



Faculty of Computer Science and Information Technology

**A Framework to Preserve the Authenticity of Cultural Product Based
on Blockchain Technology**

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A Framework to Preserve the Authenticity of Cultural Product
Based on Blockchain Technology

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A thesis submitted

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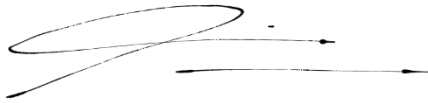
Faculty of Computer Science and Information Technology

UNIVERSITI MALAYSIA SARAWAK

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

This research proposes a framework for preserving the authenticity of Songket, a traditional woven fabric, by leveraging Ethereum's public blockchain technology. The goal is to ensure the transparency and traceability of Songket patterns, which are crucial for maintaining the cultural integrity and craftsmanship of the fabric. The framework involves the creation of a blockchain-based supply chain system, SongketChain, which allows for the secure registration, tracking, and validation of Songket products from weavers to consumers. By utilizing smart contracts and a local blockchain environment (Ganache), the system provides a robust method for verifying the ownership and authenticity of Songket patterns. The blockchain-based solution developed on the Ethereum platform ensures that each piece of Songket retains its original quality and design throughout its lifecycle. The blockchain-based solution incorporates OTIF (On Time In Full) in order to evaluate the transparency and traceability of the Songket product. Key findings demonstrate that Ethereum's public blockchain effectively preserves Songket authenticity by offering an immutable, decentralized ledger for verifying its origins and production history. This approach safeguards the cultural heritage of Songket, protecting it from counterfeiting while promoting transparency in its production process. The study highlights the importance of using blockchain technology, specifically Ethereum, to preserve high-quality, time-intensive cultural products like Songket, benefiting both artisans and consumers.

Keywords: Songket, blockchain, authenticity, transparency, traceability, cultural assets, smart contracts.

Rangka Kerja untuk Melindungi Produk Budaya Unik menggunakan Teknologi Rantai Blok

ABSTRAK

Penyelidikan ini mencadangkan rangka kerja untuk memelihara keaslian fabrik Songket, tenunan tradisional, dengan memanfaatkan teknologi blockchain awam Ethereum. Matlamatnya adalah untuk memastikan ketelusan dan kebolehkesanan corak Songket, untuk mengekalkan integriti budaya dan ketukangan fabrik. Rangka kerja ini melibatkan penciptaan sistem rantai bekalan berasaskan blockchain, SongketChain, yang membolehkan pendaftaran, pengesanan dan pengesahan produk Songket daripada penenun kepada pengguna. Dengan menggunakan kontrak pintar dan persekitaran blockchain tempatan (Ganache), sistem ini menyediakan kaedah yang teguh untuk mengesahkan pemilikan dan ketulenan corak Songket. Melalui metodologi percubaan, penyelesaian berasaskan blockchain yang dibangunkan pada platform Ethereum memastikan setiap bahagian Songket mengekalkan kualiti dan reka bentuk asalnya sepanjang kitaran hayatnya. Penyelesaian berasaskan blockchain menggabungkan OTIF (Tepat Masa Secara Penuh) untuk menilai ketelusan dan kebolehkesanan produk Songket. Penemuan utama menunjukkan bahawa blockchain awam Ethereum berkesan mengekalkan keaslian Songket dengan menawarkan lejar yang tidak berubah dan terdesentralisasi untuk mengesahkan asal usul dan sejarah pengeluarannya. Pendekatan ini melindungi warisan budaya Songket, melindunginya daripada pemalsuan sambil menggalakkan ketelusan dalam proses pengeluarannya. Kajian itu menunjukkan kepentingan menggunakan teknologi blockchain, khususnya Ethereum, untuk mengekalkan produk budaya yang berkualiti tinggi seperti Songket, yang memberi manfaat kepada kedua-dua tukang dan pengguna.

Kata Kunci: *Songket, blockchain, keaslian, ketelusan, kebolehesanan, integriti budaya, kontrak pintar.*

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LIST OF ABBREVIATIONS

CGS	Centre for Graduate Studies
CM	Consumer
IPFS	Interplanetary File System
PC	Producer
SP	Supplicant
UNIMAS	Universiti Malaysia Sarawak
XAMPP	Cross-Platform, Apache, MySQL, PHP, and Perl

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia is a country full of diversity and culture since Malaysia achieved its independence on 31 August 1957. Furthermore, Malaysia's diversification strengthened with the joining of Sarawak and Sabah on 16 September 1963. Since then, people have been socializing with each other and learning about each other's culture. One of the main things that people have learned with each other was the cultural products such as Chinese calligraphy, Henna, blowpipe, *wayang kulit*, *sape*, *pua kumbu*, *songket*, and other cultural products. This cultural product is one of the ways for each ethnic to preserve their culture and as a source of income.



Figure 1.1: A person making Chinese calligraphy (Chong, 2022)



Figure 1.2: A person making a sape (Sabrina, 2023)

The creation of songket, a traditional fabric revered in Southeast Asia, particularly in Malaysia, Indonesia, and Brunei, is a meticulous process that combines skilled craftsmanship and intricate design. The process begins with the preparation of the base fabric, typically cotton or silk, which forms the foundation for the weaving. The hallmark of songket is the use of metallic threads, often made of gold or silver, which are interwoven into the fabric to create shimmering, raised patterns. The design process involves detailed planning, where traditional motifs inspired by nature or geometry are drawn out and incorporated into the weave. The weaving itself is done on a traditional handloom using a supplementary weft technique, where metallic threads are inserted into the base fabric to form distinct patterns. This method requires a high level of expertise, as the threads must be interlaced precisely to ensure the design is accurate and visually striking. Once woven, the fabric undergoes washing and sometimes steaming to enhance the sheen of the metallic threads, while some pieces are dyed in vibrant colours without compromising the integrity of the gold or silver threads. After completing the weaving and finishing stages, the fabric is inspected for quality before being used in the creation of traditional garments for ceremonial purposes. The entire process reflects a deep cultural heritage, with regional variations in motifs and techniques adding to the richness of this

revered craft. Songket remains a symbol of luxury and artistry, with its creation involving both artistic expression and skilled craftsmanship passed down through generations.



Figure 1.3: A person making a *Songket*

In 2018, Malaysia's textile and garment industry was valued at RM13.2 billion (Ministry of International Trade and Industry, 2018). Malaysian *Songket* is one of the most important cultural assets in maintaining national identity. Most *songkets* are sold locally, with a small amount exported. Kelantan, Terengganu and Sarawak are the main states for songket production. Each songket has a unique pattern belonging to a specific individual or culture. Some *songkets* include *Songket Bunga Penuh*, *Songket Bunga Bertabur*, *Songket Corak Berjalur*, *Songket Corak Melintang*, *Songket Corak Siku Keluang*, *Songket Corak Tapak Catur* and *Songket Corak Pucuk Rebung*.



Figure 1.4: *Songket corak penuh* (Nawawi, Aziz, Legino, Ahmad & Ismail, 2015)



Figure 1.5: *Songket corak berterabur* (Nawawi, Aziz, Legino, Ahmad & Ismail, 2015)

Songket bunga penuh consists of full flower pattern on the songket with full artistic art compared to *songket bunga bertabur* which consist of flower pattern but does cover the whole *songket* with arts.



Figure 1.6: *Songket corak jalur melintang* (Nawawi et al., 2015)



Figure 1.7: *Songket corak jalur menegak* (Nawawi et al., 2015)

For *songket corak berjalur*, the pattern consists of vertical lines whereas *songket corak melintang* consists of horizontal lines.



Figure 1.8: *Songket corak petak catur* (Nawawi et al., 2015)



Figure 1.9: *Songket corak pucuk rebung* (Nawawi et al., 2015)

Songket corak siku keluang consists of a zigzag pattern whereas *songket corak tapak catur* consist of square pattern that mimics the chessboard pattern. For *songket corak pucuk rebung*, the pattern consists of young bamboo shoots at the side. *Songket* is mostly produced in the east coast states like Terengganu and Kelantan. However, other states such as Pahang, Selangor, and Sarawak also produce songket in the Malaysian market.

Other than *songket*, there are other products that also use gold or silver threads same as *songket* production such as *keringkam*. *Keringkam* is a traditional scarf mainly used by Malay Sarawakian women in Sarawak for social functions such as wedding ceremonies and other major festivals. Back then, *Keringkam* was only used for people that had a high social status in society and eventually as time passed by, other people started wearing it. The tradition of wearing *keringkam* is kept alive as each family passes down the *keringkam* from generation to generation. *Keringkam* dimension is usually 54CM x 95CM, having motifs like roses, cape flowers, and shoots stitched on a cloth or rubia gauze.



Figure 1.10: *Keringkam* example (Ibrahim, 2020)

A stunning piece of traditional Malay cloth, a *songket* is handwoven using silk or cotton threads and patterned with colorful metallic threads. The term *menyongket*, which means to embroider in Malay, refers to the extra weft technique used to create the *songket* designs. This technique involves weaving metallic threads into the material. *Songket* weaving is an extremely arduous and time-consuming procedure that necessitates intense focus from the weaver (Ngo, 2010).

Songket was historically associated with the Srivijaya empire from the 7th to 13th century, which was based in Sumatra, Palembang. According to tradition, the songket was created by mixing silk threads from China and gold threads from the Middle East which produce glittering golden songket. Songket represents social status with nobility which most of the time is the personification of the King to provide divine status to the king. Since then, songket has been used traditionally for special occasions such as wedding ceremony, religious ceremony and traditional social functions for the Palembangese, Minangkabau and Balinese people.

While creating the songket, most of the time the songket pattern consists of certain motifs which are Flora, Fauna, Cosmos, Object, Geometric, Food and Calligraphy. These motifs most of the time connected with the relationship with the Creator, uniqueness, symbolism and benefit.

The Malays' daily lives are influenced by their environment and way of life, which serves as the inspiration for the motifs. The characteristics of domestic animals and other parts of nature, like flora and foliage, serve as inspiration for Malays creating motifs. This ultimately turns into a metaphor or symbol for life. The Malays' long-standing affinity with nature formed and inspired their inner ideas and worldviews (Wan Abdul Kadir, 1993).

Ideas are sought after at the start of most motifs. It is amazing how they can select, refine, and transform a perception into something concrete, distinctive, and appealing. By using denaturalization, style, and abstraction, the weavers demonstrate their inventiveness and maturity in the choosing of motif sources. A songket's motif is assessed either favourably or from a perspective that is deemed acceptable by the community. This is due to the need to comprehend the purposes, needs, and aesthetics of songket as well as to satisfy the racial and philosophical demands of society (Aziz, 2020). Songket is therefore one of the valuable resources for history and cultural heritage.

1.2 Problem Statement

Songket or keringkam are a type of weaving that involves a painstaking laborious and tedious process that requires a great deal of concentration from the weaver (Ngo, 2010). To make a songket, certain appliances that are made from bamboo or wood are needed to weave the songket. For the materials, it usually consists of silk threads and golden or silver threads. To weave the songket, the thread is inserted in between the wefts as the will eventually wove into a warp which is fixed to the loom. This process is tedious

which consumes a lot of time, and it takes a lot of skills. Due to this complex process and materials required, it cost a lot for one good pair of songket.

Completed songket products in the Malaysian market lack information for the customer who bought such as the materials used, weaving technique, and motif information. To provide transparency of the songket product, all details of the songket in the supply chain such as materials used, and weaving techniques should be recorded and stored for the customers.

The process of songket production also involves other parties such as suppliers of materials, logistics and the seller of the songket products. The flow of the songket product in the supply chain from the weaver to the customer in the supply chain should be recorded to trace the flow of the product which will ensure the authenticity of the songket.

The authenticity of the songket depends on the pattern of the songket which is the motifs, and the materials used. Complexity of the pattern itself will increase the value of the songket. However, the pattern of the songket was patented by the weaver because of the complex process to apply a patent. Another solution to ease the weaver is by using the blockchain to patent the songket pattern. Blockchain by nature is immutable, thus will make sure the pattern of the songket can be patented and stored in the supply chain.

Nonetheless, this industry does encounter certain difficulties. According to Isa (2019), imitation *songket* is imported from India at a lower cost; grade A costs RM900 each pair, while grade B costs RM500. The local *songket* community would suffer, and the economy will be impacted, since local vendors typically mark up the price of the phony *songket* to a higher amount of between RM3000-RM7000. Since the manufacture of the *songket* is not marketed, the handcrafted *songket* in Kampung Rajang, Sarawak, which ranges in price from RM900 to RM10000 depending on quality and pattern, is among the finest *songket* made. To increase the *songket* market's present productivity in Sarawak, a

more intelligent solution for pattern rights is required as the market expands. The use of blockchain technology for *songket* pattern management is one workable alternative.

Most of the existing songket producers practice strong documentation of the pattern but lack security. Songket created can be copied by irresponsible people to gain profit, which will hurt the local songket industry and the economy. This lack of security feature is usually unintentional, as some of the producers do keep track of their patterns. The addition of key aspects such as transparency, traceability, and immutability could help address this issue and prevent the unauthorized use of these patterns. Transparency ensures that songket patterns are visible and verifiable by the public, allowing consumers and producers alike to confirm the authenticity of a design. Traceability ensures that every pattern can be tracked back to its creator, so that any infringement can be easily identified and resolved. Finally, immutability guarantees that once a songket pattern is documented, it cannot be altered or erased, preserving its originality and preventing unauthorized copies from gaining credibility. Without these features, the value of the songket in Malaysia could plummet, as the authenticity and uniqueness of the designs would be at risk of being diluted. Economic rights are often synonymous with exploitation rights, this right is because the copyright gives a certain period to exploit the economic benefits of the copyrighted work to the creator (Yurnida, 2020).

1.3 Objectives

The main objective of this research is to formulate a framework that ensures the authenticity of the songket of using blockchain technology which can be evaluated in terms of traceability and transparency. Traceability refers to the ability to track and verify the entire journey of a songket, from its inception to the final product that reaches consumers,

whereas transparency refers to the open and accessible nature of the information surrounding the songket production process, facilitated by blockchain technology

Other objectives include:

- i. To study the characteristics of cultural assets that can be protected using blockchain technology.
- ii. To enhance security protection of songket for motif ownership using immutable characteristics of blockchain.
- iii. To formulate a framework for supply chain with traceability and traceability capability of songket using blockchain technology.
- iv. To evaluate the effectiveness of the proposed framework based on traceability and transparency.

1.4 Scopes of Study

The features of both blockchain technology and business procedures must be determined to integrate them into operations effectively. A significant obstacle to the operation of business processes, particularly those that are time-sensitive, is the inconsistency of confirmation settlement, which mostly depends on the use of consensus protocol (Viriyasitavat et al., 2018). The study's main objectives are transparency and traceability.

Blockchain nowadays consists of private and public blockchain. The availability of the blockchain is one of the main purposes for this study. The difference of the public and private blockchain are both using different consensus algorithms to approve creation of transactions and the difference of algorithm on both blockchain would affect the traceability and transparency. In the process of a little research, this study will adopt Ethereum blockchain which will ensure transparency and traceability on the songket production.

1.5 Significance of Research

Contributions of this study can be described as below:

- i. The proposed blockchain based solution implements two different private blockchain technologies with different blockchain components such as consensus algorithm, smart contract technology, and database management.
- ii. The results of the proposed solution will be analysed based on the blockchain traceability and transparency framework.

1.6 Outline of the Thesis

The problem statement, project objectives, research background, and research scope are all covered in Chapter 1. According to sources from the official website, relevant journals, and papers, Chapter 2 covers the traditional supply chain process of pepper, the definition of supply chain traceability and transparency, and blockchain technology. Chapter 3 discuss the methodology implemented. The investigation of blockchain technology and the creation of study-related solutions are covered in Chapter 4. The application and testing of the suggested solution to ascertain its traceability and transparency are covered in Chapter 5. An overview of the study, including its contributions, limitations, and future directions, is given in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Every civilization in the world has their own achievements and identity that can be tracked through recorded history. Some of the identities include their own cultural product that define people at that time. Cultural products usually represent the demographic of the population based on race and religion at that time. For instance, *tanjak* was used by the Malay and Indonesian people as a headgear.



Figure 2.1: Modern day tanjak

Cultural products are important to the heritage since they preserve one culture and identity that can be traced back according to the history recorded. With this perseverance, one culture can be passed down from generation to generation. Cultural products also provide practicality to people who use them. For example, *labu sayong* can be used to store

water and the water temperature remains cold even though the outside temperature is hot. Up until today, labu sayong is still used to store water in some rural areas such as Kuala Kangsar.



Figure 2.2: Labu sayong

Cultural products also provided an economic benefit back then. During the Malacca Sultanate, local products that are produced locally such as tin and gold were bartered together with cultural products such as *keris*. With the rising trade, demands of domestic products and cultural products increase. Today, cultural products such as songket contribute to economic growth through the textile industry. Malaysian handicrafts sold for RM508,251,684.45 in 2016 (Malaysian Handicraft Development Corporation, 2016). The largest contributor to this total was textiles, such as songket, batik, and silk, with sales of RM239,784,324.65, or 47.2% of the total (Malaysian Handicraft Development Corporation, 2016).

A *songket* is a high-end item that is customarily worn as a headpiece, sarong, shoulder cloths, or head ties at ceremonial events such as Malay festivals and weddings (Zhang et al., 2018). Songket is one of the economic backbones for the textile industry in Malaysia. The powerhouse for the songket production includes Kelantan, Terengganu, Pahang, Selangor and Sarawak. Most of the songket produced in each state are similar in terms of pattern and the patterns are *songket bunga penuh*, *songket bunga bertabur*, *songket corak berjalur*, *songket corak melintang*, *songket corak siku keluang*, *songket corak tapak catur*, and *songket corak pucuk rebung*.



Figure 2.3: Songket bunga penuh



Figure 2.4: Songket bunga tabur

Songket bunga penuh consists of full flowers art on the songket whereas *songket bunga tabur* consists of spaced-out flowers on the songket.

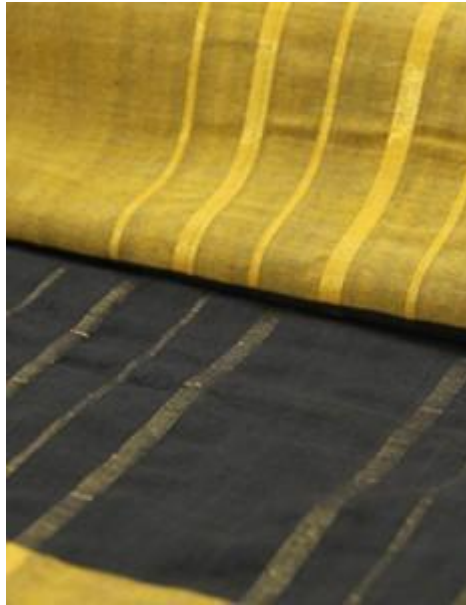


Figure 2.5: Songket berjalur



Figure 2.6: Songket melintang

For *songket corak berjalur*, the pattern consists of vertical lines whereas *songket corak melintang* consists of horizontal lines.



Figure 2.7: Songket siku keluang



Figure 2.8: Songket tapak catur

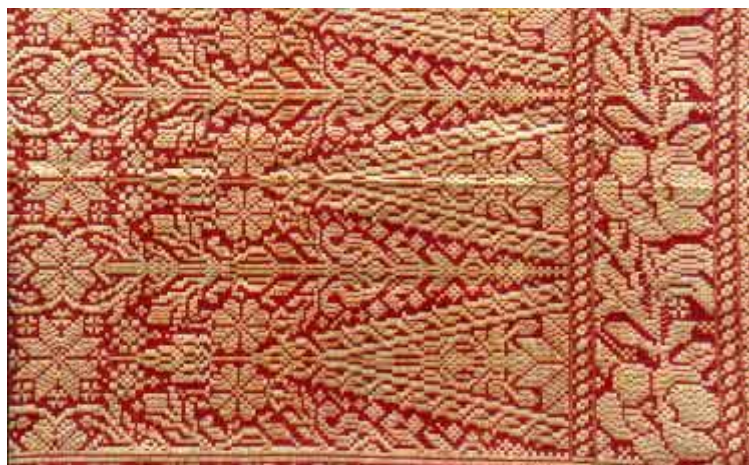


Figure 2.9: Songket pucuk rebung

Songket siku keluang consist of zigzag pattern on the edge of the songket whereas *songket tapak catur* consist of square pattern. For *songket pucuk rebung*, the pattern consists of a triangular shape that mimics the shape of bamboo shoots.

Before songket is produced, the materials to produce a songket such as yarn and dye to colour the yarn. Due to the increase of gold and silver, modern day songket used coloured yarn instead of dipping the yarn in gold or silver. Once the yarn is coloured, the yarn would be trimmed to remove the excess thread that cannot be used. Remaining thread will be used and the length of the songket will be determined at this process. The thread then will be rolled on the roll board according to the width of the gear tooth and the specified width will determine the size of fabric used. Plunging yarn is the process of two loose veins linked through the gear gap. Running yarn will ensure strangled yarns, odd yarns and yarns will be lifted automatically while weaving the songket. The most complicated process of making a songket is the flowering work after running the yarn. Normal technique used for making the pattern is a five-pointed technique where one thread is pushed down, and the thread left available will be disassembled. The weavers then use bamboo skewers to make the pattern based on inspired motifs such as geometric and flora. The pattern will be weaved together with the remaining yarn to form a songket cloth by using a tool called ‘*kei*’ which will tighten the yarn all together. This process is repeated until the desired length of the songket is achieved.

