganisational relationships?	a. Yes, the transaction between parties need to be assessed (for example the amount of goods actually delivered vs. what the suppliers were paid is a transaction that will need auditing). b. Yes, if there is a system that can enhance that trust it will be greatly embraced in Company X's ecosystem
6.Benchmarking against competition	a. How will BT differentiate the company from its competitors? b. Is there a competitor that is using BT for its entire SCM systems? c. If yes, what will make our product unique?	a. Being the first organisation within the South African 4PL industry to adopt the technology, Company X will have the first to market advantage and likely get more customers. b. There is no competitor that has made the decision to adopt BT in its SCM systems and packages, therefore opportunities to be first in South African markets exists.

5.4.2.1 Phase Conclusion

The nature of the business allows for Company X to adopt BT within its industry and this is because Company X has the advantage of having several clients that they offer services to. This means that if Company X adopted BT, it would benefit from having the opportunity to manage its ecosystems more effectively considering the significant reduction in paperwork. Regardless of the

risk associated with the newness of BT, the fact that Company X has the potential of being the first to market means it will likely grow its market share. This shows that a trade-off has to be reached since as much as the newness of the technology is a threat, it may still aid Company X's competitive advantage.

5.4.3 Phase There

Table 5.3 Technical analysis implementation

Step	Question	Response
7.Applicable BT types and Parameters	a. Identify if there is a type of Blockchain that can meet the needs identified	a. Based on Figure 4.2, the best blockchain type that will meet Company X's needs will be the hybrid/consortium blockchain as the consensus determination, read permission, immutability, efficiency, centralisation and the consensus process align with Company X's needs.
8.Technology Adoption strategy	a. What is the organisation's technology adoption strategy?	a. Company X generally prefers to adopt the technologies that possess a satisfactory level of a proven track record. However, the adoption is also backed by market research and an element of risk taking. The organisation is there not an early adopter when it comes to innovation or technology adoption
9. IoT and other technical supports readiness	a. Does the SC already embrace IoT? Are they willing to invest in it?	a. The SC that Company X manages do make use of IoT devices, however for full integration and use of BT there is still need in the invest more IoT devices and also networks to ensure quality connectivity.

5.4.3.1 Phase conclusion

Based on the blockchain type selection criteria, it can be established that there exists a type that can meet Company X's needs (identified in Phase One). This is crucial before making the decision to invest in the adoption of the technology as an organisation will not want to find that the technology does not meet its needs. Company X will need a blockchain in which the consensus

determination is done only by selected parties with the SC, and also read permission that are restricted for some parties to allow for the protection of certain critical data within the system. The blockchain will be highly efficient and partially centralised allowing Company X to handle most of the BT management. If the organisation is to adopt BT, it may need to be willing to take the risk (as stated earlier) of being an early adopter as it will bring them much benefit. IoT devices and other supports as discussed are critical enablers for the successful adoption of BT and therefore Company X may need to ensure the necessary supports exist in the various SCs it manages or at least take up the task of ensuring that the necessary supports are invested in.

5.4.4 Overall Conclusion

If Company X becomes an early BT adopter in South Africa, it will present itself an opportunity to better its competitive advantage within the 4PL sector. Another opportunity that may potentially be presented is more clientele and also this may include growth in the organisation's portfolio as they easily manage both international and national scale SCs. The benefits presented to Company X and its ecosystem partners feed into its value chain and will definitely grant Company X a competitive advantage. The ROI of the investment however may be hard to quantify initially but the benefits that the technology will bring to an organisation will translate to a meaningful return especially in terms of service delivery. Based on the analysis performed through the formulated framework, it appears that internally Company X stands to benefit from BT, externally, Company X's ecosystem will also benefit and technically, Company X will find a type BT that suits its needs although necessary supports (BT enablers) need to be invested in throughout the ecosystem. BT adoption would be a feasible move for Company X both from a technical and operational perspective. However, a strategic decision will need to be made by Company X as to whether they are willing to take the risk of being an early adopter and investing in the necessary skills and technology supports.

5.5 Chapter Summary

The framework that an organisation can follow to assess the feasibility of using BT in SCM was developed in this section. The framework developed was then tested on Company X to see if it may bring about a conclusion regarding Company X's adoption. It was concluded that it is feasible for Company X to adopt BT in its SCM system and the specific decisions that the organisation may still need to make were highlighted.