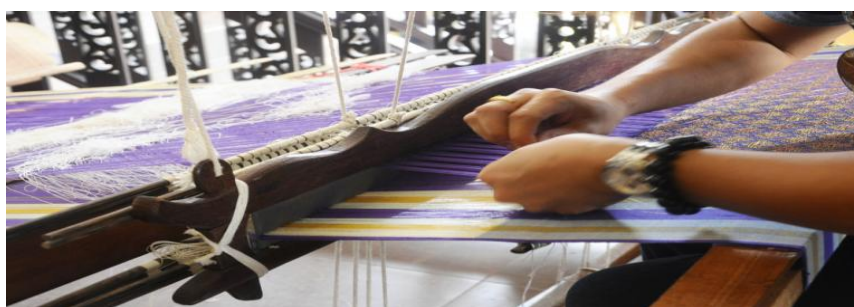


Figure 2.10: Weaver using bamboo skewer to make a pattern.



Figure 2.11: Completed *songket* with *corak jalur* and *corak bunga tabur* (Jamaluddin, 2019)

Figure 2.12 illustrates the overview of *songket* production in Malaysia. The main phases characterize a generic *songket* production which consists of three (3) participants and how products flow in the process.



Figure 2.12: Typical process of songket industry in Malaysia

Before weaving the songket, the preparation worker will prepare the warp boards, threads and design sample for the weaver which the warp board will be ready for the weaver. The role of a weaver is to weave and design the *songket*. For instance, the product of *songket* will undergo the process of yarn coloring, bending thread, wear yarn, rolling yarn, blow yarn, running yarn, *menyongket* yarn and weaving yarn. The produced *songket* will be packed and sent to the middleman.



Figure 2.13: Example of packaged songket

The representation of the process above from Figure 2.12 looks simple, however there is another actor that takes place behind the scenes which is the merchant. To bring trust to the process, retailers play an important role in protecting the customer from buying low quality songket and the weaver from getting scammed. In the real-world scenario, when weaver completes the production of a songket, the whole process usually involves another entity (a middleman) in the main process as shown in Figure 2.14.



Figure 2.14: Retailer in supply chain

Retailers are distinguished between two categories. First up is the small-scale retailer, who typically purchases their materials locally and sells the *songket* to a smaller group of weavers (between 1 and 10). Large-scale retailers are a different kind of retailer; they typically purchase materials and sell goods not just locally but also nationally and

even worldwide (Sas et al., 2019). They typically have a workshop or shop, a wider customer base, and at least thirty weavers (Sas et al., 2019). The primary reason merchants are involved is to restore trust in the system.

Nonetheless, weaving is a gendered profession that is influenced by several variables that increase the economic vulnerability of rural weavers, including the high demands of reproductive labour that restrict their ability to leave their homes, the lack of access to alternative employment opportunities and education, and their inability to own the tools and raw materials needed for production. Weavers now receive minimal welfare benefits because of the commodification of their labour due to these factors (Wethey, 2004).

Additionally, they unfairly only receive subsistence pay, with the weaving designer merchants taking an excessively big amount of the extra value (up to 8–10 times more for high-end bespoke *songket*). Furthermore, a lot of merchant's function as the exclusive suppliers of songket orders in a particular village, typically due to their deep historical ties and implicit claims regarding the uniqueness of their weavers' labour force (Sas et al., 2019).

2.2 Songket Supply Chain Transparency and Traceability

Traceability and transparency are the key processes in making the songket management secure and reliable. To develop a useful solution for songket management, the differences between these terms need to be defined to get a good indicator of a good songket management system.

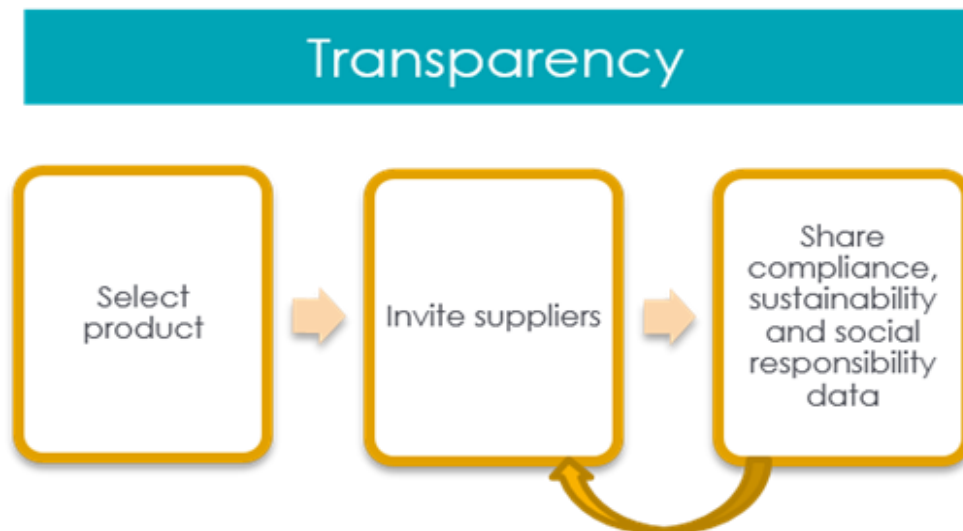


Figure 2.15: Supply Chain Transparency (Tsai, 2018)

The word "transparency" is frequently used in an ambiguous manner when discussing supply chains for commodities that are sustainable. Transparency is frequently viewed normatively as a tool to support the values of accountability, democracy, and participation. According to Gardner et al. (2018), there are others who believe that openness has the capacity to aid in reversing significant disparities in the ways that various parties obtain information. A supply chain's various actors, including those in the production, transportation, and processing systems, as well as their roles and the nature and rigidity of the connections between them (including supplier and contractual relationships and the power dynamics they entail) and to production locations, are all covered by traceability information. Transparency regarding relationships between players and between actors and locations is provided by traceability information (Gardner et al., 2018). Supply chain transparency allows participants to identify every source for every component in a product, right down to the origin, as shown in Figure 2.15. Transparency in the supply chain network facilitates the identification and gathering of hitherto unidentified product data, as well as the communication and establishment of precise requirements by network participants. As a result, everyone involved can see their global supply chains

more clearly and make sure that safety, sustainability, and social responsibility regulations are being followed.

However, in practice, supply chain openness has many drawbacks, including restrictions on data collection and dissemination and potentially unfavourable outcomes regarding the information's usage, by whom, and to what effect (Mol, 2015). Although more openness is generally associated with more democratic and emancipatory forms of government, it can also worsen inequality and give the powerful more power (Egels-Zandén et al., 2015). A process of simplification, reduction, standardization, and dis-embedding from regional social and ecological settings is typically involved in efforts to increase the transparency of extremely complicated supply chains. As a result, some characteristics will become more apparent while others will become less evident. Power dynamics determine what information is included and excluded (Scott, 1998), with weaker actors only having influence when their goals coincide with those of stronger actors. Transparency varies simultaneously depending on the user and the scale (McDermott, 2014). Local producers and communities do not have access to the same types of information as do national governments, multinational corporations, or highly resourced international non-governmental organizations (NGOs). Examples of this type of information include scientific studies, databases, registries, and detailed written reports.

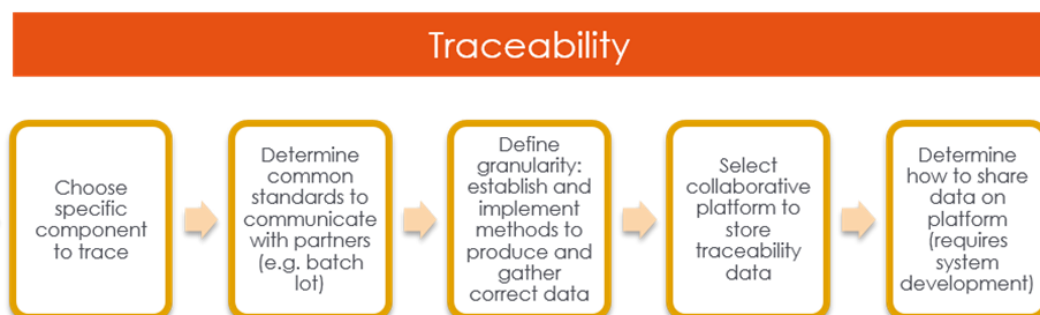


Figure 2.16: Supply Chain Traceability (Tsai,2018)

Tsai (2018) noted from Figure 2.16 that supply chain traceability records significantly more detailed information about a product component, including purchase order data, batch-lot data (harvest date, field data, etc.), and other operational data. In contrast to supply chain transparency, traceability focuses more on tracking the movement of product components or purchase orders through the supply chain than it does on mapping the complete end-to-end supply chain. More focused recalls are made possible by the granularity of the data utilized in traceability, which lowers size and expense.

Transparency is a prerequisite for traceability, and data collection for traceability cannot occur without transparency. Without transparency, traceability implementation is impractical. For instance, it is nearly hard to obtain information on the raw material price, purchased order data, or commodities used without the supplier's information. Traceability requires transparency to have a good supply chain.

The necessity for a traceability system in the agricultural sector is driven by several negative behaviours and issues. First, there is the extensive use of fertilizers and pesticides on fruits and vegetables, which leaves some residues that are extremely dangerous to human health in the finished product. During the culture phase, hormones and other chemicals are frequently utilized to shorten the maturation period, which increases field productivity. Even rice and cookies have been known to be brightened using mineral oil. All these methods pose a serious risk to the safety of customers in addition to lowering the agricultural product's nutritional value (Lin et al., 2018).

2.3 Blockchain

The original Peer-to-Peer Electronic Cash System, or Bitcoin, was developed in 2008 by Satoshi Nakamoto with the goal of enabling internet transactions to be accepted without the need for banking institutions to physically verify them. Blockchain is the primary technology behind Bitcoin. It is an electronic payment system built on cryptographic proof that enables any two interested parties to conduct business directly with one another without the involvement of a reliable intermediary. Regular escrow mechanisms may be easily constructed to protect purchasers from fraud, and sellers would be protected from it by transactions that are computationally hard to reverse (Nakamoto, 2008).

One of the most promising solutions to distributed transaction management issues in peer-to-peer networks (Dinh et al., 2017) is the decentralized nature of blockchain technology. Public blockchains operate in a completely decentralized environment, enabling earlier unidentified or untrusted nodes to build trust in the transactions. To accomplish the same goal, private blockchains use access control methods within a secure and restricted environment. The choice of nodes made by an owner determines the level of decentralization (Viriyasitavat et al., 2018).

Since each node in the network keeps and manages its own records, transactions entered a Blockchain ledger are regarded as durable. Persistence is preserved persistently if most nodes are benign. This trait yields several features, such as immutability (temper resistance) and transparency. Blockchains are auditable due to their transparency and immutability (Hammerschmidt, 2017).

In contrast to certain distributed systems, blockchains don't need every node to execute an operation. Other nodes in a blockchain system would validate the transactions, or blocks, that were broadcast. Therefore, any falsification might be quickly identified.

Three main roles make up this system: (1) proposers who put out a value; (2) acceptors who determine which value to accept; and (3) learners who accept the value that has been selected (Correia et al., 2011).

Another feature of public blockchains is their anonymity. Users' identities in this system are not linked to their identities outside of it. To prevent identity disclosure, a single user can assume many identities (Yeow et al, 2018). Private information does not need to be maintained by a central organization. Consequently, a certain level of anonymity is preserved because the transaction information indicates that the real-world identity cannot be acquired. However, in environments such as private and permissioned Blockchains, where systems are run and managed by well-known entities, identity is typically necessary (Viriyasitavat et al., 2018).

Karl Wust (2018) claims that the term "blockchain" refers to the system's technological structure, which is a chain of blocks. Every block has a cryptographic hash that connects it to the one before it. A data structure called a block makes it possible to keep a list of transactions. Peers in the blockchain network originate and trade transactions, which change the blockchain's state. As a result, transactions can trade money, but they are not limited to that; for instance, they can also run arbitrary code inside of what are known as smart contracts. Fundamentally, they facilitate the creation of a community by allowing users to enter transactions in a shared ledger inside that community. Once a transaction is published, it cannot be altered by the blockchain network normally (Yaga et al., 2018).

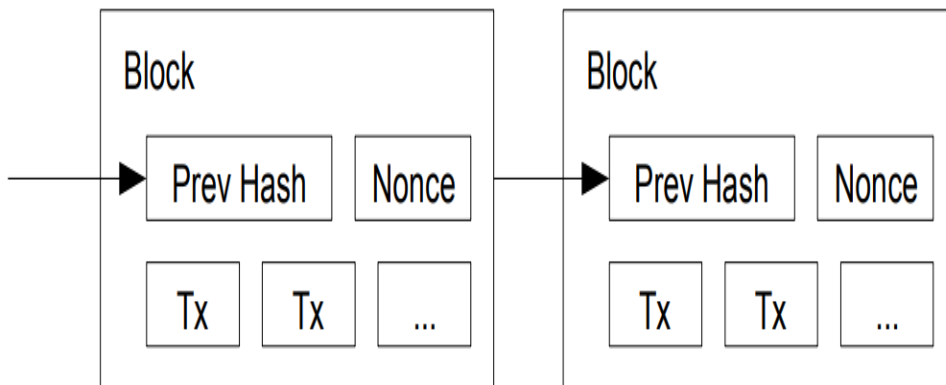


Figure 2.17: Proof-of-Work implementation of Blockchain (Nakamoto, 2008)

Finding a number that, when hashed, like in the case of SHA-256, results in the hash starting with a few zero bits is the proof-of-work. One hash can be used to verify that the average work required is exponential in the number of required zero bits (Nakamoto, 2008). The proof-of-work is implemented by increasing a nonce within the block until a value is discovered that provides the necessary zero bits for the block's hash. Once the CPU effort is used to satisfy the proof-of-work, it is impossible to modify the block without starting over from scratch. Since the block is chained to other blocks, changing it would require reworking every block that comes after it (Nakamoto, 2008). Public and private blockchains are the two different kinds of blockchains. Different consensus algorithms are used in blockchain technology for various goals.

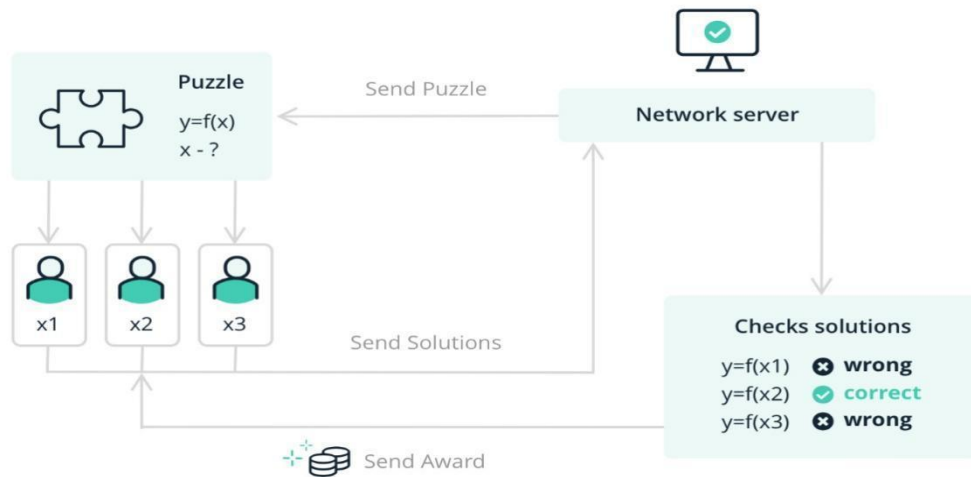


Figure 2.18: Proof-of-Work implementation

The issue of determining representation in majority decision-making is also resolved by the proof-of-work. Anybody with the ability to assign many IP addresses might undermine the majority if it were based on one IP address per vote. In essence, proof-of-work is one CPU, one vote. The longest chain, which has required the most proof-of-work, represents the majority choice. An honest chain will expand faster than any other chain if honest nodes control most of the CPU power. An attacker would need to redo the proof-of-work for the previous block and all subsequent blocks to alter it, and then they would need to catch up with and exceed the honest nodes' effort. Later, we shall demonstrate that when more blocks are added, the likelihood of a slower attacker catching up decreases exponentially (Nakamoto, 2008).

2.3.1 Public Blockchain vs Private Blockchain

Anyone can sign up to use public blockchains (permissionless) as a regular user or miner. Smart contracts allow all participants to carry out transactions or function according to predetermined guidelines (Politou et al., 2019). Bitcoin is the original public blockchain platform. Bitcoin is the first cryptocurrency to use a hash algorithm and blockchain as the

primary infrastructure for untampered storage of transaction data. Since Bitcoin is a public blockchain network and anyone may make a transaction with it, anyone can access it from anywhere in the world. The proof of work consensus protocol in the bitcoin blockchain network allows anyone to become a miner. The regulated network restricts participant participation and data accessibility in private blockchain. An in-depth comparison and explanation of the differences will be provided using Ethereum, an example of a public blockchain, and Hyperledger Fabric, an example of a private blockchain.

Ethereum is a well-liked substitute for Bitcoin that significantly incorporates elements of its architecture. It is a public blockchain with the cryptocurrency Ether integrated into it. By offering a framework for blockchain-based smart contracts—programs that other Ethereum addresses and players can audit and participate in—Ethereum enables decentralized execution of the "world computer." As per Kim et al. (2018), a contract can encode a fair lottery that can be audited by any member of the network. Moreover, Ethereum uses smart contracts to reach agreements and enforce responsibilities through rules and penalties. By building and implementing smart contracts that will be performed in the Ethereum virtual machine (EVM), developers can create a variety of apps on the Ethereum platform. By using smart contracts, regular individuals can send Ether to other people and utilize those applications. To prevent harmful or pointless transactions that deplete Ethereum's resources, users must pay transaction fees (Chen et al., 2020).

Proof-of-stake is currently used by Ethereum (PoS). Some of the consensus techniques that blockchains employ to reach widespread consensus are based on proof-of-stake. Miners use proof-of-work to demonstrate that their capital is at risk by using energy. Ethereum employs a proof-of-stake model in which validators voluntarily stake Ethereum currency (ETH) in a smart contract. The ETH that has been staked then serves as collateral

that can be lost if the validator acts dishonestly or carelessly. The validator is therefore in charge of periodically producing and propagating new blocks itself in addition to verifying that newly propagated blocks via the network are legitimate (Ethereum.org, 2023).



Figure 2.19: Proof-of-Stake implementation

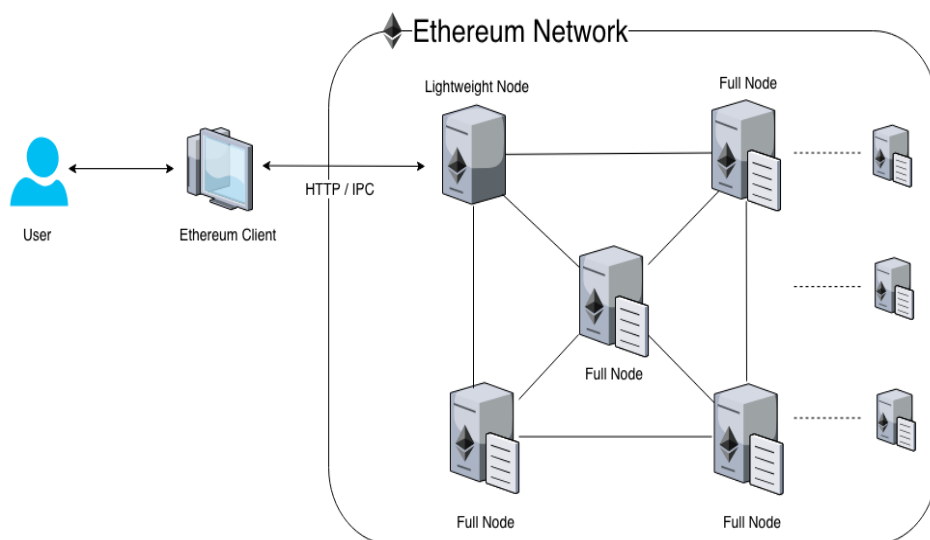


Figure 2.20: Ethereum Architecture

A decentralized peer-to-peer (P2P) network made up of Ethereum clients functioning as network nodes is the Ethereum blockchain network. Any node on the chain that can process new blocks, validate transactions, and carry out smart contracts is considered an Ethereum client. It is an enclave connected by the Ethereum P2P network that lives on thousands of PCs or other Internet-connected devices. The Ethereum virtual

machine, or EVM, and P2P network's operational environment for smart contract execution are enclosed (Ethereum.org, 2023).

Although there are numerous other developing public blockchains, including Ripple, Stellar, and many more, Ethereum stands out from the competition because of its purpose-driven design (Bambrough, 2019). Ethereum functions more like a broad blockchain for a range of uses by enabling the construction of dApps and smart contracts, in addition to establishing cryptocurrencies through initial coin offerings (Hayes, 2019).

Decentralized apps are commonly referred to as trustless or peer-to-peer due to their unique feature of not being controlled by a single server or entity, unlike client-server models. The blockchain is the fundamental component used by a DApp for processing and storing data. To do this, a smart contract is used. The general characteristics of a DApp and a regular application are the same. Therefore, the primary distinction is that the blockchain provides the computation and data. Typically, DApps require smart contracts to function.

The phrase "smart contract" was first used in 1994 by computer scientist and legal scholar Nick Szabo, who defined it as "a computerized transaction protocol that executes the terms of a contract" (Szabo, 1994). Smart contracts are computer programs that operate on the Ethereum network. Like a vending machine, they can enforce some kinds of agreements between parties, but they are not inherently related to legal contracts.

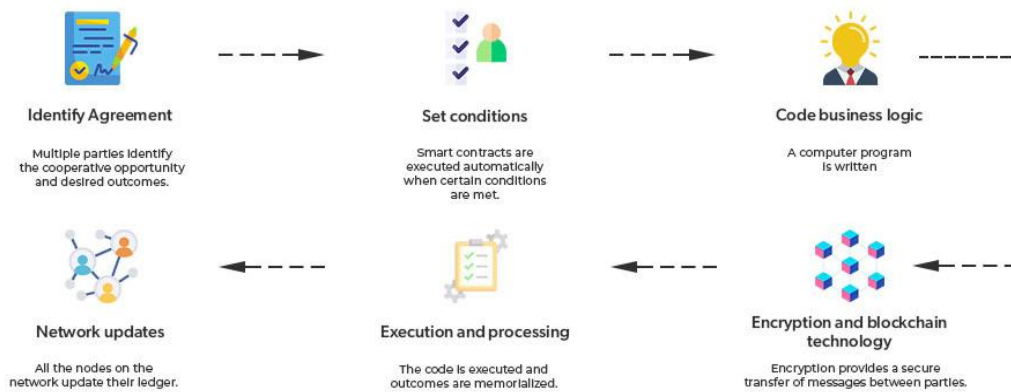


Figure 2.21: Smart Contract Process

Permissioned blockchains are known as private blockchains. Access controls are the foundation of how private blockchains function; they limit who can join the network. The network is controlled by one or more entities, which makes transactional reliance on third parties necessary. Only the parties involved in a transaction will be aware of it on a private blockchain; other parties will not have access to it (Kumar, 2018).

A cooperative endeavour, the Hyperledger Project aims to develop an open-source, enterprise-class distributed ledger system and code base. By developing and implementing an open, industry-wide standard platform for distributed ledgers, it seeks to promote blockchain technology and potentially revolutionize the global commercial transaction landscape. As of early 2016, the Hyperledger Project—which was founded as a Linux Foundation project—has over 50 members (Cachin, 2016). Using well-known and tested technologies, Hyperledger Fabric is a distributed ledger platform that enables pluggable implementations of different functionalities. Its modular architecture facilitates this. Peers manage the distributed ledger protocol of the fabric. The fabric makes a distinction between two categories of peers: A node on the network that manages consensus, verifies transactions, and keeps the ledger up to date is known as a validating peer. A non-validating peer, on the other hand, is a node that serves as a middleman between clients

(issue transactions) and validating peers. While it may validate transactions, a non-validating peer does not carry out transaction execution (Cachin, 2016).

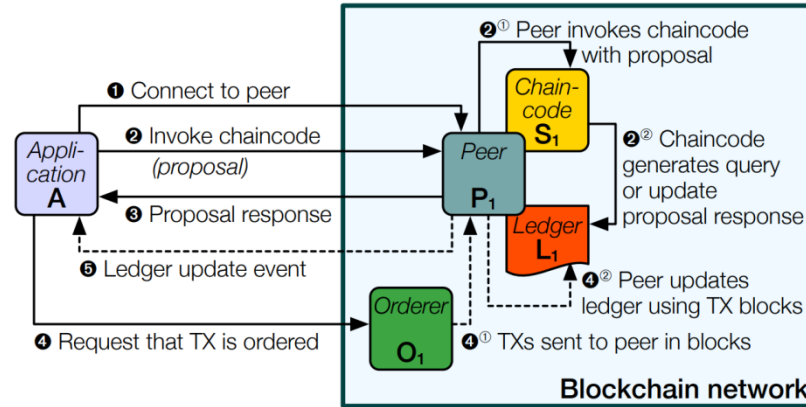


Figure 2.22: Hyperledger Fabric Architecture

According to Cachin (2016), there are three different sorts of transactions are accepted as operations by the replicated state machine that is executed by the validating peers using a BFT consensus protocol:

- **Deploy transaction:** Accepts an argument that is a Go chaincode (a smart contract representation); the chaincode is installed on peers and prepared for execution.
- **Call transaction:** Calls a specific chaincode that was previously installed using a deploy transaction; the parameters are unique to the call type; the chaincode runs the call, may read and write entries in its state in accordance with the call, and reports success or failure.
- **Query transaction:** Provides an entry of the state straight out of the persistent state read from the peer; this might not guarantee linearizability.

Table 2.1: Ethereum vs Hyperledger Fabric (Richardson, 2017)

Characteristics	Ethereum	Hyperledger Fabric
Founded Date	July 2015	July 2017
Currency	Ether	None
Governance	Ethereum Developers, Enterprise Ethereum Alliance	Linux Foundation, IBM
Consensus	PoW (Proof of Work)	PBFT (Practical Byzantine Fault Tolerance)
Network	Permissionless, Public	Permissioned, Private

The intended user base and design of Ethereum and Hyperledger are where they diverge most from one another. With its EVM, Ethereum can run programs with any level of sophistication and make them publicly available to everybody, even without authorization. This blockchain is intended for applications that are dispersed. However, the modular architecture of the Hyperledger fabric guarantees flexibility and scalability in a permissioned mode of operation (Sajana et al., 2018).

2.3.2 Consensus Algorithms

In the blockchain, a consensus process is essential to the creation and validation of transactions. Consensus algorithms can be classified as either private or public blockchain networks (Khan et al., 2019). Given that mining is necessary, one of the primary determinants of the consensus mechanism for a public blockchain is cryptocurrency. Conversely, consensus on a private blockchain takes a more measured approach when it comes to involving nodes in transaction validation.

2.3.2.1 Public Blockchain Consensus

PoW is used by two well-known cryptocurrencies, Ethereum and Bitcoin, to reach an agreement on the construction of new blocks. PoW's fundamental concept is to have all participants compete to solve a CPU-bound puzzle. The first person to finish the puzzle

gets to make the next block, which is then confirmed by all other participants (Zhao et al., 2019). Typically, public blockchains have their own cryptocurrency, like ether and bitcoin. A miner who solves a challenging computational puzzle and creates a new block in the blockchain network will be rewarded with this cryptocurrency. PoW is being criticized, nevertheless, as Kumar (2018) noted that because of the computationally demanding technique, it uses a lot of energy. On the other hand, PoW is not long-term viable because of its high transaction validation delay and significant electricity consumption for concentrated mining power.

Since Proof of Stake (PoS) is a different consensus technique that has been suggested by Ethereum and Bitcoin, it is a key concern for these two platforms. This algorithm refers to the miners who are no longer active in creating new blocks as "validators." Instead of mining the blockchain, they validate the transactions to receive a transaction fee; mining is not necessary because the creator of a new block is selected at random based on the wealth of the validator, which is also known as "stake" (Kumar, 2018). But there's another issue with this algorithm, which is called "Nothing at Stake."

Despite the diversity of PoS protocols, validators are motivated to work on multiple forks since creating a block in PoS is equivalent to creating a single signature. Put another way, with nothing at risk, validators could produce conflicting blocks on any conceivable fork to optimize the advantages. This issue is frequently called the "Nothing at stake attack." This attack lowers the system's efficiency by slowing down the network's consensus time. Additionally, it leads to blockchain splits, which impair the blockchain's defense against threats like double spending (Li et al., 2017).

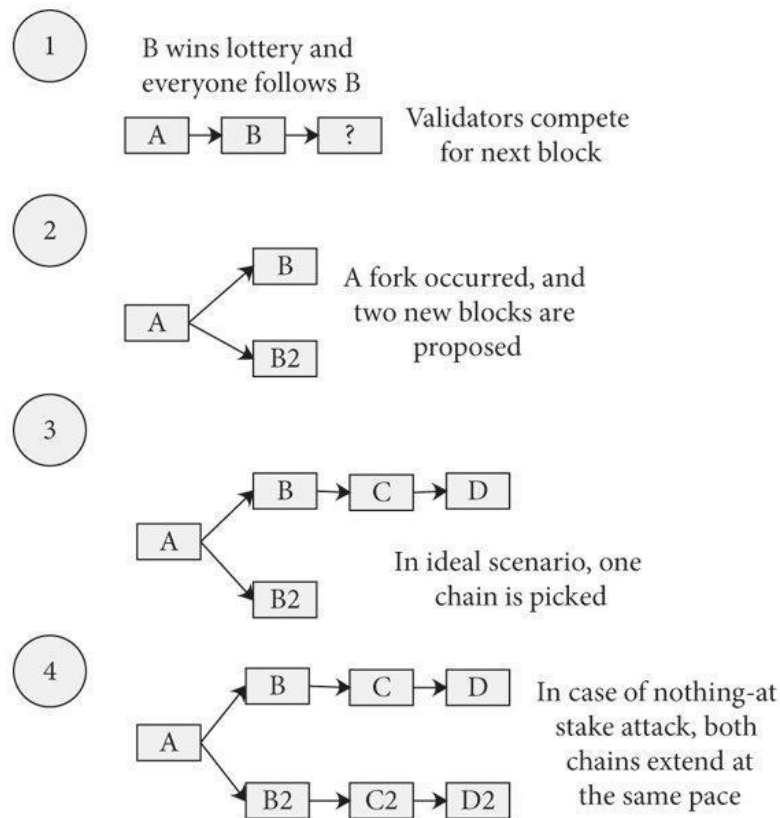


Figure 2.23: Nothing-at-Stake problem in Proof-of-Stake consensus

2.3.2.2 Private Blockchain Consensus

With private blockchains, voting consensus algorithms are preferred because the nodes are known. This is the main difference between proof-based consensus computations, in which nodes are routinely permitted to join and leave the system for testing, and this. When using vote-based consensus, the network must exchange the results before the block can be added to the blockchain. Voting consensus comes in two flavors: crash fault tolerance (CFT) and byzantine fault tolerance (BFT).

Conversely, many consensus algorithms derive from Crash Fault Tolerant (CFT) and Byzantine Fault Tolerant (BFT), which are distinct yet comparable. CFT, in the words of Jain (2018), is defined as a system that can tolerate hardware or software malfunctions in its component parts. Two examples of CFT that are used as consensus algorithms in the

Hyperledger Fabric platform are Kafka and Solo. As orderers in a blockchain network, Kafka and SOLO decide which transactions to add to the blockchain and in what order. Because SOLO is a CFT-based solution, transactions can still occur even when part of the blockchain's nodes are unavailable. There are two types of BFT instances: Simplified Byzantine Fault Tolerant (SBFT) and Practical Byzantine Fault Tolerant (PBFT), both of which are explained in further detail below.

The first premise of the Practical Byzantine Fault Tolerant (PBFT) in a blockchain network is that there would be independent node failures and altered messages spread by independent nodes (Coyler, 2015). Every node in the PBFT is arranged in a sequential order, with the primary node (leader) being the first and the other nodes being referred to as backup nodes. For the PBFT model to function, it is assumed that the total number of nodes in the system cannot be greater than or equal to $\frac{1}{3}$ of the number of malicious nodes in the network at the same time (Coyler, 2015). If there are no more than $(n-1)/3$ malicious or defective nodes, where n is the total number of nodes, PBFT operates efficiently and safely (Coyler, 2015). Coyler (2015) PBFT consensus (called views) comes down to 4 phases as below:

1. A client sends a request to the leader node to invoke a service operation.
2. The leader node multicasts the request to the backup nodes.
3. The nodes execute the request and then send a reply to the client.
4. The client awaits $f + 1$ (f represents the maximum number of nodes that may be faulty) replies from different nodes with the same result. This result is the result of the operation.

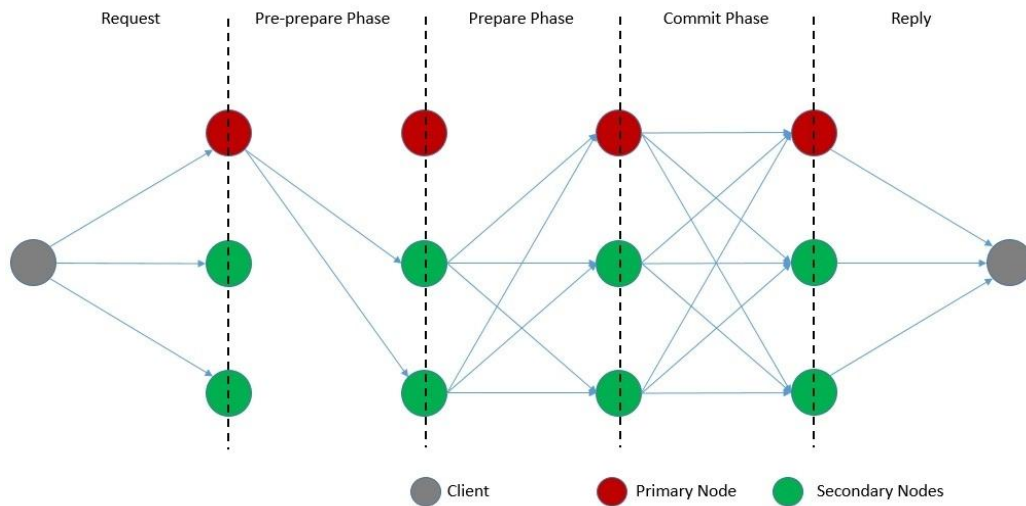


Figure 2.24: The Practical Byzantine Fault Tolerant consensus

For permissioned network blockchains, the Simplified Byzantine Fault Tolerant (SBFT) consensus algorithm is an improvement on the PoW algorithm. A validator who combines suggested transactions into a new block is a part of SBFT. Because the ledger is permissioned, consensus is reached when a minimal number of other nodes in the network ratify a new block, unlike the Bitcoin blockchain where the validator is a known party (Randall, 2018). In a system with $3f+1$ nodes, the number of nodes that must come to a consensus to be tolerant of a Byzantine fault is $2f+1$, where f is the total number of faults in the system. For instance, if the system consists of seven nodes, then two of those nodes must act improperly for the other five nodes in the system to agree (Randall, 2018).

A consensus mechanism called Proof-of-Authority (PoA) can be applied to blockchains in permissioned networks. It makes use of a group of nodes called "authorities," or chosen nodes with the ability to safeguard the ledger and add new blocks. In PoA ledgers, the approval of most of the authority is necessary before a block may be generated (Randall, 2018).

One of the private blockchain consensus algorithms is the Torneo consensus algorithm. A node sends a request to every other node in the network asking permission to

join the blockchain. The node will receive the blockchain, the ability to create transactions, and the ability to attempt adding new blocks if it is verified as approved. A request is sent to each connected node every 15 seconds (this period can be adjusted) asking them to select a random integer between 0 and 1. Each node will broadcast this number and then watch for each subsequent random number to arrive. Once each random number has been received by a node, it chooses the largest one and forwards it as a "winner vote" to the node that originally picked it. A node is declared the winner and granted permission to add the subsequent block when it has amassed the same number of "winner votes" as the total number of linked nodes. After that, the node must mine the block using a consensus technique similar to a proof of work, but with very little effort, making it possible for a regular computer to find the nonce value in less than a second. Time loss and energy waste are prevented in this way (Lucas et al., 2019).

Finding the consensus algorithm that works best for the problem must be confirmed. Certain agreements are reached for distinct uses. For example, compared to PoW and PoS, CFT, BFT, and PoA may be better to use in the solution because they don't require mining, which uses a lot of processing power and isn't required for supply chain transactions when a new block is created.

2.3.3 Hyperledger

The Hyperledger Fabric is a permissioned blockchain implementation designed to serve as a framework for creating modular blockchain solutions or applications. Hyperledger Fabric enables plug-and-play functionality for components like membership services and consensus (Hao et al., 2018). As a project of the Linux Foundation, Hyperledger was launched in 2016 and now has over 50 active members.

A distributed ledger platform application is called Hyperledger Fabric. Its pluggable implementation is made possible by its modular architecture, which is utilized to run smart contracts. Peers manage the distributed ledger Hyperledger Fabric protocol (Hyperledger, 2018). NEM, R3 Corda, Ripple and other private blockchain frameworks are available other than Hyperledger Fabric. For proof of concept, Sawtooth and Fabric are preferable in this study as both blockchain frameworks are under the same Hyperledger community. Each framework has some differences but shares some similarities.

Hyperledger (2018) states that it is an open-source cooperative project aimed at advancing blockchain technology that spans multiple industries. Leading figures in banking, supply chains, technology, supply chains, finance, and the Internet of Things are involved in this global partnership, which is being facilitated by The Linux Foundation. As of now, Hyperledger encompasses 5 blockchain frameworks: Fabric, Sawtooth, Iroha, Indy, and Burrow (Hyperledger, 2018). Every one of these frameworks has distinct characteristics of its own and was created at a different period.

Table 2.2: Differences of Hyperledger framework

Framework	Contributor	Domain	Consensus Algorithm	Development environment
Fabric	IBM	Smart contracts	BFT	Java, JavaScript
Sawtooth	Intel	Tokenize logistics and sales chain	PoET	Any language
Burrow	Monax	Smart contracts	PoET	Solidity
Iroha	Soramitsu	Mobile applications	YAC	C++
Indy	Sovrin	Digital identities	RBFT	Python, Java, C#, node.js

2.3.4 Truffle and Ganache

In the exploration of frameworks that can be used, Truffle offers an Ethereum programming environment, a testing framework, and an asset pipeline for testing during the framework exploration process. With built-in smart contract compilation, linking, deployment, and binary management, truffle simplifies Ethereum development.

Ganache is used to work with the Truffle framework because it offers a private Ethereum blockchain environment where smart contracts may be interacted with. To accelerate the development of Ethereum apps, Ganache was designed to mimic the Ethereum public blockchain. Blockchain log output, sophisticated mining control, an integrated block explorer, an Ethereum blockchain environment, and desktop applications are all offered by Ganache.

Ganache can be integrated with smart contracts. This provides a smooth development process for developing Ethereum applications. Creating any decentralized applications made easier with the implementation of Truffle and Ganache which will save cost and time. Testnet coins are used for testing purposes while developing the decentralized application. Testnet is a special type of cryptocurrency used for testing purposes without using real money due to the price of respective cryptocurrency.

Depending on the preferences, decentralized applications typically feature a front end made up of HTML, CSS, Bootstrap, and other elements. Web3.js will be used on the front end of the decentralized application to communicate via HTTP, IPC, or WebSocket with a nearby or distant Ethereum node. In addition, Metamask serves as an Ethereum-based wallet that lets users exchange, buy, sell, store, and convert cryptocurrency tokens.

Table 2.3: Decentralized Application Components

Blockchain	Ganache
Front End Design	HTML, CSS, Bootstrap
Browser tools	Metamask, Mozilla Firefox or Google Chrome
Web Interface	Web3.js
Framework	Truffle

2.4 Related Works of Blockchain on Real World Scenario

Although blockchain technology is gaining a lot of hype, it is still not a hot trending field of research. Relevant research has been extracted for the support for this study. From recent literature, there are wide range approaches on applying blockchain technology on retail, all of it can be categorized in three categories.

The first category is more about exploring the potential of blockchain and finding out whether it can be applied in the retail domain. Studies like this mostly emphasize the requirement gathering and analysis and feasibility study. The second type of research is carried out on top of the first category of research and then formulates a theoretical framework but without much technical implementation. The third category of research is carried out on top of first and second category research then implements the framework or solution, regardless of the type of blockchain that will be applied. The third category of research's findings are mostly only about the implementation of blockchain, but without any validation on the outcome of the research.

2.4.1 Computing A Blockchain Implementation Prototype for the Electronic Open-Source Traceability of Wood along the Whole Supply Chain

With the use of automated identification systems that provide a connection between the product and a database of the product and the procedures it goes through, it is now

feasible to follow the entire product supply chain in both industries and agriculture (Tzoulis et al., 2013). A method of maintaining documentation that shows the path taken by an input from suppliers to customers is known as an info tracing system (Costa et al., 2013). The ability to track a product forward and backward at any point in the supply chain is typically the foundation of a traceability system, which ultimately enables the prompt and efficient implementation of corrective actions where and when they are required. The capacity to trace products is crucial for all firms, including importers and retailers (Figorilli et al., 2018).

The inefficient use of resources is typically a recurring issue in many supply chains, which can be resolved by using automated and electronic real-time traceability systems for the full working flow (Pizzi et al., 2006). All nations that produce timber are required by laws and regulations to mark the ends of all legally harvested logs with particular markings. The authorization method for cutting trees is based on the forest technician's primary technical and administrative responsibility, which is to identify and mark trees that are eligible for felling. The timber marking is an identification system consisting of pressed numbers and characters on the wood surface. Beginning at this stage, the use of Radio Frequency IDentification (RFID) technology may prove to be a useful instrument for potentially streamlining this process in terms of time, materials, and expenses throughout the whole supply chain, from the point at which the timber is marked until the wood product's eventual traceability to its destination. RFID technology, being electronic, closes some information gaps, particularly in logistics, allowing supply chains to be seen in real time (Angeles, 2005). Production logistics procedures typically take up to 95% of the time needed to complete a production process, which has a big impact on how efficiently a product is produced overall (Qu et al., 2016). RFID technology connects real-world objects to their virtual counterparts, allowing for automatic traceability. A temporal data model

must be used by this traceability system to facilitate raw material tracking and process monitoring. In 2015, Picchi et al. assessed how well two tag models, and two fixing solutions performed in steep terrain during cable yarding and logistical operations across the timber supply chain. Even with partial log tagging, which permits some degree of load tracing, an economic benefit can be realized throughout the supply chain (Bjork et al., 2011). In a 2010 study, Kaul evaluated the effectiveness of various RFID tag models for both single item identification and bulk reading (such as a truckload of tagged logs).