CHAPTER 6. RECOMMENDATIONS AND CONCLUSIONS

6.1 Introduction

The purpose of this chapter is to summarise the research conducted. The chapter outlines the main recommendations regarding the implementation of the technology, the limitation of the research and also any further research that may be done in this area of study. The areas of improvement with regards to the framework formulated and an overview on the outcome of the project based on the initially set objectives will be given.

6.2 Research question and key findings

The study addressed the primary and secondary research questions adequately. The key findings for each question are shown in Table 6.1.

Table 6.1 Research question and key findings

Research Question	Key Findings
What factors must be included in a framework that is meant to assess the suitability of blockchain technology in the supply chain industry?	Internal analysis: • Conducting a needs and resources assessment • Conducting an appropriateness assessment • Conducting a capacity and readiness assessment External analysis: • Analysis of business network • Assessing the importance of audit trails • Analysis of BT effect on company differentiation Technical analysis: • Identifying an applicable Blockchain type. • Assessing the technology adoption strategy in place. • Assessing the attitude towards IoT.
How does Company X measure up against these factors?	It was determined that BT adoption would be technically and operationally feasible for Company X, from the internal, external and technical analysis perspective.

6.3 Limitations of the study

The author experienced challenges in finding experts that were willing to participate in the study whilst possess knowledge in both BT and SCM. A more in-depth analysis could have been conducted if there were no confidentiality clauses that could have led to breach of contract between Company X and its clients.

6.4 Recommendations

- Based on the characteristics of BT discussed in section two, if an organisation does decide to implement BT in its SCM, it must do so gradually. The implementation must first prove successful before it is rolled out throughout an organisation. For example, when it comes to the aspect of reducing paper trail, the first step must be to handle parallel flows of paper and digital documents, whilst gradually moving towards pure digital documents and data over time.

6.5 Areas of future study

The framework may look further into the issues of interoperability between platforms/networks, with internal systems and with industry standard systems and protocols. This will mean a thorough analysis of each of the supply chain parties' SCM systems.

The framework scope maybe be widened to not only focus on the operational and technical feasibility assessment but also aspects such as cultural feasibility which focuses on the organisation's attitudes and behaviours towards the technology.

6.6 Conclusion

The framework formulated in this research will hopefully provide important insight into the key factors leading to an organisation's decision to adopt blockchain technology in its supply chain management. The framework focuses on the operational and technical feasibility of adopting BT and was formulated from questionnaires responses from experts in both fields, literature presented by other researcher and interviews with the organisation personnel. It was tested on Company X and concluded that it would be feasible to adopt BT only after some critical strategic decisions had been made. In conclusion, the decision-making authorities of an organisation may use this framework to understand BT and the benefits that it may bring to their organisation, whilst

focusing on its SC network and ecosystem. The technical analysis allows the decision-making authorities to also assess if the blockchain architectures can meet their needs. Each of the objectives of the study were achieved, and these included the analysis of Company X's SCM systems, the formulation of a BT adoption assessment framework, and the testing of that framework on Company X.

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APPENDICES

Appendix A: Questionnaire Structure

Questionnaire on the adoption of Blockchain Technology in Supply Chain Management

Good day,

This questionnaire is for the collection of data for a research being carried out by Tsitsidzashe Goto a Master of Engineering (Industrial Engineering) candidate at University of the Witwatersrand in South Africa. The research aims at assessing the benefits and drawbacks associated with the adoption of blockchain technology in supply chain networks at the present moment. The research project title is as follows 'A study on the feasibility of using blockchain technology in supply chain management and logistics : A case study approach.' The project will include the development of a framework, that will in turn be used to assess the feasibility of applying blockchain technology in a case study organisation's supply chain network.
The results of this study will be written up as part of my research project, which will be available at the University library and online thesis repository. It may also be published at a later time. If you wish to receive a summary of this report or require any further information please feel free to contact me.

Please fill in the questionnaire.

* Required

1. **May you briefly describe yourself in terms of education and work experience ?** *

2. **Would you like that we keep your identity (including employer's name) anonymous in the research report ?** *
   Mark only one oval.
   - ◯ Yes
   - ◯ No

3. *
   Check all that apply.
   - ☐ My participation is voluntary and I consent to this information being used for the purposes of the research.

4. **Which field are you knowledgeable in ?** *
   Mark only one oval.
   - ◯ Blockchain Technology *Skip to question 7.*
   - ◯ Supply Chain Management *Skip to question 5.*
   - ◯ Both Blockchain Technology and Supply Chain Management

Supply Chain Management related questions

5. **Please respond to the following :** *
Mark only one oval per row.