Figure 2.25: Wood infotracing using supply chain

Phases of wood information tracing and related multiple actors, multiple tags, and multiple devices: The first RFID (RFID₁) was applied above the cut in the timber marking phase, and its tag association with database information was accomplished; additional RFID (RFID_n) tags (one for each derived log; the same used for the Timber marking phase) were applied on the cutting portion for each log (excluding branches and pieces of lesser quality); the RFID_n as read in the stacking phase to check flows and orient the production; the RFID_n was read during the logs transport in the transport phase; each log was recognized by an antenna in the sawmill processing phase, and the RFID_n information

was associated with the database. To improve and certify the timber and its origin, the highest-quality pieces were marked with QR code stickers in this step. The tags were then applied to the finished goods during the production and selling phases, and finally, they were applied to the consumers (Figorilli et al., 2018).

The Azure Blockchain Workbench (Microsoft Corporation, Redmond, WA, USA) with a cloud deployment was utilized to easily leverage blockchain technology. The Azure Blockchain Workbench is a set of Azure services and tools intended to facilitate the development and implementation of blockchain applications for the purpose of exchanging data and business operations with other entities. Developers may concentrate on developing business logic and smart contracts by using Azure Blockchain Workbench, which offers the technical scaffolding needed to construct blockchain applications. Additionally, it streamlines the development of blockchain applications by combining several Azure features and services to assist in the automation of routine development operations (Figorilli et al., 2018).

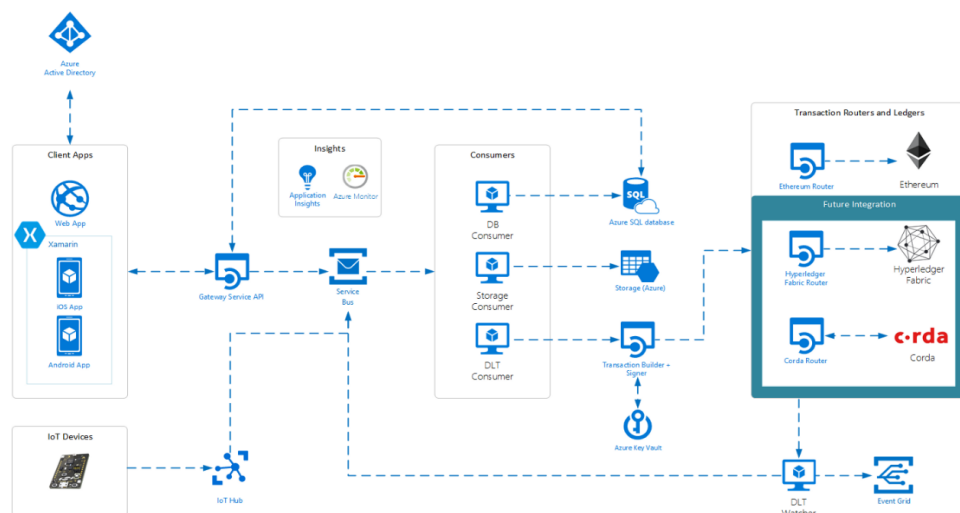


Figure 2.26: Azure Blockchain Workbench Overview

The current software design has been adjusted to communicate with the blockchain architecture. The modifications included adding a data manipulation software layer to the

supply chain database's synchronization section to make it compatible with the relevant blockchain contract. To interface with the Azure blockchain workbench, a connection section to the Gateway service Application Programming Interface has been included in addition to the data manipulation. Prior to the permanent validation and storage on the blockchain, parallel procedures of information consolidation and coherence can be implemented using the "security policy" aspect. The associated contracts (wood marking and cutting) were generated with the contract status management in reference to the information that was controlled via the app.

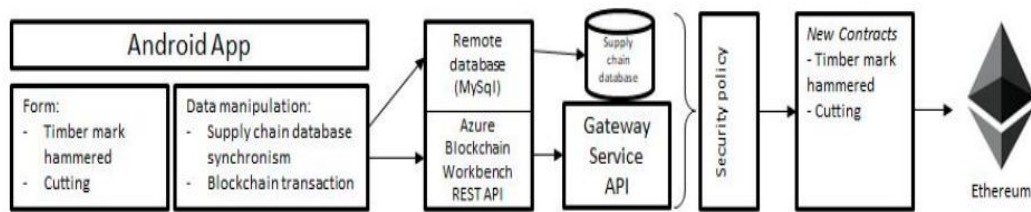


Figure 2.27: Interconnection diagram between the app developed and the blockchain.

To support field operations from timber marking to cutting, an app called SmartTree has been developed. This app gives users an easy-to-use smartphone tool for wood traceability data collection. The data that is entered into the application is kept in an internal database and then synchronized with a distant server. Additionally, the app gathers data via the smartphone's internal technologies, such as Bluetooth and GPS. The location of the tree was determined using the GPS receiver. Bluetooth was used to establish a link between the smartphone and the external, bespoke portable RFID reader. The synchronization on the remote server requires internet connectivity, which may be obtained during field operations (if the internet connection is available) or after field operations, after the internet signal becomes available. According to Fiorilli et al. (2018), the app was designed to function either during the cutting and remote synchronization phase or the timber marking phase.

2.4.2 Blockchain-enabled Logistics Finance Execution Platform

Global e-commerce is expanding at an exponential rate, revolutionizing our way of life and how we purchase in the last few years. E-commerce's explosive rise has also made a significant contribution to economic expansion, particularly in China. By the middle of 2017, Chinese e-commerce transactions had reached 13.35 trillion RMB, up 27.1% over the previous year, according to data from the China e-Business Research Center. E-commerce is quickly becoming one of the most significant retail channels and has accelerated the revolution in the retail sector. More opportunities as well as obstacles have arisen, particularly for small and medium-sized businesses (SMEs). On the one hand, SMEs may quickly and inexpensively create their retail channels on e-commerce platforms because of the benefits of e-commerce. However, in the age of e-commerce, distributors are also dealing with hitherto unseen challenges (Li et al., 2019).

But because bank funding is so tight, SMEs are having trouble managing their retail operations due to a lack of capital. Additionally, SMEs must accept unfavorable terms like advance payment or risk having their goods delayed while being free from liability, which increases company risk. Logistics financing (LF), a fusion of finance and logistics, has arisen to support SMEs. The blockchain-enabled LF execution platform (BcLFEP) has been suggested to enhance LF services (Li et al., 2019).

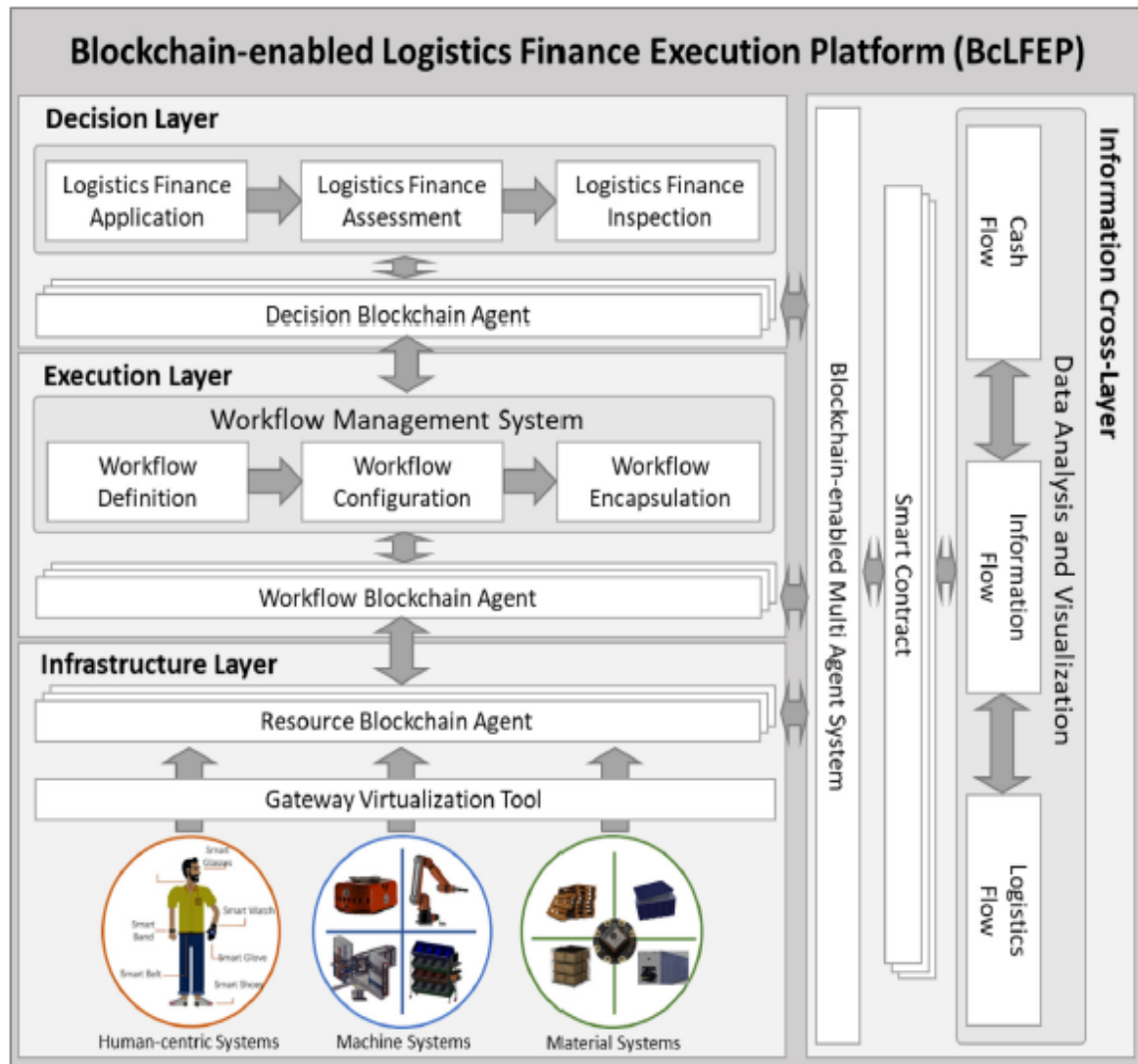


Figure 2.28: Conceptual framework of BcLFEP (Li et al., 2019)

The Decision Layer, Execution Layer, Infrastructure Layer, and Information Cross-Layer are the four layers shown in Figure 2.28. Layer of Decision Making Provide decision-making tiers for protection and important decision-making contacts. Together with the LF process, these decisions can be broken down into three phases. LF application, which includes all choices pertaining to LF preparation and application research, is the initial step. At this point, the retailer's fundamental data—such as its credit, financial, and company status—will be gathered. The second step is called LF evaluation, and it includes things like payback plans, LF approval, and the selection and supervision of pledges. The

LF agreement also needs to fulfill certain requirements (such making a promise or paying a deposit). LF inspection, which monitors particular implementation, is the third level. For instance, there is typically little processing time and frequent participatory decision-making amongst several stakeholders in pledge management and payback. Next, create a decision-making blockchain agent (DBA) to facilitate decision-making processes. Changes in these judgments should be given more consideration because they are typically recorded as digital data. As a result, the DBA is also in charge of guarding against unauthorized changes and ensuring the validity of decisions.

The business logic involved in LF is executed by the execution layer. The primary source of the business logic is the abstraction of the LF operation's operational processes, which include techniques for managing events, particular logistics tasks, and financing procedures (Li et al., 2019). Business logic has been developed with workflow. Workflow management is typically broken down into three primary phases. The process of transferring business logic to a workflow and encapsulating it in the Workflow Blockchain Agent (WfBA) begins with the workflow definition stage. The criteria, guidelines, and resources pertaining to the setup of the workflow execution comprise the second step, which is known as workflow configuration. WfBA will be called upon to carry out particular business logic during the third step. The complete lifecycle management of business logic is preserved, and execution is safeguarded in a secure and impenetrable way (Li et al., 2019).

Building an intelligent resource architecture that can give LF real-time visibility and traceability requires the infrastructure layer. The physical system, the gateway virtualization tool, and the resource blockchain agent (RBA) make up its three components. The physical system oversees gathering data from LF operations in real-time. Three forms of data—machine, material, and human-centred data — generally receive

more attention. Previous studies have shown that the heterogeneity of physical systems can be resolved by using gateway virtualization techniques to create a unified infrastructure framework. As a result, it makes it possible for every participant to deploy these systems using Universal Plug and Play (UPnP) for data collecting. A physical system's digital doppelganger is called an RBA. It is packaged as a software entity and inherits all of the characteristics and functionalities of the physical system. Three primary functions are often enabled by the infrastructure layer. It first aids in the deployment and integration of the required UPnP systems. Additionally, it creates a single, unified design to enable "infrastructure as a service," allowing diverse parties to call necessary information from different infrastructures using the same service architecture. Furthermore, at the resource level, it ensures a dispersed, secure service sharing environment among participants (Li et al., 2019).

Integrating all pertinent data from the other three layers is the responsibility of the information cross-layer. It's divided into three sections. Blockchain technology and multi-agent systems are integrated in BcMAS, a peer-to-peer communication network. It makes three things possible. To execute smart contracts, it first creates a decentralized execution environment for different blockchain agents. Second, it contains the blockchain agent's block and hash data while the smart contract is executing. Third, it confirms the enclosed block's insertion to the blockchain by using a particular consensus process to verify it. This layer's fundamental component is smart contracts. It oversees all LF operations and is linked to three blockchain agents for deployment. In addition, it offers a number of APIs for implementing particular data operations while keeping the specifics of the blockchain network hidden. We take three key data streams out of the LF blockchain network. Information flow, which combines the other two categories, is the most crucial factor. This accurately captures the way business is done in LF. The capital flow across LF is

characterized by cash flow. Typically, two components of money flow receive more attention. The opinions of stakeholders, particularly the capital flows of retailers, are the subject of one dimension. Another feature is that it can monitor and audit how loans are used from the standpoint of initial funding. The movement of tangible products between stakeholders is described by the logistics process. To give real-time digital visibility and traceability to the actual logistics process, it can be pulled from the blockchain network (Li et al., 2019).

There are three ways to expand on this research. First off, the primary purpose of the blockchain agents that are in use now is to fulfil LF requirements in retail e-commerce. More blockchain agents ought to be created with needs in mind for various LF or even SCF circumstances (Li et al., 2019). Additionally, smart contract security is a common worry for blockchain-based solutions, particularly for initial coin offerings (ICOs). Although the focus of this study is on assessing the viability and efficacy of the proposed BcLFEP, further research needs to be done on any potential security concerns before large-scale implementations. Lastly, to better identify and control risks during LF execution for SMEs, specific risk prevention methods could be developed based on tamper-proof data in blockchain (Li et al., 2019).

2.4.3 Blockchain-Driven Supply Chain Finance Application for Auto Retail Industry

Introduced in China as a dependable and effective financing platform for the retail vehicle industry, BCautoSCF is a blockchain-driven platform for supply chain finance. Participants in the supply chain (SC) network collaborate widely and transparently to operate dependable, practical, and traceable enterprises because of the trust mechanism incorporated into the blockchain. In a similar vein, traditional supply chain finance (SCF) can benefit from smart contracts in BCautoSCF, which partially automate SCF operations and reduce human mistake and interference. The viability of BCautoSCF in SCF is demonstrated by this open and secure function.

The ability of SCF solutions to establish a trustworthy custody mechanism on multilateral trades and the willingness (i.e., trust) of the relevant parties to participate in the complex trades where consortiums are assembled are the two main requirements for their adoption, according to Chen et al. (2020). Fast and dependable funding from the trust mechanism mediated by BCT may produce more stable SCF ecosystems. An integrated SCF platform was built for the automotive retail industry with the use of BCT and the utilization of other technologies such as cloud computing and the Internet of Things. Numerous services are offered by the platform, such as purchase order management, funding and credit service management, logistics and warehousing management, and platform administration. It provides buy order financing and inventory financing in close collaboration with financial institutions. By integrating the data and business flows of its clients' upstream and downstream operations, BCautoSCF not only has the market penetration and logistical skills but also assists clients in identifying new growth opportunities and reducing overall trade costs in SC operations. To a certain degree, BCautoSCF acts as the SC operations' orchestrator and coordinator (Chen et al., 2019).

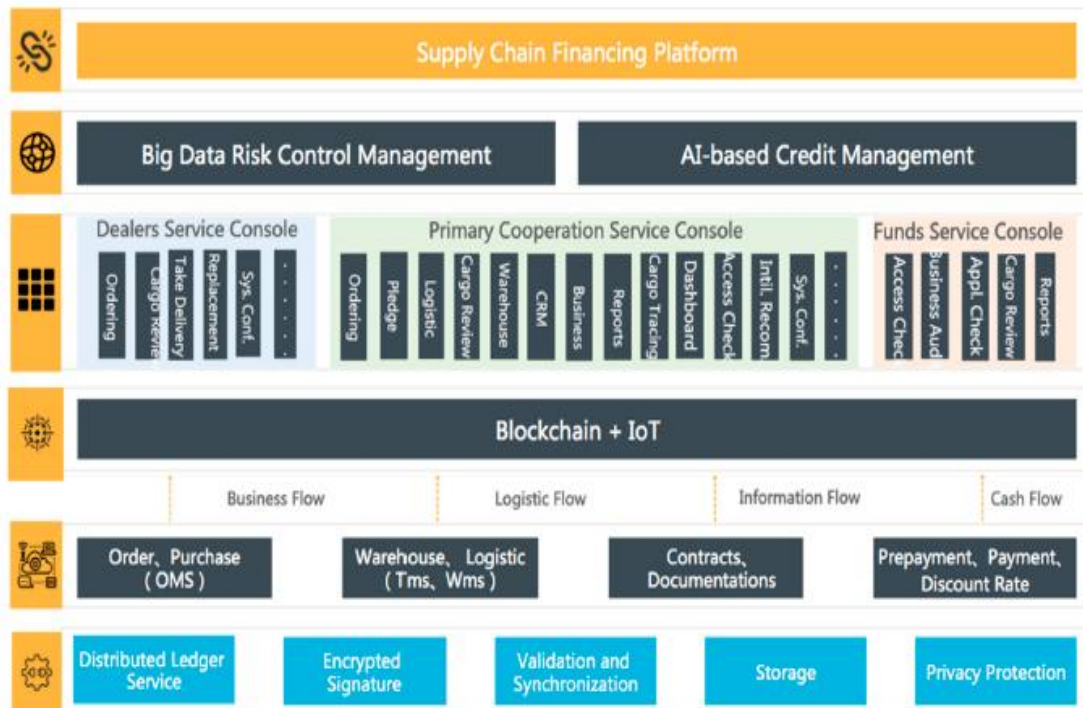


Figure 2.29: The functionality of the BCautoSCF platform (Chen et al., 2019)

The Internet of Things (IoT) and BCT work together to promote BCautoSCF. IoT is used as a tool for data collection and circulation, while BCT makes sure that the information released and exchanged is trustworthy and trustworthy in transactions (Yang, 2019). It runs software as a service (SaaS) and is built on commercial BCT implementation infrastructure (e.g., Xuper, <https://xuper.baidu.com>, PBFT as a consensus method), produced by several programming technology stacks (e.g., Java, Python, C++, etc.). The first item in the functional hierarchy is the basic protocol, as seen in Figure 2. It serves as the foundation for several trust-related systems, including as distributed ledgers, privacy security, block link storage, encryption signature, and verification/synchronization. (2) Preserve data. It combines data from multiple sources, including ordering and purchasing, warehousing and logistics, contracts and papers, and prepayment and bills, to create a time-stamped data stream. (3) The infrastructure. The platform serves as the fundamental physical and virtual structure upon which other building blocks such as blockchain

implementation, the Internet of Things, BDS, GPS, radio frequency identification, and image recognition are built. (4) Management of businesses. It uses a variety of business management and visualization modules, such as a car monitoring system that typically has Internet of Things gear attached to make sure the collateral is maintained up to date. Reliable logistics services are offered via warehouse management systems and transportation management systems. 5. Integration with third parties. It establishes connections with outside services (like Ant Credit) to manage risk. (6) Interface for users. Using network technology, it puts the user interface into practice (Yang, 2019).

2.4.4 Intellectual Property Protection of 3D Print Supply Chain

Plagiarism and 3D printing are closely related topics now. The Spectaris Industry Association cautions that the use of 3D printing in the medical technology industry will significantly raise the danger of plagiarism. Technical attorneys have also issued warnings regarding the possibility of 3D printing fraud. The likelihood of theft will rise significantly once more if copying technology continues to become more affordable.

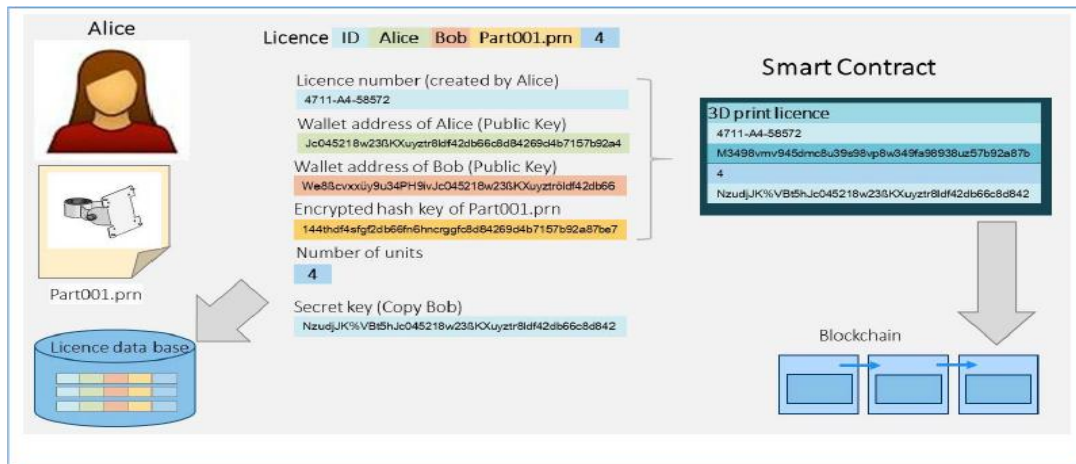


Figure 2.30: License information pictured by means of Blockchain Technology (Holland et al., 2018)

Both visible and invisible labelling techniques may be used in additive manufacturing procedures. They could be applied during rework or during the production process. Two fundamental concepts can be identified in product labelling: first, providing information about the product's producer or place of origin; and second, taking steps to ensure each product's unique identity and, consequently, its traceability (Stjepandi et al., 2015).

There is a chance when data is encoded and licensed using blockchain technology. Blockchain technology is used to identify print templates, encode pertinent data, and grant printing authority. The financial world has been the primary source of this knowledge thus far. This encryption tool is employed to demonstrate the legitimacy of financial transactions involving digital payments. One blockchain application is the cryptocurrency known as Bitcoin. But in terms of franchising, blockchain technology is essentially useful for transactional applications. Instead of printing Bitcoin, you can print a specific quantity of components with this license.

Alice gives Bob permission to print four copies of a specific product in a Blockchain, as seen in Figure 2.30. The license data is stored in the Blockchain and

protected so that only Alice and Bob can access it thanks to a smart contract. Later, before printing anything, Bob's printer checks the license. Furthermore, the Blockchain can record the serial numbers of the individually printed components to demonstrate that the type and amount were printed in compliance with the license requirements (Holland, 2016).

2.4.5 Using blockchain to signal quality in the food supply chain: The impact on consumer purchase intentions and the moderating effect of brand familiarity

Food security is considered important as fraud cases regarding image theft to produce low quality food that mimics the original product is increasing. This will lead to false information and malnutrition since the food produced by faking the original product consists of ambiguous ingredients and information on the label. To solve this problem, blockchain labels were used to provide reassurance towards customers that are purchasing the food products.

Retailers need to be very explicit about what they're doing to build consumer trust in the quality of their products. Labelling is a very helpful way to indicate the quality of a product. According to Sigurdsson et al. (2022), the quality signalling effect explains why a sustainability label is the third most significant factor in product choice, according to recent study. The study's objectives were to investigate the relationship between perceived product quality and traceability's effects on purchase intention, as well as the direct impact of traceability labelling on intention to buy (H1). We employed a one-factor between-subjects design in this study, and the altered variable was traceability labelling. As the control group, we used a no-label condition, and as the experimental group, we used a blockchain-based traceability label. The brand was presented in the no-label state without being altered or changed from its initial look. A fake label with the words "Blockchain Tracking" and "Source verified" was made for the blockchain-based traceability labelling condition (Treiblmaier et al., 2022).

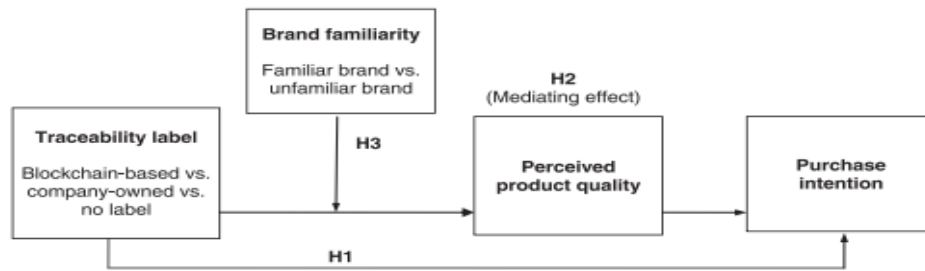


Figure 2.31: Theoretical model and hypotheses. (Treiblmaier et al., 2022)

In the online poll, every product was shown for precisely 15 seconds to make sure that each participant gave the stimuli similar attention. Three experimental groups were randomly assigned to the responders. A total of 151 people (39% female, 58% male, 1% transgender, 2% choose not to say), with a mean age of 27, the greatest level of education (61% university degree, 38% high school, 1% apprenticeship), met the requirements for the final analysis (Treiblmaier et al., 2022).

We questioned respondents about whether the goods they had just seen had a label to gauge how successful the manipulation had been. The results of the Chi-Square test indicated that there was a significant correlation ($\chi^2(2, N = 151) = 74.42, p < 0.01$) between the two experimental groups and label recognition. ANOVA verified that the presence of a traceability label elevates the intention to buy ($F(1149) = 12.58, p < 0.01$). Compared to the control condition (MNoLabel=3.38, SD=1.80), the blockchain-based traceability label (MBCLabel=4.41, SD=1.76) boosted purchase intention (see Fig. 3). These findings support H1. According to hypothesis H2, the impact of traceability labeling on purchase intention is mediated by perceived product quality. Using 10,000 bootstrapping samples, PROCESS model 4 was estimated, and the experimental condition was used as the independent variable to test this hypothesis (Hayes, 2018). According to the coefficients, there is an increase in the mediator and dependent variable for the blockchain-based traceability label when compared to the no-label condition. This is

because the dichotomous independent variable employed the control condition as a reference category (Treiblmaier et al., 2022).

Table 2.4: Summary of Research

Paper Title	A Blockchain Implementation Prototype for the Electronic Open-Source Traceability of Wood along the Whole Supply Chain	Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail	A Blockchain-Driven Supply Chain Finance Application for Auto Retail Industry	Using blockchain to signal quality in the food supply chain: The impact on consumer purchase intentions and the moderating effect of brand familiarity
Year	2018	2019	2019	2022
Author	Simone Figorilli, Francesca Antonucci, Corrado Costa, Federico Pallottino, Luciano Raso, Marco Castiglione, Edoardo Pinci, Davide Del Vecchio, Giacomo Colle, Andrea Rosario Proto, Giulio Sperandio and Paolo Menesatti	Ming Lia, Saijun Shaoc, Qiwen Yed, Gangyan Xue, and George Q. Huangg	Jingjing Chen, Tiefeng Cai, Wenxiu He, Lei Chen, Gang Zhao, Weiwen Zou and Lingling Guo	Horst Treiblmaier, Marion Garaus
Problem	Timber supply chain issue	Capital shortage, poor liquidity and SME's financing	Lack of trust in traditional financial mode	Food frauds on manufacturing side
Solution	Implementing a mobile app with Azure Blockchain	Lack of trust in traditional financial mode	Blockchain technology driven supply chain finance platform	Implementing blockchain label on food products
Results	Consumer can get details through the mobile app	Plagiarism of products using 3D printer	Verifiable authenticity and protection against design manipulation for consumer	Provides trusts towards customer purchasing food products

Supply chain transparency and traceability are critical in building consumer trust because they offer insights into how products are sourced, manufactured, and delivered. In today's world, where sustainability, ethics, and authenticity are significant concerns for consumers, they want to know more about where their products come from, the processes involved, and the people behind them.

2.4.6 Existing Work vs Current Study

Table 2.5 provides a summary on how the existing works compare with this study.

Table 2.5: Existing Work vs Current Study

Existing Work/ Current Study	Nature of the Blockchain Solution	Evaluation on the solution
Robust Retail POS System Based on Blockchain and Edge Computing	Private (Local Independent)	Evaluate the solution in terms of transparency and traceability qualitatively.
Blockchain-enabled Logistics Finance Execution Platform	Private (Hyperledger Composer)	Evaluate the capital management in terms of transparency and traceability qualitatively.
Blockchain-Drive Supply Chain Finance Application for Auto Retail Industry	Private (Local Independent)	Evaluate the solution in terms of transparency and traceability qualitatively.
Intellectual Property Protection of 3D Supply Chain	Public (Ethereum)	Evaluate the solution in terms of transparency and traceability qualitatively.
Using blockchain to signal quality in the food supply chain: The impact on consumer purchase intentions and the moderating effect of brand familiarity	Private (Local Independent)	Evaluate the solution in terms of transparency and traceability qualitatively.
Proposed Study	Public (Ethereum)	Provide a qualitative metric on the evaluation in both blockchain solutions in both traceability and transparency.

The evaluation in most solutions provides a qualitative approach, whether it is traceability or transparency, some do. Qualitative methods refer to those studies that are implementing blockchain solutions that only describe improvements in transparency and

traceability in words, which are different from the current research that shows actual indicators of transparency and traceability. On the other hand, most solutions only implement one blockchain solution, and the current research is to implement two blockchain frameworks.

2.5 Summary

This chapter first describes the current scenario of the songket industry. It contains 3 main parties in the order of preparation worker, weaver, and customer. The difference between public and private blockchain is dissected in terms of governance, consensus, and the nature of the network of each blockchain. Further in-depth explanation of private blockchain is carried out among Hyperledger Fabric and Sawtooth on their similarities and differences. A list of consensus algorithms is explained in terms of their behavior and the blockchain framework it supports. This chapter ends with a detailed review of previous work, some of the most related work is discussed to highlight a sense of higher clarity of significance of this study compared to those related work. Most of the solutions use private blockchain (i.e., Hyperledger Composer) solutions that are permissioned, meaning the ledger is not visible to non-relevant parties. Some other solution is merely determining the feasibility or potential of applying blockchain technology on the supply chain rather than providing a usable solution for the retail and finance industry.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the research design, data collection methods, tools for data analysis, and the overall approach adopted to address the research questions and achieve the objectives of the study. The primary aim of this research is to develop a comprehensive framework for ensuring the authenticity of songket using blockchain technology. The research methodology is structured to support the development and validation of this framework, with a focus on qualitative analysis to gain an in-depth understanding of the challenges and opportunities related to integrating blockchain in *songket* authentication.

3.2 Research Design

This study employs a qualitative research design to explore the complexities of ensuring the authenticity of songket and how blockchain technology can address the challenges in the traditional textile supply chain. By focusing on qualitative analysis, the study seeks to gain deep insights into the perspectives of various stakeholders involved in the songket supply chain, such as artisans, manufacturers, consumers, and retailers. The research is divided into two major phases:

Phase 1: Qualitative Exploration - This phase focuses on exploring the current challenges in ensuring the authenticity of songket, understanding stakeholder perspectives, and analyzing the potential of blockchain as a solution. Data will be gathered primarily through in-depth interviews and case studies, providing rich, detailed narratives on the experiences and views of key stakeholders regarding songket authenticity and blockchain's potential role.

Phase 2: Experimental Validation of Blockchain Framework - This phase will involve the development and testing of a prototype of the blockchain framework in a controlled, experimental environment. The effectiveness of this prototype will be assessed using qualitative methods such as observation, focus groups, and expert feedback to evaluate how blockchain could improve authenticity and transparency in the songket supply chain.

3.3 Data Collection Methods

The data collection in this study follows a primarily qualitative approach, utilizing a combination of primary and secondary data.

3.3.1 Primary Data

Primary data will be collected through the following qualitative methods:

3.3.1.1 In-Depths Interview

Semi-structured interviews will be conducted with key stakeholders in the songket production and distribution process. These stakeholders include:

- **Artisans and Weavers:** To understand their current practices for ensuring authenticity and the challenges they face with traditional methods.
- **Manufacturers and Retailers:** To explore the challenges in the supply chain and their perspectives on how blockchain can improve transparency and prevent counterfeiting.
- **Consumers:** To gauge their level of awareness regarding songket authenticity and the potential impact of blockchain in ensuring product integrity.

The interviews will be focused on understanding stakeholders' views on authenticity, transparency, and traceability in the songket market and their opinions on the

role blockchain could play in addressing these issues. Responses will be analyzed thematically to identify key patterns and insights.

3.3.1.2 Focus Groups

A small number of focus groups will be conducted with selected participants from each stakeholder group to explore in-depth their attitudes towards blockchain technology and its potential integration into the songket production process. These discussions will offer a deeper understanding of the cultural, economic, and practical considerations surrounding blockchain adoption.

3.3.1.3 Case Studies

The research will examine case studies of blockchain applications in other industries, such as luxury goods, art, and textiles. This will provide insight into best practices and potential pitfalls in the implementation of blockchain for product authentication, which will inform the development of the blockchain framework for songket.

3.3.2 Secondary Data

Secondary data will be collected from academic literature, industry reports, and publications related to:

- Blockchain technology and its applications in supply chain management.
- Current systems for product authentication and certification in the songket industry.
- Songket production processes and market dynamics.
- Consumer behaviour related to transparency and traceability in the songket industry.

Secondary data will be used to contextualize the primary data and provide a theoretical framework for the proposed blockchain-based authentication system.

3.4 Blockchain Framework Development

A key element of this research is the development of a blockchain-based framework to ensure the authenticity of songket. This framework will address two critical issues: **transparency** and **traceability**. Both are essential for safeguarding the integrity of the songket supply chain.

- **Transparency** in the songket supply chain will be achieved through a decentralized, immutable ledger on the blockchain, where every transaction (from raw material sourcing to consumer purchase) is recorded and accessible to all stakeholders. This ensures that all information regarding the songket's production, origin, and movement is open, unalterable, and readily verifiable by artisans, manufacturers, retailers, and consumers. As a result, transparency fosters trust and reduces the risk of counterfeit products entering the market.
- **Traceability** will be facilitated by recording each stage of the songket's lifecycle on the blockchain, from production to sale. By linking a **unique QR code** or **digital certificate** to each product, stakeholders can track the songket's journey and verify its authenticity at any point in the supply chain. This capability ensures that any songket in circulation can be traced back to its origin, confirming the legitimacy of its materials and craftsmanship.

Through this approach, the blockchain framework will enable real-time updates and seamless access to traceable information, providing an effective solution to the challenges of counterfeiting and fraud in the songket industry.

The central component of this research is the development of a blockchain framework to ensure the authenticity of songket. This framework will be designed based on the qualitative insights gathered from the interviews, focus groups, and case studies. It will include the following components:

- **Smart Contracts:** To automate the verification of each transaction in the supply chain, ensuring songket is authenticated at every stage, from raw material sourcing to final consumer purchase.
- **Decentralized Ledger:** An immutable and transparent record of each songket's journey, stored on the blockchain, which stakeholders can access to verify authenticity.
- **QR Codes/Digital Certificates:** Each songket product will have a QR code or digital certificate linked to the blockchain, enabling consumers to verify authenticity at the point of sale.

This blockchain framework will be tested experimentally within a controlled setting. During this phase, qualitative data will be collected via interviews, observations, and focus group discussions to assess how stakeholders interact with the system and how it impacts their perceptions of authenticity and traceability.

3.5 Data Analysis Techniques (Qualitative and Quantitative)

1. Qualitative Analysis

The qualitative data collected from interviews, focus groups, and case studies will be analyzed using thematic analysis. Thematic analysis involves identifying and analyzing recurring themes, patterns, and differences across participant groups. This analysis will focus on gaining insights into the opportunities and barriers associated with blockchain adoption in the songket supply chain. The primary themes to be explored are:

- **Characteristics of Cultural Assets Protected by Blockchain Technology:**

Identifying and exploring key features of cultural assets, such as songket, that can benefit from blockchain protection.

- **Enhancing Security Protection for Songket Motif Ownership Using**

Blockchain: Understanding how blockchain's immutable nature can improve security around the ownership and design rights of songket motifs.

- **Formulating a Framework for Supply Chain Traceability Using Blockchain:**

Exploring how blockchain technology can enable traceability and transparency in the songket supply chain, from production to final sale.

- **Evaluating the Effectiveness of the Proposed Framework:** Assessing the effectiveness of the proposed blockchain-based framework in terms of its ability to provide traceability and transparency, and its impact on the songket industry.

Thematic analysis will allow for an in-depth understanding of participant experiences, perceptions, and suggestions, enabling the identification of both the benefits and challenges of blockchain adoption in the cultural heritage sector.

2. Quantitative Analysis

For the quantitative analysis, data will be gathered through surveys and questionnaires administered to participants involved in the songket supply chain. These respondents will be asked to rate their perceptions on various aspects of blockchain technology's impact, such as security, traceability, transparency, and overall effectiveness. The data will be analyzed using statistical methods to quantify the following key aspects:

1. Perceived Effectiveness of Blockchain in Protecting Cultural Assets:

- **Survey Item Example:** "How effective do you think blockchain is in protecting the ownership and authenticity of cultural assets like songket?"

- **Scale:** Likert scale (1 = Not effective, 5 = Very effective)
- **Analysis:** Descriptive statistics (mean, median) will be used to summarize responses, while inferential statistics (e.g., t-tests, ANOVA) may be employed to assess differences between respondent groups (e.g., artisans, designers, consumers).

2. Impact of Blockchain on Security of Songket Motif Ownership:

- **Survey Item Example:** "Do you think blockchain technology can reduce the risk of motif theft or unauthorized reproduction?"
- **Scale:** Likert scale (1 = Strongly disagree, 5 = Strongly agree)
- **Analysis:** Correlation analysis to identify the relationship between perceived security and other variables (e.g., familiarity with blockchain, previous experiences with intellectual property theft).

3. Blockchain's Role in Supply Chain Transparency and Traceability:

- **Survey Item Example:** "Do you believe blockchain can enhance the traceability and transparency of the songket production and supply chain?"
- **Scale:** Likert scale (1 = Strongly disagree, 5 = Strongly agree)
- **Analysis:** Factor analysis to identify key components of traceability and transparency, followed by regression analysis to explore how these factors influence trust in the supply chain.

4. Evaluation of the Blockchain Framework's Effectiveness:

- **Survey Item Example:** "To what extent do you think the proposed blockchain framework will improve transparency and reduce fraud in the songket industry?"
- **Scale:** Likert scale (1 = Not at all, 5 = Very much)
- **Analysis:** Descriptive statistics to summarize overall satisfaction with the framework and inferential statistics (e.g., chi-square tests) to identify factors that predict higher levels of satisfaction.

The integration of both methods will provide a comprehensive view of the opportunities and barriers associated with blockchain adoption in this sector. The quantitative analysis will provide statistical evidence regarding the perceived benefits and challenges of blockchain technology in the songket industry, complementing the qualitative insights gathered through thematic analysis.

3.6 Ethical Considerations

This research will adhere to ethical guidelines to ensure the protection of participants' rights and privacy. Informed consent will be obtained from all participants, and confidentiality will be maintained by anonymizing the data. Participants will be informed about the purpose of the research, and all data will be used solely for academic purposes. Ethical approval will be sought from the relevant institutional review board before the commencement of data collection.

3.7 Summary

This chapter has outlined the research design, methodology, and data collection methods used to investigate the potential of blockchain technology for ensuring the authenticity of songket. By using an experimental approach focused on qualitative analysis, the study aims to provide deep insights into the challenges and opportunities of integrating blockchain in the songket supply chain. The findings will contribute to the development of an effective and practical blockchain framework for enhancing songket authenticity, traceability, and transparency.

CHAPTER 4

PROPOSED FRAMEWORK

4.1 Introduction

This chapter addresses the research methodology that will be implemented based on the literature review, utilizing blockchain technology based on Chapter 2 and the approach presented in Chapter 1. The main contribution of this chapter is a concrete framework which provides a generic implementation of the songket supply chain. To our knowledge, no such attempt has been made to design and develop such a framework to protect the unique pattern of songket. The value of such a framework is to provide an implementation blueprint for system designers and system developers as a guideline to design and develop a songket supply chain system. The songket supply chain will be addressed as Songketchain.

The remainder of this chapter is organized as follows: Section 4.2 lays down the requirements and assumptions of the framework. Section 4.3 introduces important terms used throughout this chapter with regards to the framework and introduces the generic architecture for the framework. The next section, Section 4.4 presents the overall picture of the framework. Section 4.5 presents the key contribution in which the different sub-components of the songket supply chain are described in more detail. Section 4.6 provides the overall sequence diagram of interactions between the entities. Finally, Section 4.7 summarizes the chapter highlighting key findings and contributions.