	Strongly Disagree	Disagree	Nuetral	Agree	Strongly Agree
Trust is a critical success factor for inter-organizational relationships					
Trust is important in a supply chain network					
It is not easy to insert a new technology inside established supply chain systems because integration challenges are likely to be faced.					
Visibility can fix already flawed relationships between parties in a supply chain network.					
Immutability is a desirable quality in Supply Chain records (Immutability is the assurance that actors in the ecosystem cannot change the historical record)					

6. **Rate the importance of the following based on your opinion :** *
Mark only one oval per row.

	Not at all important	Slightly Important	Important	Fairly Important	Very Important
The customer experience					
Traceability of products along a supply chain network					
Sustainability of trading partners' businesses in supply chain (e.g How environmentally friendly their business is)					
Supply Chain data file security					
Reduction of paper trail					
Efficiency of Supply Chain networks					
Accessibility of Information to all Supply chain network partners					
Inter-organisational relations					

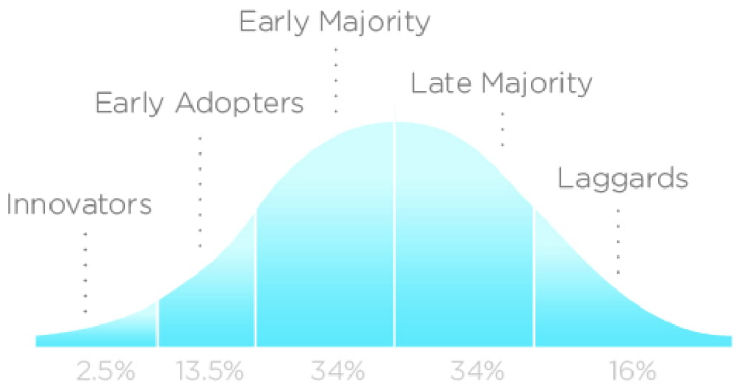
Blockchain Technology Section

7. **What is your opinion on the following :** *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
There aren't enough specialists with relevant experience in the blockchain technology space for organisation to start considering using it					
A company should conduct thorough research on blockchain technology before adopting it.					
Blockchains are complex when it comes to their development and correction					
Blockchain technology is overhyped					
Blockchain brings about trust between parties in a network					
Blockchain brings about visibility in a network					
Blockchain technology is unproven					
There is lack of compelling application of the technology					
This technology has uncertain Return on Investment (ROI)					
Blockchain technology is broadly scalable.					
Blockchain technology will eventually achieve mainstream adoption, just not yet					

8. **Based on the innovation adoption lifecycle, what would you consider as the best strategy when it comes to Blockchain technology:** *



INNOVATION ADOPTION LIFECYCLE

Mark only one oval.

- ◯ Be an early adopter
- ◯ Be an early majority adopter
- ◯ Be a late majority adopter
- ◯ Be a laggard

9. **Will blockchains be able to handle large amounts of data generated in Supply Chain networks?** *

Mark only one oval.

- ◯ Yes
- ◯ Maybe
- ◯ No

10. **In your opinion, what are the risks associated with the adoption of blockchain technology in supply chain management and logistics ?** *

Supply Chain and Blockchain related questions

11. **Please respond to the following questions:** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Nuetral	Agree	Strongly Agree
Implementing blockchain in a supply chain requires the full cooperation of everyone involved					
Blockchain technology will maximise the efficiency of conducting activities along the supply chain					
Blockchain adoption will minimise inventories along the supply chain					
Blockchain adoption will minimise cycle times along the supply chain					
Blockchain will help achieve an acceptable level of quality along the supply chain.					
Blockchain will help minimise the bullwhip effect (The bullwhip effect is a distribution channel phenomenon in which forecasts yield supply chain inefficiencies. It refers to increasing swings in inventory in response to shifts in customer demand as one moves further up the supply chain.)					
Blockchain technology adoption can make reverse logistics smoother					
Organisations will lose a competitive advantage if they don't adopt blockchain technology in their supply chains					
Blockchain will increase the security of a product in the supply chain					
Firms will use blockchain technology more in years to follow					
Overall , my attitude toward Blockchain technology is favourable					

12. **If blockchain implementation were to face any resistance within the supply chain sector, from whom will the resistance come from ?** *

Check all that apply.