4.2 Generic Framework Scenario

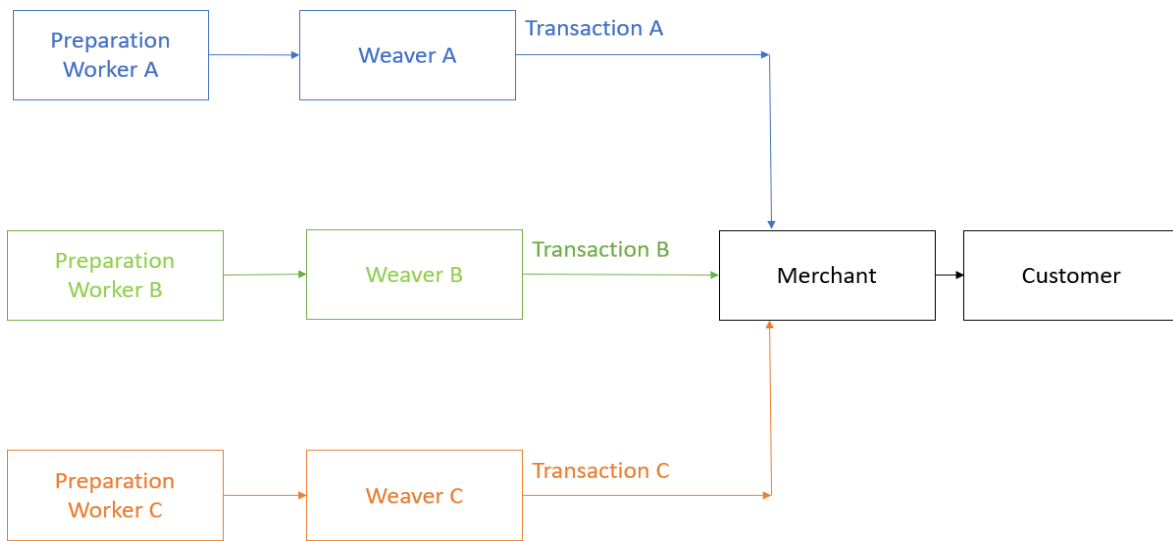


Figure 4.1: Framework assumptions

The *songket* supply chain generic framework presented in the chapter is based on the following key assumptions:

- i. Preparation workers (A, B, C) and Weaver (A, B, C) all have transactions with Merchant.
- ii. Preparation worker (B, C) and Weaver (B, C) have a transaction with Merchant.
- iii. Preparation worker C and Weaver C have a transaction with Merchant.

4.3 Framework Fundamentals

The term framework used in this chapter and the thesis refers to an application-level development blueprint which provides two important pieces of information. Firstly, the framework shows components required for the *songket* supply chain to function, plus the logic behind each of the sub-components. Secondly, it provides the logical flow of the *songket* supply chain process based on blockchain technology.

Beside the term framework, there are several other terms used throughout this chapter that need explanation and definition. An entity in the framework refers to the

parties involved in the songket supply chain, namely the producer, supplicant, and consumer (which will be defined in the next section). Each entity contains an agent and each entity's action is conducted through the agent. In the context of the framework, an agent is defined as a computer program that acts on behalf of an entity. An engine in the framework is a conceptual term that implies a set of processes to achieve an outcome.

4.3.1 Transparency and Traceability

Based on the discussion mentioned in Section 2.2, retail chain transparency is about providing information about the supply chain parties, thereby mapping the entire supply chain network. Retail chain traceability is about providing information about the product level and mapping the product flow from the source. The relationship between retail chain transparency and traceability can be described as traceability depends on transparency, and higher transparency will provide higher traceability strength, as shown in Figure 4.2.

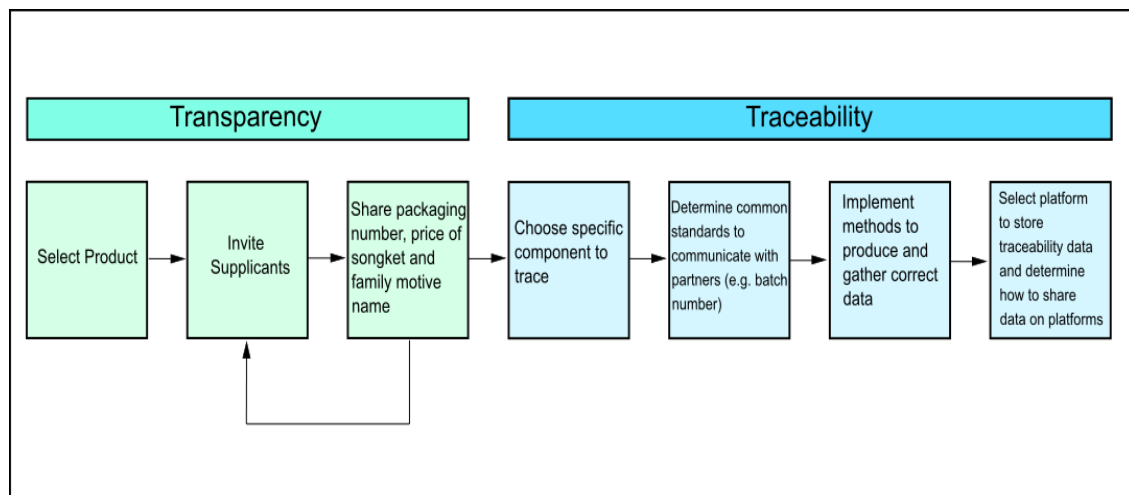


Figure 4.2: Transparency and Traceability mechanism

To produce authentic products and minimize counterfeit issues, transparency and traceability can be used as a functional requirement that contribute to product authenticity. Transparency consists of two quality factors which are to provide information and to

provide mechanisms. To achieve transparency, the system must fundamentally provide information about data, processes, and events (in the form of evidence).

- **Data:** Refers to information that are crucial in the system
- **Processes:** Refers to what happening when data are stored in the system
- **Events:** Refers to situation that happens after one process is complete

To date, there are no existing metrics being used specifically to measure transparency for blockchain based implementation for supply chain, however there is existing research work that measures transparency.

For this framework, the metrics proposed are based on the above reference metrics, however changes are made in terms of the definition and the calculation to suit the nature of the supply chain scenario. The proposed transparency metrics are:

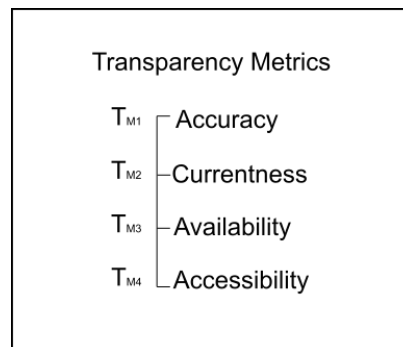


Figure 4.3: Transparency Metrics

- **Accuracy:** These metric measures how similar the information stored in the system matches the information queried to the system. Measurement requires extracting sentences from the information to be observed in the actual system and compared to information retrieved by the customer (as one of the end users). To measure accuracy, it is necessary to define what is a statement. These statements will depend on the nature of the information, but it is recommended that at least claims and affirmations about what the system is or really are should be considered.

To illustrate the above metric, let's look at the following scenario:

Assume that information is stored in Songketchain (from any of the stages in the supply chain) (labelled as I100 in Figure 4.4). The customer can obtain the information about the process or other details through a QR code mechanism in the product. In the case where the QR code is legit, it should connect to the Songketchain system and retrieve the information. This information from the QR code can be compared to the info retrieved and can be measured in terms of accuracy. If a malicious party tries to counterfeit the product, the QR code and the subsequent information generated will not be the same as the one stored in the Songketchain system, thus affecting the accuracy.

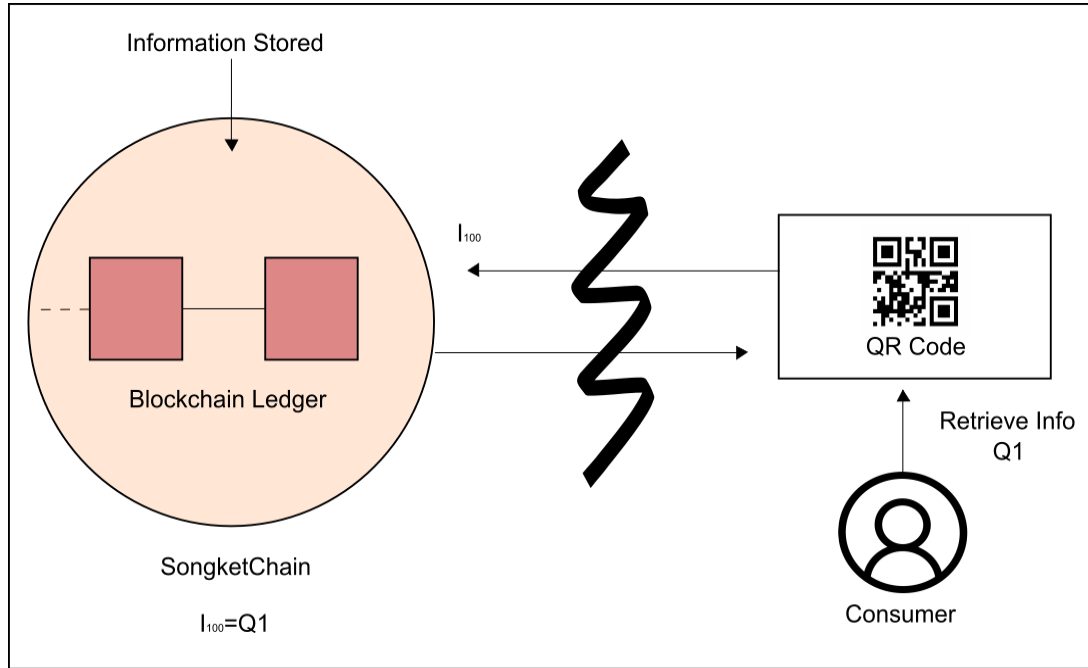


Figure 4.4: Information retrieved from SongketChain

The accuracy metric can be calculated as follows:

$$OTIF = \frac{\text{number of deliveries}}{\text{total number of deliveries}} \times 100\% \quad \text{Equation 3.1}$$

OTIF stands for On Time and In Full. OTIF is a key metric for measuring the success of a company's delivery process. OTIF calculates on-time deliveries as a percentage of total deliveries and can be used as a performance indicator for suppliers, manufacturers and logistics companies.

- **Currentness:** Currentness is the time that elapses between the time an event or activities being conducted/occurred in the supply chain as compared to a system providing information about the event/activities. Currentness is important due to the nature of the system that requires time to update the information into the system. Δt is the interval of time that the system has taken to inform about the change, and Δt_u is a time unit that measures what a reasonable interval time (i.e., the ideal time) for updating that piece of information would be, the currentness is measured as shown below.

$$C_u = \begin{cases} 1, & \text{if } \Delta t \leq \Delta t_u \\ 2^{-\lfloor \frac{\Delta t - \Delta t_u}{\Delta t_u} \rfloor}, & \text{if } \Delta t > \Delta t_u. \end{cases}$$

Figure 4.5: Formula of Currentness

- **Accessibility:** These metric measures how easy it is for users to access the instrument (accessibility). Accessibility, here in the sense of “being easy to obtain”, is a quality that refers to both categories of instruments. Since the instrument expresses the act of providing something, it must be easy for a user to obtain it, regardless of whether this something is information or mechanisms (Spagnuolo et al., 2016).

- **Availability:** These metric measures how easy it is for a user to access the instrument, if accessible at all. To measure the availability Av , we first define N_{int} as the number of interactions the user needs to perform to reach the desired instrument. An interaction is considered as any action the user must perform, such as typing, clicks, taps, slides, etc (Spagnuolo et al., 2016). Formula of availability are shown below:

$$Av = \begin{cases} 1 - \frac{(1-\omega)}{k} N_{int}, & \text{if } 0 \leq N_{int} \leq k \\ \omega e^{(1 - \frac{N_{int}}{k})}, & \text{if } N_{int} > k \end{cases}$$

Figure 4.6: Formula of Availability

Here k is the maximum number of interactions that are considered acceptable for reaching access, while $\omega \in [0, 1]$ is the grade that we give when accessing the instrument takes exactly k steps. Equation above degrades linearly from the maximum value 1, obtained when no steps are required to get access to the instrument, till value ω , obtained when k steps are required to get access to the instrument. From that point on, the degradation is exponential in the number of steps (Spagnuolo et al., 2016).

In a supply chain context, traceability evaluation metrics help ensure that products and materials can be tracked from origin to destination, providing visibility and accountability throughout the entire process. Here are some key metrics to evaluate traceability specifically within a supply chain:

- **End-to-End Traceability:** The ability to trace a product or material throughout its entire lifecycle from raw material to product, across every step in the supply chain. Full traceability helps detect issues early, prevent fraud, and provide accountability

for the entire product journey. Percentage of products or materials measured whose full journey is recorded, from raw material procurement to final delivery

- **Real-Time Tracking:** The ability to track products in real time as they move through the supply chain. Real-time tracking helps with faster decision-making, especially in cases of product recalls, delivery delays, or inventory management. Percentage of products or shipments tracked for which location and status data is updated in real time.

Some key metrics to evaluate transparency specifically within a supply chain:

- **Ledger Transparency:** Public Accessibility of Transactions which the degree to which transaction data is accessible to the public or authorized parties.
- **Auditability and Monitoring:** Real-Time Monitoring of Blockchain Activity where the ability for users and third parties to monitor blockchain transactions and activities in real-time.

Immutability plays a crucial role in enhancing both transparency and traceability in supply chains by ensuring that once data is recorded, it cannot be altered or tampered with. This guarantees the accuracy and reliability of information, building consumer trust in product origins and quality claims. In traceability, immutability allows for the precise tracking of a product's journey from raw material to destination, making it easier to identify and resolve issues like defects or safety concerns. Technologies like blockchain further strengthen these attributes by providing a decentralized, tamper-proof ledger, ensuring that supply chain data remains transparent, trustworthy, and easily verifiable.

Supply chain traceability is an essential practice that involves capturing and providing comprehensive, detailed information about the manufacturing process. This includes specific data such as the types of materials utilized, quantities of materials

involved, manufacturing processes employed, and the time required to complete a single product. These details play a critical role in justifying the price of a product by offering transparency and insight into its value proposition. While supply chain transparency encompasses a broader view of the entire supply chain, traceability zooms in on the flow of product components and processes. By focusing on these specific aspects, traceability aims to ensure accuracy, reliability, and accountability in the supply chain.

In the context of the songket supply chain, which represents a traditional hand-woven textile industry, the implementation of traceability practices is of particular importance. Within this industry, traceability serves to provide clarity and visibility throughout the supply chain, shedding light on the intricate details of the songket production process. By capturing information related to the raw materials used, such as the specific types and sources, traceability allows stakeholders to track and record the quantities of materials involved in each production stage. Additionally, traceability practices extend to monitoring the manufacturing processes employed, including the selection of techniques and the allocation of time and resources required for each product.

By leveraging traceability in the songket supply chain, stakeholders gain insights into the product's journey, enabling them to justify the pricing strategies adopted. This granular information helps demonstrate the value inherent in the songket products, reflecting the craftsmanship, materials utilized, and the intricate production processes involved. Moreover, traceability supports consumer perception of value, as customers can appreciate the transparency provided and gain confidence in the product's authenticity and quality.

Figure 4.2, presented in the thesis, serves as a visual representation of the songket supply chain, illustrating the interplay between transparency and traceability. It highlights how traceability practices within the songket industry contribute to the overall transparency

of the supply chain. Through the depiction of various stages, processes, and information flows, the figure clarifies how traceability serves as a key enabler of transparency, facilitating a deeper understanding of the songket supply chain dynamics.

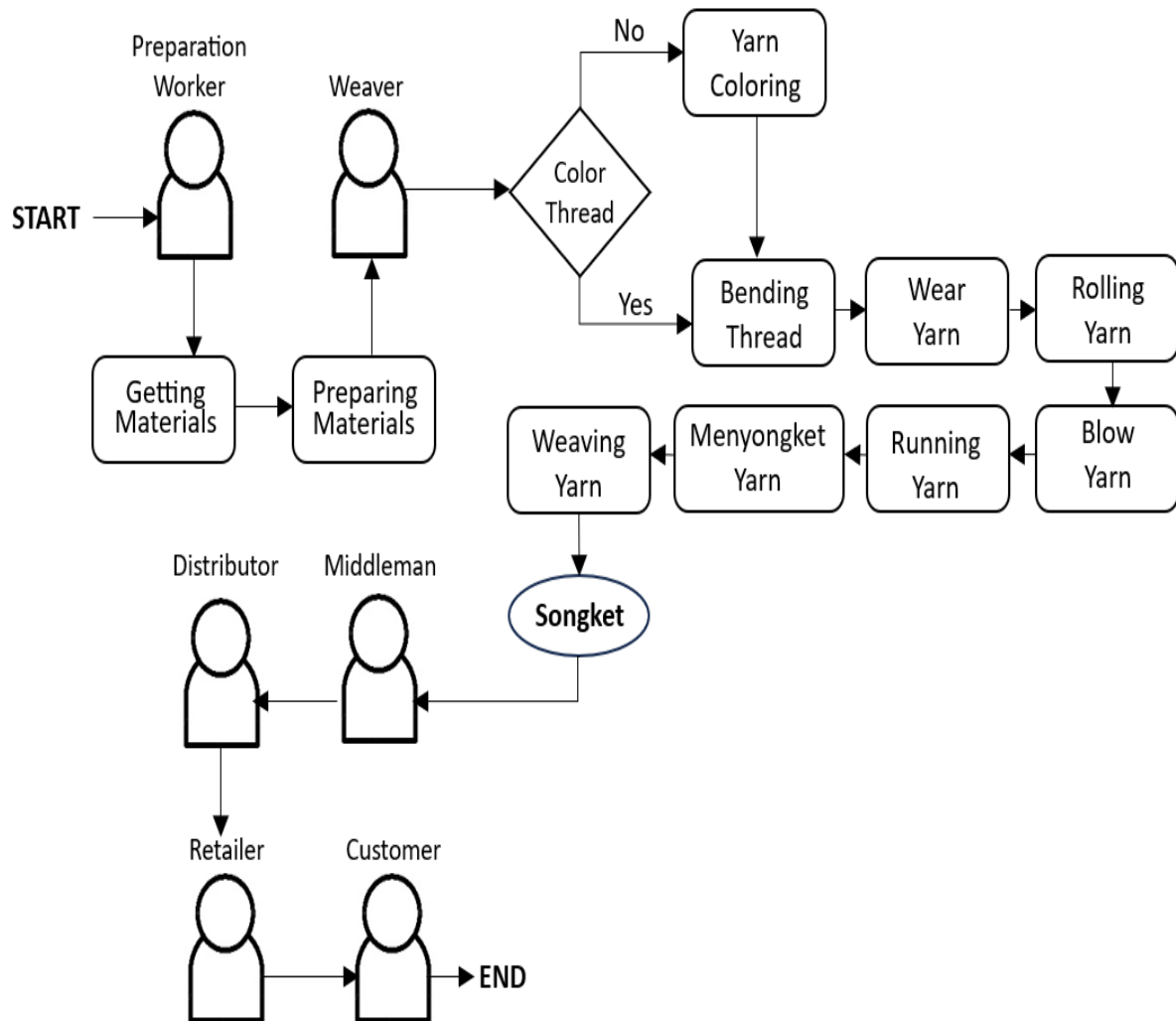


Figure 4.7: Songket Supply Chain Flowchart

The Songket Supply Chain are explained as shown below:

- **Preparation Worker:** Preparation Worker is the person in charge of collecting the raw materials for the songket production.
- **Getting Materials:** Raw materials are collected for the songket production such as cotton, silk, yarn and dye colour.

- **Preparing Materials:** Materials gathered from the preparation workers will undergo a cleaning process and are categorized in each category which is cotton and silk.
- **Yarn Colouring:** Clean cotton and silk will be coloured respectively according to which yarn will be created such as cotton yarn, silk yarn, gold yarn and silver yarn. The coloured yarn will be dried up for the next process.
- **Bending Thread:** Dried yarn will undergo a bending process to make the yarn stiff for the next process.
- **Wear Yarn:** This process will determine the length of yarn that will be used to create the songket.
- **Rolling Yarn:** Once the length of yarn is determined, the yarn will be rolled into a rolling board.
- **Blow Yarn:** Rolled yarn will undergo a blowing yarn process where the yarn will be trimmed and cleaned to get rid of the residue and impurities.
- **Running Yarn:** Running yarn will ensure strangled yarns, odd yarns and yarns will be lifted automatically while weaving the songket.
- **Menyongket Yarn:** The yarn then will be used to create motifs of patterns depending on the weaver. This process took a lot of time to be done.
- **Weaving Yarn:** Once patterns are completed, the last process before the songket is produced, the yarn will be weaved based on the desired pattern to form a songket cloth.
- **Middleman:** Middleman will take the songket cloth and send it to the distributor.
- **Distributor:** Distributor will distribute the songket cloth based on the retailer location and songket pattern.

- **Retailer:** Retailer will sell the songket cloth according to the pattern/motifs. More complex patterns will cost slightly more than the others.
- **Customer:** Individual who bought the songket.

4.3.2 Generic Architecture of the System

A **system** is defined as a group of entities that interact with each other. In the context of the songket supply chain, we have defined three types of entities that make up the system, which are producer, supplicant, and consumer. In the following section, the supplicant will be known as distributor, middleman, and retailer that work together before sending the product to the consumer. A **relationship** in the system is defined as a connection between two entities in the system which is represented by an arc connected between those two entities. The connection represents the action or process between the entities. **Store** process in the system is the process of registering the product in the system through producer and supplicant. **Enquiry** is the process of requesting information from the system and **view** is the process gaining information after the enquiry process.

4.3.3 Placement Consideration for Songket Supply Chain Engine

Another important consideration is for the placement of the *songket* supply chain engine. In general, there are three possible locations for the engine, based on the *entity* in the system, which are: (1) at Producer (PC), (2) at Supplicant (SP), and (3) at Consumer (CM). The three possible locations are discussed as follows:

- **Producer:** the PC is an independent entity that can log into the system. PCs can create a new product and register into the system while reading the transactions that are happening. The key requirement is that the PC must be trusted by SP and CM. To provide access to SP and CM, PCs need to register their product in the system.

However, there is one drawback. SP and CM could not access the system until the PC already registered their product in the system.

- **Supplicant:** the SP is a dependent entity that can log into the system and read the transactions that are happening. The key requirement is that SP must be trusted by the CM. To provide access to CM, SP needs to bind the product registered by PC to make it accessible to CM. However, there is one drawback. CM could not access the system until PC already registered their product in the system and SP already bound the registered product.
- **Consumer:** the CM is a dependent entity that can log into the system and read the transactions that are happening. There is no requirement for CM since CM is the endpoint for the *songket* supply chain. To access the system, products need to be registered from the PC and bind with SC to take the product.

Based on the discussion above, to achieve smooth transaction in the *songket* supply chain, the most logical placement for the *songket* supply chain engine is not in one of the entities listed. This is due to the supply chain process that happened in one flow which is not suitable to put the engine in any entities listed. If the engine is included in one of the entities, it will disrupt the flow of the *songket* supply chain. The engine will be located somewhere else in the system.

4.4 General View of the Framework

Figure 4.8 shows the general view of the framework for the *songket* supply chain. The framework consists of various modules located in different entities. Each of the modules will be discussed in detail in the following sections.

One property of the framework is that it should be as transparent as possible so that it is possible to implement the framework in the *songket* market. For example, the storage

of data modules discussed in Section 4.3.1 uses the *accuracy* as the metric validated by the module, but the storage of data modules can also cater for other metrics such as *currentness* and *availability*. One limitation is that, in its current implementation, the module (and subsequently the framework) is unable to cater for composite metrics (combination of several metrics) and can be addressed in future works.

Several processes such as the register, search, and buy are not discussed from the implementation from the point of view since those processes are part of underlying specific service provisioning system implementation, such as web services.

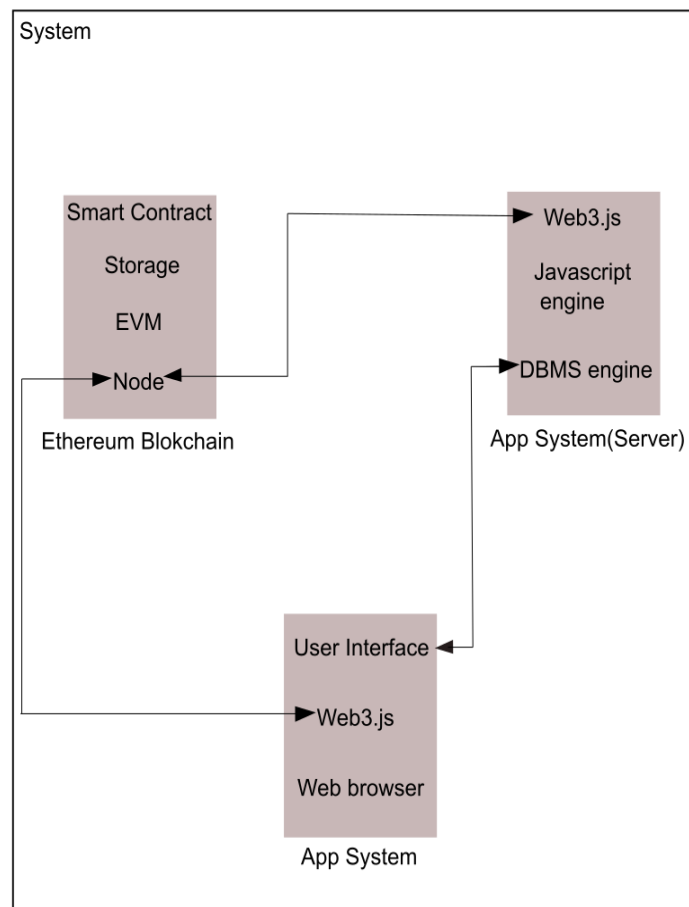


Figure 4.8: General View of the Songket Supply Chain Framework

4.5 Framework Components

This section provides detailed discussion on each of the components and functions within the framework, focusing on the logic of each component. The breakdown of the following discussion is based on entities in the framework.

4.5.1 Producer Entity

A Producer (PC) is one of the entities in the system. The PC serves one main function which are add blocks into the blockchain system (as in registering new songket products into the framework). Transaction happens when the data captured by Songketchain already undergoes a consensus algorithm and the new transaction(block) is

added into the chain. The prerequisite is Songketchain will verify the identity of the current user, whether they have the access to read, write or both.

The PC will submit a transaction request to be appended to the blockchain database. Songketchain will authenticate the PC before allowing transaction data to accept consensus algorithms. After the transaction data is signed by the consensus algorithm, the transaction data will be added to the blockchain database, and Songketchain will notify and display the results to weavers. A processor also in the same blockchain network will query transaction information when needed. Before accessing transaction data, they will still need to be authenticated. This basically describes how the general blockchain- based supply chain system operates in the Songketchain framework. In the implementation phase, Ethereum will be applied to this framework, and the evaluation model will be used, which will be analysed later.

4.5.2 Supplicant Entity

Supplicant (SP) is a generic term for an entity that consists of distributor, middleman, and retailer. Songketchain will authenticate SP before allowing transaction data to accept consensus algorithms. Transaction would not be verified unless there is existing data in the blockchain (registered by PC). Songketchain will notify and display the result whether the product is available in the system and display the result. A processor also in the same blockchain network will query transaction information when needed. Before accessing transaction data, they will still need to be authenticated. Figure 3.8 shows the flow of SP in the framework from the transaction of data point of view.

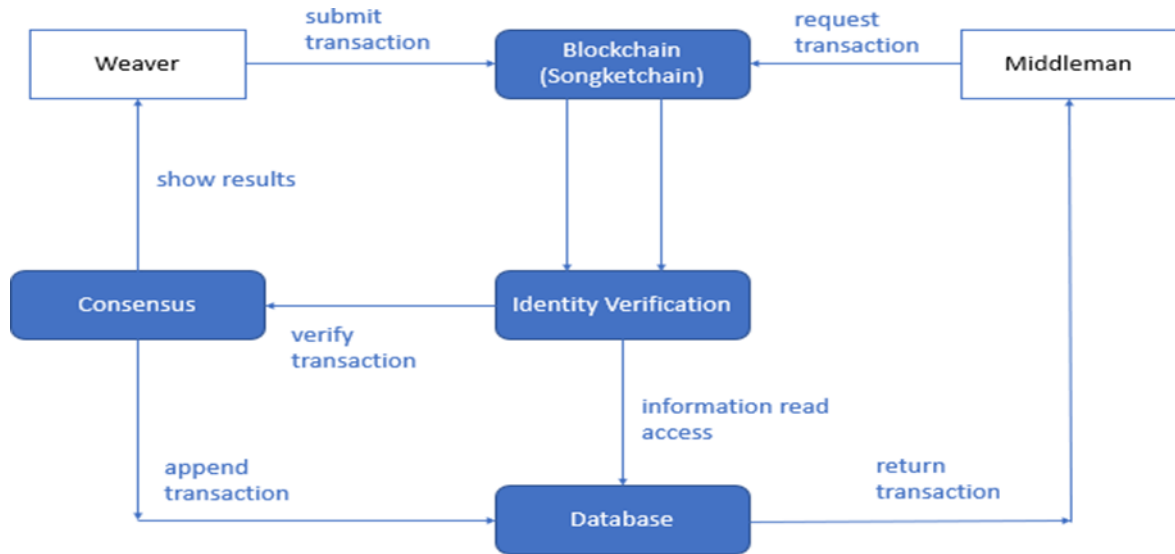


Figure 4.9: Transaction flow for Supplicant

- **Submit Transaction:** Data of the Songket created by the weaver will be submitted to the Blockchain (Date created, Motive Image, etc)
- **Request Transaction:** Requested data from the blockchain for the middleman.
- **Return Transaction:** Songket information and details are returned.
- **Verify Transaction:** Transactions are verified through identity verification.
- **Append Transaction:** Details of the songket (location based) can be updated
- **Information read access:** Login details verified through the database.
- **Show results:** Songket motive picture and details are shown.

4.5.3 Consumer Entity

A consumer (CM) is an entity that buy the registered product by using the framework. Product information can be disclosed to the CM in many ways depending on the relevant party that sells the product, and consumer does need to authenticate identity to get the product information. By the end of the transaction, the ownership of the product will be given to the CM.

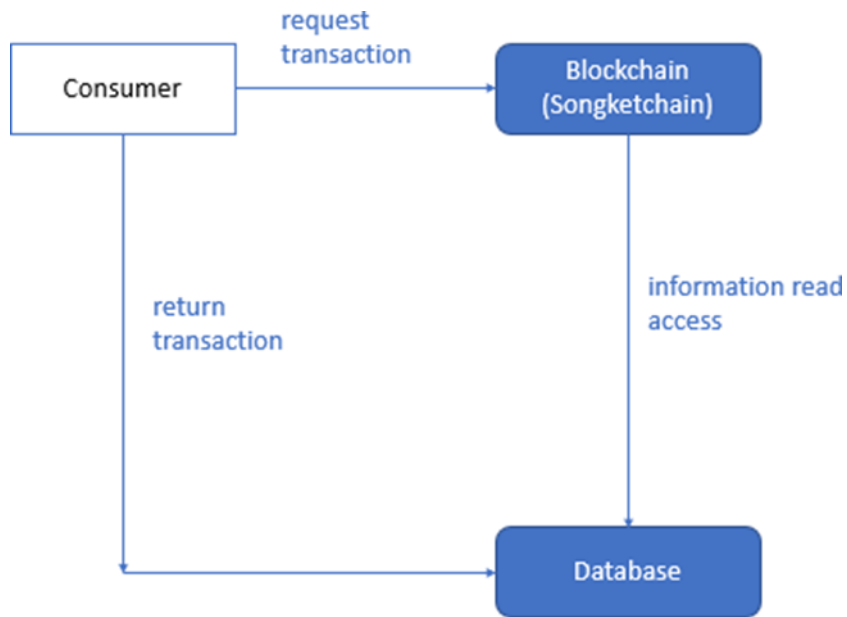


Figure 4.10: Transaction flow for Consumer

- **Request Transaction:** Consumer requesting data and information from the blockchain ledger.
- **Return Transaction:** Data and information returned to the consumer.
- **Information Read Access:** Verification process of the consumer for the data requested.

4.6 Store process (Data Input)

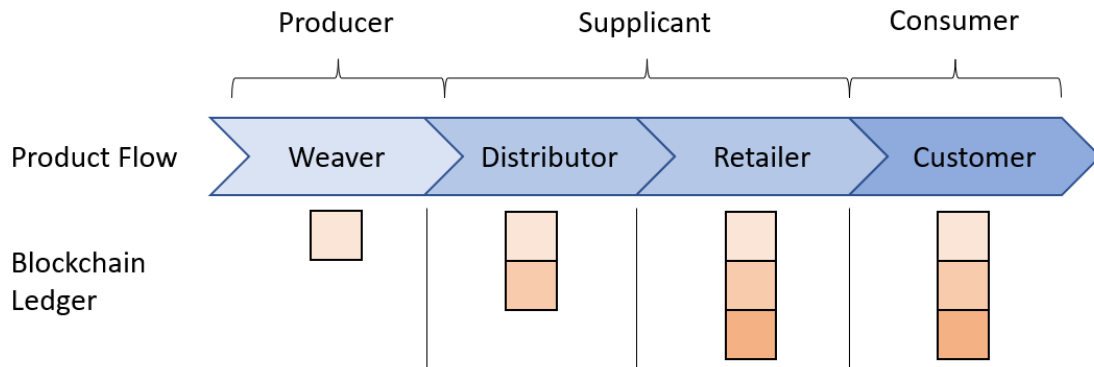


Figure 4.11: Flow of Product on Blockchain Ledger

Figure 4.11 illustrates a simple representation of the songket supply system and its main phases. As the flow of product goes further, more and more ledgers will be appended to the blockchain system as there will be new information generated every time the product is transferred to a new owner.

```

1  create contract;
2  |   constructor weaver1 = product 1
3  |   |   credentials;
4  |   |   add id
5  |   |   add name
6  |   |   add qCount
7  |
8  |   If credentials not available
9  |   |   repeat credentials;
10 |   Else
11 |   |   mapping;
12 |   |   map weaver qCount
13 |   |   add WeaversCount
14 |   |
15 |   |   function addWeaver
16 |   |   |   WeaversCount++
17 |   |
18 |   |   constructor addWeaver(product 1)
19 |
20 |   end

```

Figure 4.12: Pseudo-code of the Framework

The backbone of decentralized applications is the creation of smart contracts. It is the foundation of every decentralized application. Once created and started, even the creator cannot change it. This application “smart contract” is like a voting system. Weavers need to put their products into the app, just like entering the date. Then, customers need to choose their products. During the voting process, the “voting” of the event is initiated by calling the “votedEvent” function. Some metadata is passed so that we can view all activities on the blockchain. We can then “watch” this event. Inside the pseudo code, if the “votedEvent” is triggered, the suggested system log will be logged to the console. We will also re-render everything on the page. This is one of the voting systems of the process, After the voting is over, the decided product will reach the customer, and the farmer repeats the process. Figure 4.12 shows the Ethereum pseudo-code involved in the smart contract, which shows the creation of a constructor when product 1 and product 2 are called. The explanation of the codes are as follows:

- Line 1: Create contract is the command for smart contract creation.

- Line 2: Constructor is an optional function which is used to initialize the state variables of the contract.
- Line 3: Credentials is the name of the variables.
- Line 4-6: Credentials properties
- Line 8-9: If the Credentials is not available, repeat the Credentials.
- Line 10-11: Else if the credentials are available, mapping will be called. Mapping is a hash table that stores data as key-value pairs which the key can be any data type. The value of the data type can be any type.
- Line 12: Storing weaver qCount
- Line 13: Adding the value WeaversCount
- Line 15: Declaring a function that add Weaver.
- Line 16: WeaversCount++ will add the numbers of weaver.
- Line 18: The constructor will add the number of weavers with the product details included.
- Line 20: End of the code

Table 4.1 provides some insights into the data used for experimental research in the framework. The data is populated to the stage before the consumer. The consumer is assigned read access in the retail chain network. Please note that in actual implementation, the system will generate more technical data and metadata. This table provides an overview of the data related to the retail chain. This is when creating a new transaction or product from one owner to another. Required when transferring. Some data such as location and date and time seems to be duplicated, but this is necessary in the process, because at each stage of supply changes, these data need to be updated accordingly instead of overwriting previous data values. It is required as part of the backtracking process.

Table 4.1: Data of Blockchain Ledger

Weaver	Middleman	Distributor	Retailer
Family Motive Name	Family Motive Name	Family Motive Name	Family Motive Name
Location	Location	Location	Location
Created DateTime	Created DateTime	Created DateTime	Created DateTime
Songket No	Songket No	Songket No	Songket No
Material	Packaging No	Packaging No	Packaging No
Price	Price per Songket	Price per Songket	Price per Songket
Technique	Quantity	Quantity	Quantity

If each table contains at least 4 transparency data. This information is defined as transparency data and consists of the Family Motive name, Location, Created DateTime, and Songket No. The name represents the family motive of an entity, by creating a family heritage that currently owns the current ledger and is transferred to another party by itself or with it. The location and creation date and time of this ledger when it was created or transferred.

The remaining data will be classified as traceability data, which will provide more granular information about the product (songket), such as technique, material, and price (in the weaving phase). Since the ledger is only appended, when transferring existing data to another owner, there is no need to record the existing data again because the previous information remains in the database. However, certain information may change over time, such as each price. Price per songket is different when transferred from Middleman to Distributor and Distributor to Retailer, same goes to other information like Packaging No. and Quantity.

4.7 System Architecture for SongketChain Framework

Objective of this system architecture is to illustrate how the SongketChain framework can be realized through software systems. This system will be used as a validation platform in the next chapter. The following Figure 4.13 shows the proposed framework.

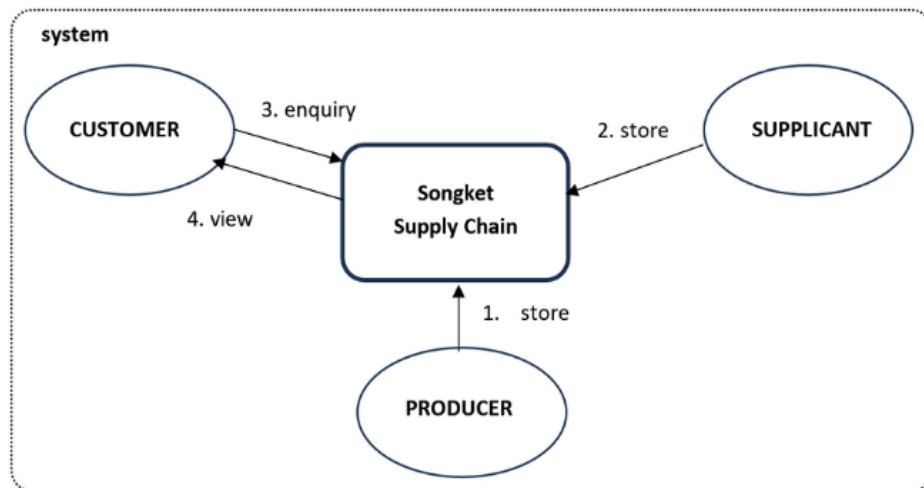
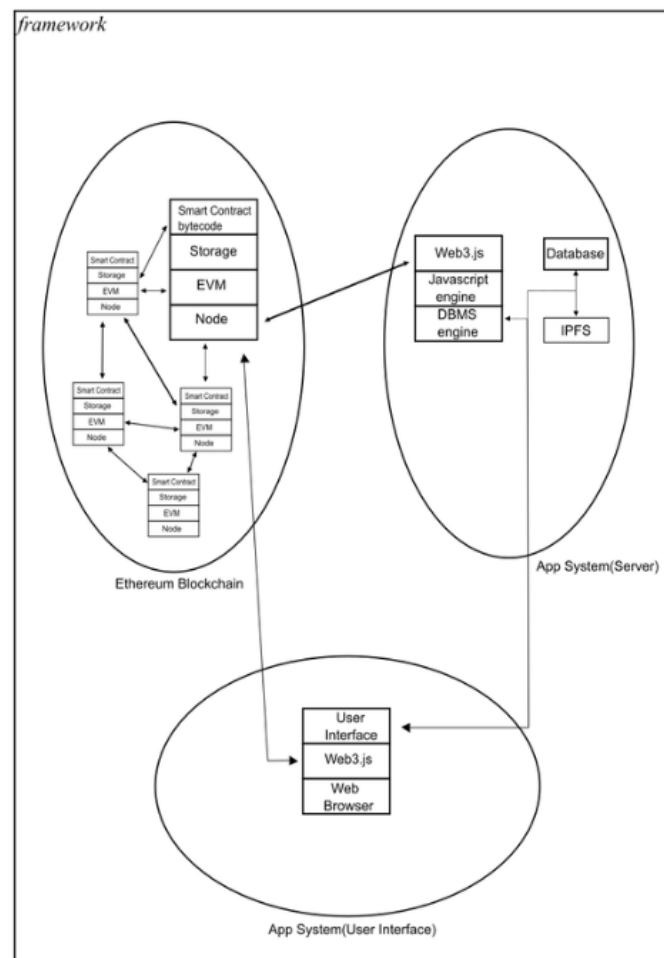


Figure 4.13: Proposed Framework

- **Ethereum Blockchain:** Consists of multiple smart contracts. The code of smart contracts will be compiled and sent to the Ethereum Virtual Machine (EVM). EVM

will change the code from high-level programming language to low-level programming language. EVM is a virtual machine which is placed between operating systems (OS) and application layer. Node in the Ethereum blockchain is an instance of the Ethereum client software that is connected to other computers that run Ethereum network, hence creating a network. Storage in Ethereum blockchain is known as blocks of data which are stored in the form of transactions. The blockchain will have a lot of data which then will create a chain of blocks, hence blockchain.

- App System (Server): Consists of web3.js which is an Ethereum JavaScript API. It allows us to interact with local or remote Ethereum nodes by using HTTP, IPC or WebSocket. The JavaScript engine will execute the code from the web3.js script. DBMS is a database management system that will create, delete and update the user. In this scenario, the user should be registered in the database for the web3.js to function properly. IPFS is known as Interplanetary File System, is a file sharing peer-to-peer network for storing, protocol, hypermedia and sharing data in a distributed file system. In this scenario, the picture of the songket is stored in the IPFS so that the picture can be retrieved anywhere since IPFS has another peer that stores the picture.
- App System (User Interface): Consists of user interface for the user to use the system. Users that use the system's user interface will trigger the web3.js script to interact with the server (like storing data and updating data). Web browsers such as Google Chrome are used to display the user interface.