- [ ] Internal employees
- [ ] Other supply chain network participants
- [ ] Other: _____

13. **In the development of a decision making framework for the adoption Blockchain Technology, what critical factors do you believe must be included ?** *
(For example the availability of human resources or skilled personnel)

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Appendix B: Question value assignment.

Table B.1 Question value assignment for analysis.

Question	Assigned Value
Trust is a critical success factor for inter-organizational relationships	1
Trust is important in a supply chain network	2
It is not easy to insert a new technology inside established supply chain systems because integration challenges are likely to be faced.	3
Visibility can fix already flawed relationships between parties in a supply chain network	4
Immutability is a desirable quality in Supply Chain records	5
The customer experience	6
Traceability of products along a supply chain network	7
Sustainability of trading partners' businesses in supply chain	8
Supply Chain data file security	9
Reduction of paper trail	10
Efficiency of Supply Chain networks	11
Accessibility of Information to all Supply chain network partners	12
Inter-organisational relations	13
There aren't enough specialists with relevant experience in the blockchain technology space for organisation to start considering using it	14
A company should conduct thorough research on blockchain technology before adopting it.	15
Blockchains are complex when it comes to their development and correction	16
Blockchain technology is overhyped	17
Blockchain brings about trust between parties in a network	18
Blockchain brings about visibility in a network	19
Blockchain technology is unproven	20
There is lack of compelling application of the technology	21
This technology has uncertain Return on Investment (ROI)	22
Blockchain technology is broadly scalable	23
Blockchain technology will eventually achieve mainstream adoption, just not yet	24
Implementing blockchain in a supply chain requires the full cooperation of everyone involved	25
Blockchain technology will maximise the efficiency of conducting activities along the supply chain	26

Blockchain adoption will minimise inventories along the supply chain	27
Blockchain adoption will minimise cycle times along the supply chain	28
Blockchain will help achieve an acceptable level of quality along the supply chain.	29
Blockchain will help minimise the bullwhip effect	30
Blockchain technology adoption can make reverse logistics smoother	31
Organisations will lose a competitive advantage if they don't adopt blockchain technology in their supply chains	32
Blockchain will increase the security of a product in the supply chain	33
Firms will use blockchain technology more in years to follow	34
Overall, my attitude toward Blockchain technology is favourable	35

Table B.2 Hypotheses question allocation.

Hypothesis	Allocated Questions
H1: The ease of technology integration has a positive impact on BT adoption	3, 25,
H2: The availability of human resources (skill) is critical to the adoption of BT	14, 16
H3: An organisation's perceived need for the immutability of records has a positive relationship with the adoption of BT	1, 2, 4, 9, 18, 33
H4: The projected ROI has an influence on the adoption	20, 21, 22, 10
H5: If BT carries benefits that directly influence an organisation's value chain it will willingly adopt the technology	1, 5, 6, 7, 8, 9, 10, 11, 12, 18, 19, 23, 26,27 ,28, 29, 30, 31,
H6: An organisation will likely to adopt BT if it operates in an ecosystem that has many parties	1, 2, 7, 8, 10, 11, 12, 13, 25, 26, 29, 31,33
H7: Trust amongst SC parties must be of high priority	1, 2, 12, 4, 5, 7, 9, 13, 25,
H8: An organisation will adopt BT if it grants it a competitive advantage	4, 5, 6, 7, 8, 9, 11, 12, 13, 18, 19, 23, 26, 27, 28, 29, 30, 31, 32,33,34,35

Appendix C: Interview Structure and Questions

Introduction and Background

Information on the systems currently in place and the organisation's core competences.

Questions

Q: Data accessibility between SC players (strategic information may be out in the open and available to parties) Do you therefore feel BT could be a disadvantage in that regard?

Q: How do you arrive at using a particular system or technology in the organisation?

Q: What is your Framework in terms of assessing what innovation to bring to your organisation?

Q: How do you measure satisfaction of your clients, what are the key KPIs?

Q: Do you have certain compliance standards that you need your SC parties to comply to, so you work with them

Q: Is sustainability valued in your networks e.g. regular maintenance of trucks to reduce emissions (which may be linked with the depletion of the environment). Do you value the aspect of how sustainable an SC partner is?

Q: Financially, what do you look at when investing into a new project? How long does a project have to take until it pays you back?

Q: In terms of the systems that you choose for your consultancy, how do you get to adopting a certain software over the other? How do you decide on the financial feasibility of one over the other?