4.7.1 General Sequence of Interactions

Customers will get transparent information about the product from the initial level of the product and get detailed information about the weaver. If the customer is satisfied, he will get more products from weavers. Moreover, weavers get the best prices for their products, and intermediaries will not make more profits. The whole activity is divided into multiple phases, such as login phase, execution phase, verification phase, order phase and payment phase. Figure 4.14 shows a use case diagram that describes the various stages, and the stakeholders involved in these stages. During the login phase, every stakeholder involved in this system should log in to the online portal. Weavers can add new products to the portal during the execution phase.

During this execution phase, all other stakeholders can access the product. Before obtaining the product in the verification phase, stakeholders should obtain the consensus of all other stakeholders. All other stakeholders can access the product during this execution phase. A stakeholder should get a consensus from all other stakeholders before obtaining the product in the validation phase. At this stage, customers will obtain products based on the consensus given by farmers and retailers. After successfully accepting his payment request, the product will be delivered to him at the payment stage.

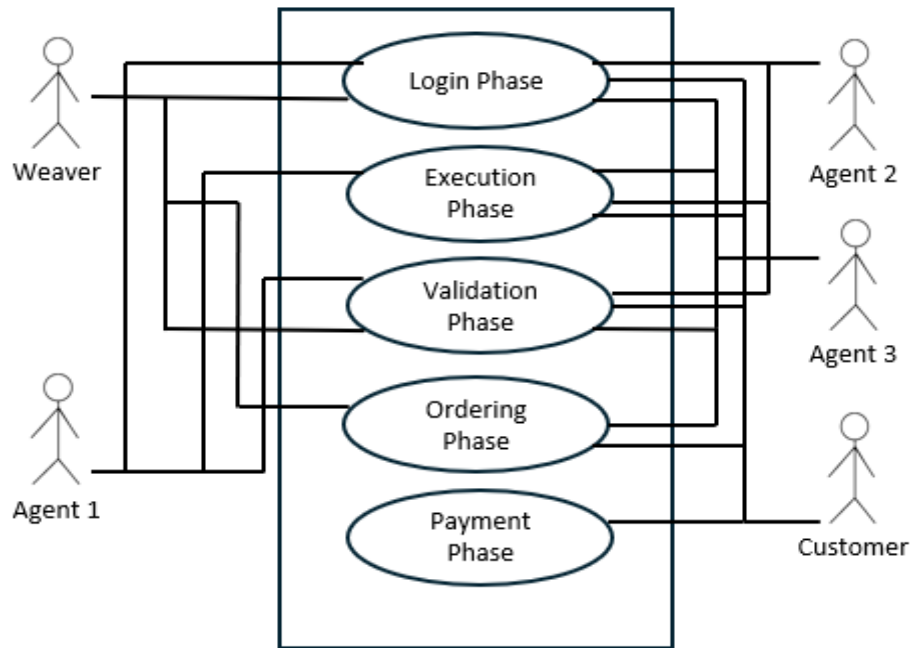


Figure 4.14: Use Case Diagram

Figure 4.15 shows the sequence diagram among the various stakeholders in the proposed system F2C. The various activities of multiple stakeholders are shown in Figure 4.15. These activities are sorted by numerical representation. The first activity is the process of logging into the online portal. All stakeholders should carry out this activity. Every stakeholder who wants to participate in the supply chain process should log in to the portal. Through the username and password, all stakeholders can enter the login portal. After successfully completing the login process (Activity 2), the product that the weaver will add is the third activity. In this way, the genesis block of the product can be created in the necessary fields, as shown in Figure 4.15

The fourth activity is that the agent/processor stakeholders increase their interest in collecting products from weaver. After obtaining the weavers' consent (activity 5), Agent 1 will obtain the product (activity 6). His information about receiving products from weavers is added as a block together with the genesis block. The blockchain creation of this product

has started. The Agent 2/distributor will then express interest in shipping support to move the product from one place to another (activity 7). His proposal will be approved by the stakeholders' weavers and agent 1 (activity 8). After successful approval, the product will be transferred from Agent 1 to Agent 2 for transportation (Activity 9). His information about the product received from agent1 is added as a block in the blockchain. Similarly, the Agent 3/retailer shows his proposal to collect products from the distributor (activity 10).

After obtaining the consensus approval of the stakeholder weaver, Agent 1 and Agent 2 (Activity 11), he will receive the product (Activity 12). His information about receiving products from Agent 3 is added as a block in the blockchain. Then, Agent 2 will publish the product to be sold on the online portal (Activity 13). Then, the customer will send a request to purchase the product (activity 14). After the farmer and Agent 3/retailer approve, his request will be approved (activity 15). Next, the customer will go through the payment process (activity 16). Finally, after successful payment, he will receive the product (activity 17).

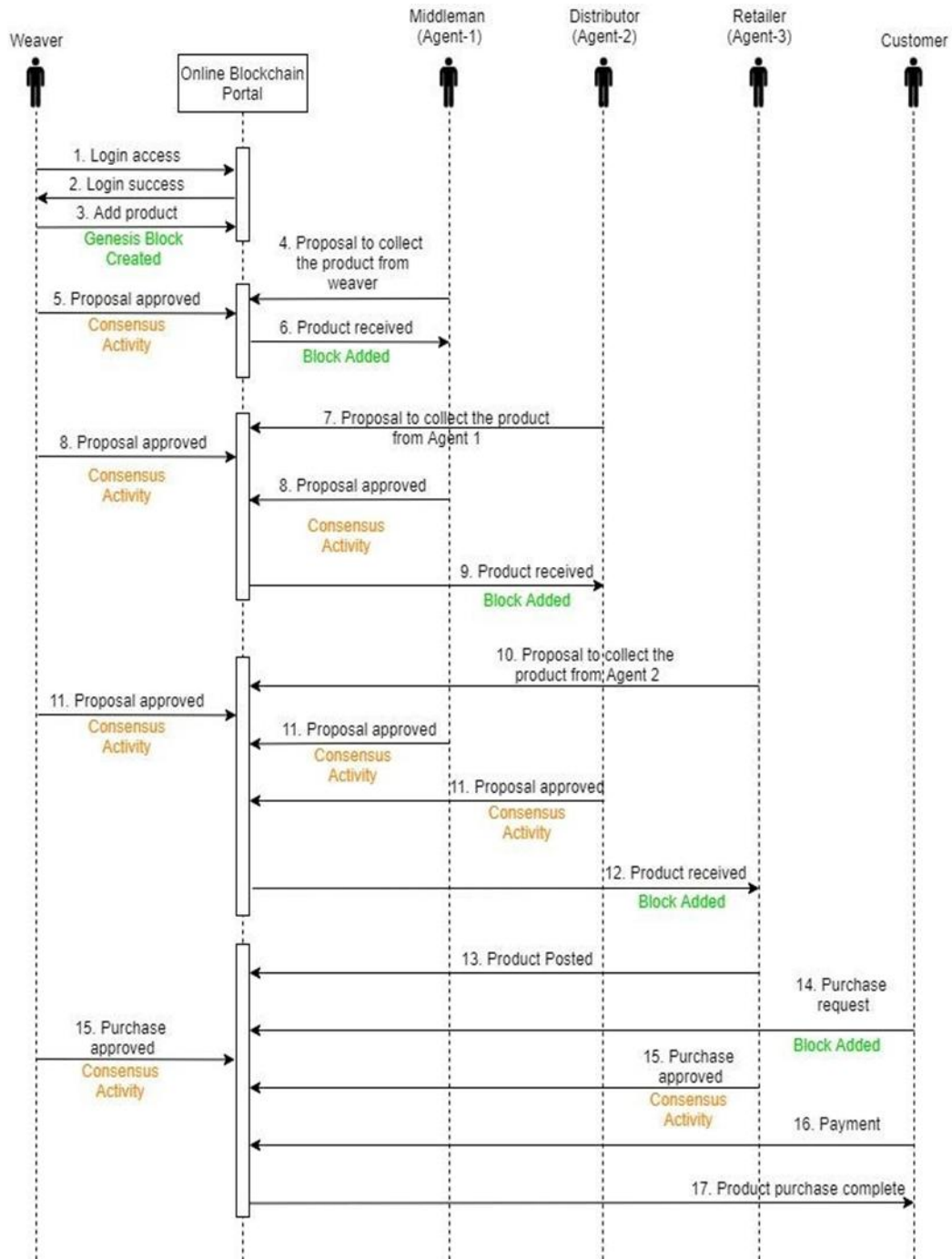


Figure 4.15: Sequence Diagram

4.8 Summary

This chapter focuses on the research methods applied from the formulation of the research problem to the proposed solution. Prior to this, some important assumptions have been made, which will affect the design of the solution Songketchain. Songketchain is

composed of three main pillars, which are a blockchain-based supply chain system, retail chain transparency and traceability. From the perspective of various stakeholders, the process of the blockchain-based supply chain system is described in detail. The last part of Songketchain, the evaluation model, is also constructed by quantifying and formulating transparency and traceability, which will be highlighted in the next chapter.

CHAPTER 5

IMPLEMENTATION AND ANALYSIS

5.1 Introduction

This chapter will evaluate SongketChain based on transparency and traceability. The first step will be populating the data that will be used for experimental purposes for both frameworks. Section 5.2.3 discuss on the implementation of SongketChain and section 5.3 discuss on the analysis of SongketChain.

5.2 SongketChain

This section will discuss the main things which are the technical specifications that are required in implementing SongketChain. The implementation is then explained in detail on how a transaction happened in the system accompanying the screenshot of the system.

5.2.1 Technical Specifications of SongketChain

Table 5.1: Technical Specifications of SongketChain

Requirement & Specifications	Version
Windows	10
Node.js	16.14.0
Npm package manager	8.3.1
Solidity	6.0.0
Ganache	2.5.4
Interplanetary File System (IPFS)	0.13.0
Metamask	10.11.3
XAMPP (Cross-Platform, Apache, MySQL, PHP, and Perl)	3.3.0

All the technical requirements and specifications of SongketChain are presented in Table 5.1. Each version of the versioning of specification is stated clearly while implementing SongketChain. These specifications are being deployed as it is being suggested as stable release by the official developer documentation at that time.

5.2.2 Applying SongketChain

Based on the transaction flow of the conceptual framework as shown in Figure 4.1 which depicts the general blockchain component interacting with each other when a transaction is made. Figure 5.1 presents a specific version of SongketChain applied.

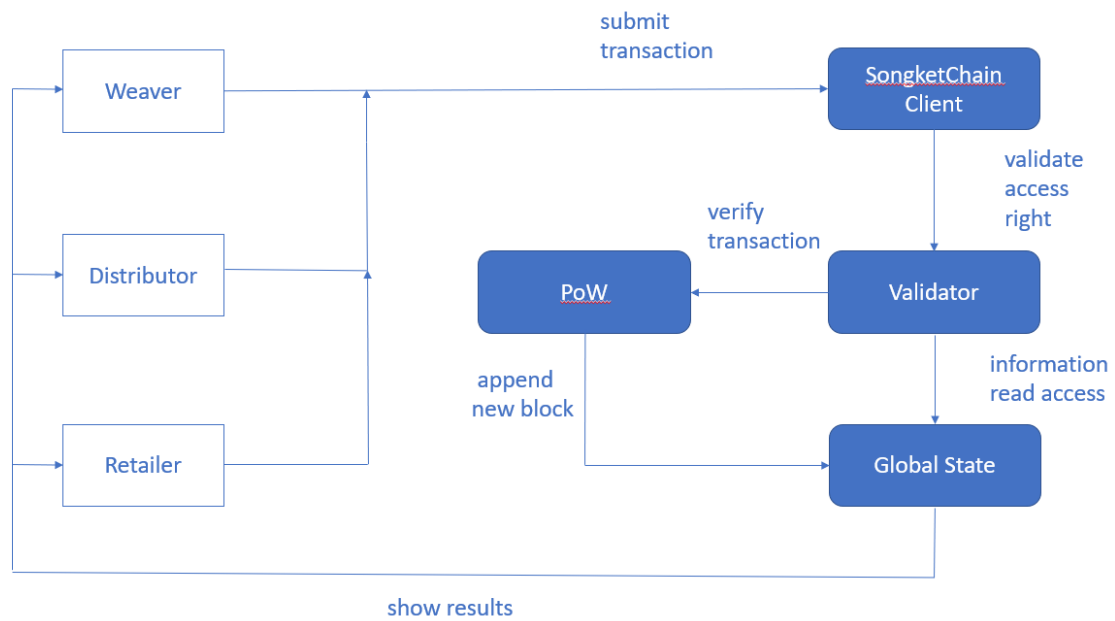


Figure 5.1: SongketChain Flow Process

Based on Figure 5.1, all users (weaver, distributor, and retailer) can have read-write access via the SongketChain client. Weaver will notify the validator in the blockchain network by being the first actor to create the product. The validator will examine to validate the access right of the user that has submitted the transaction. The validator then will communicate with the transaction processor which is the backend of the

Ethereum local blockchain (Ganache), if the transaction is valid, it will undergo the Pow (Proof of Work) consensus for the creation of the new block.

Product added via SongketChain client only applicable to the weavers because only weavers can add the songket product via the client including the songket details (Date created, location, etc). Other actors can only update the location of the product except for the customer which can only see the details of the product. Product only can be viewed for customers through the SongketChain client.

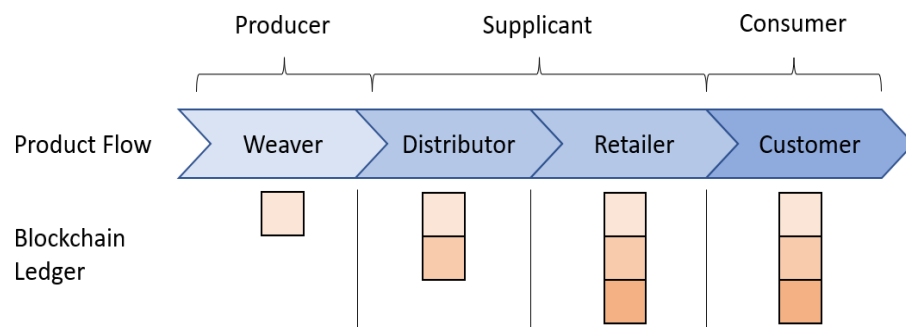


Figure 5.2: Flow of Product Blockchain Ledger

The flow on the blockchain ledger is represented as in Figure 5.2. Each transaction (create product and update location) in the system will create a new block of data in the local blockchain and each block contains transaction data that can be traced through the local blockchain. Traceability in SongketChain works by data stored in the local blockchain ledger. Each transaction (updating location of the songket) will tamper a new timestamp in the local blockchain and bind with the older block. With this timestamp, data can be traced in the SongketChain.

5.2.3 Implementation of SongketChain System

SongketChain consists of various components that are built on IPFS and on Windows. Components of SongketChain include client application, validator and database. Client applications consist of user interface, Ganache and IFPS, validator consist of Metamask and database consist of MySQL. The client application is implemented with a web app interface that is accessible at localhost once all the instances are up and running.

```
C:\Users\aixax\Desktop>ipfs daemon
Initializing daemon...
go-ipfs version: 0.11.0
Repo version: 11
System version: amd64/windows
Golang version: go1.16.12
Swarm listening on /ip4/127.0.0.1/tcp/4001
Swarm listening on /ip4/127.0.0.1/udp/4001/quic
Swarm listening on /ip4/169.254.28.198/tcp/4001
Swarm listening on /ip4/169.254.28.198/udp/4001/quic
Swarm listening on /ip4/169.254.38.14/tcp/4001
Swarm listening on /ip4/169.254.38.14/udp/4001/quic
Swarm listening on /ip4/169.254.38.2/tcp/4001
Swarm listening on /ip4/169.254.38.2/udp/4001/quic
Swarm listening on /ip4/192.168.1.3/tcp/4001
Swarm listening on /ip4/192.168.1.3/udp/4001/quic
Swarm listening on /ip6/2001:d08:e5:b988:354d:840b:c06d:7b03/tcp/4001
Swarm listening on /ip6/2001:d08:e5:b988:354d:840b:c06d:7b03/udp/4001/quic
Swarm listening on /ip6/2001:d08:e5:b988:c803:46b4:24d6:5016/tcp/4001
Swarm listening on /ip6/2001:d08:e5:b988:c803:46b4:24d6:5016/udp/4001/quic
Swarm listening on /ip6:::1/tcp/4001
Swarm listening on /ip6:::1/udp/4001/quic
Swarm listening on /p2p-circuit
Swarm announcing /ip4/127.0.0.1/tcp/4001
Swarm announcing /ip4/127.0.0.1/udp/4001/quic
Swarm announcing /ip4/192.168.1.3/tcp/4001
Swarm announcing /ip4/192.168.1.3/udp/4001/quic
Swarm announcing /ip6/2001:d08:e5:b988:354d:840b:c06d:7b03/tcp/4001
Swarm announcing /ip6/2001:d08:e5:b988:354d:840b:c06d:7b03/udp/4001/quic
Swarm announcing /ip6:::1/tcp/4001
Swarm announcing /ip6:::1/udp/4001/quic
API server listening on /ip4/127.0.0.1/tcp/5001
WebUI: http://127.0.0.1:5001/webui
Gateway (readonly) server listening on /ip4/127.0.0.1/tcp/8080
Daemon is ready
```

Figure 5.3: Initiate IPFS

Figure 5.3 shows IFPS can be initiated using a single “ipfs daemon” command to create an instance of running the IPFS locally. IPFS is a peer-to-peer (p2p) storage network. Content is accessible by peers around the world, who can share information, store information, or both. IPFS works by unique identification via content addressing, content

linking via directed acyclic graphs (DAGs) and content discovery via distributed hash tables (DHTs). Once the IPFS instance is created successfully, it will start running the IPFS node on your computer.

Figure 5.4 shows Ganache main page. Ganache is an application that creates a local blockchain for the system. Local blockchains are needed to run the system since online blockchain will consume a lot of power and time which will make the system run more slowly compared to a system that uses a local blockchain. Each of the blockchain have its own address and unique private key that can be used to link with Metamask wallets. For this system, we will only be using one blockchain for the system. Figure 5.5 shows the transaction data count for one blockchain in Ganache.

ACCOUNTS

BLOCKS

TRANSACTIONS

CONTRACTS

EVENTS

LOGS

SEARCH FOR BLOCK NUMBERS OR TX HASHES

CURRENT BLOCK
24

GAS PRICE
2000000000

GAS LIMIT
6721975

HARDFORK
MUIRGLACIER

NETWORK ID
5777

RPC SERVER
HTTP://127.0.0.1:7545

MINING STATUS
AUTOMINING

WORKSPACE
MURKY-DUST

SWITCH

MNEMONIC

give attend news slight loop drive depth bachelor popular island reject range

HD PATH
m/44'/60'/0'/0'/0/account_index

ADDRESS
0xfF698aef46C4B530F11d6bFf713f579A35d33c0c

BALANCE
99.85 ETH

TX COUNT
24

INDEX
0

ADDRESS
0x0674239754C5EDF08A001ec37D8D1aeA40a95EB4

BALANCE
100.00 ETH

TX COUNT
0

INDEX
1

ADDRESS
0x2E8Bd5884cE503Cd7800e3E0B8b48c2e5E00a968

BALANCE
100.00 ETH

TX COUNT
0

INDEX
2

ADDRESS
0x807abAA4dC50D1eA00C0c9d58a539b616f1F434c

BALANCE
100.00 ETH

TX COUNT
0

INDEX
3

ADDRESS
0x311F434816dB6A5015a3E685ccf4eF65C1b4C602

BALANCE
100.00 ETH

TX COUNT
0

INDEX
4

ADDRESS
0x09D699a7A28EC1d0AB16FD5D2506d5D91A01B1B1

BALANCE
100.00 ETH

TX COUNT
0

INDEX
5

ADDRESS
0xC797B7C4abAC84D54d50A29D08044886b010d642

BALANCE
100.00 ETH

TX COUNT
0

INDEX
6

Figure 5.4: Ganache main page

BLOCK 3	MINED ON 2022-02-09 15:55:03	GAS USED 797679	1 TRANSACTION
BLOCK 2	MINED ON 2022-02-09 15:39:24	GAS USED 797667	1 TRANSACTION
BLOCK 1	MINED ON 2022-02-09 14:37:30	GAS USED 797667	1 TRANSACTION
BLOCK 0	MINED ON 2022-02-09 14:32:37	GAS USED 0	NO TRANSACTIONS

Figure 5.5: Transaction details

The account address in the Ganache is the account that was allocated for testing purposes with some Ethereum (ETH). Each account has a different set of addresses and for this case, address 0xFF698aef46C4B530F11d6bFf713f579A35d33c0c is used for the transaction in the SongketChain. Available ETH will be shown under the balance tab and transaction count will be shown on the Tx County. Based on the diagram, the current balance for the current account is 98.85 ETH and the transaction count is 24. The index tab shows the number of accounts available in the Ganache local blockchain. The current block shows the total block created in all the accounts. Gas used is the transaction fee that is allocated for each transaction in the SongketChain.

Then, MetaMask will be launched from the browser to connect with the local blockchain which is Ganache. Figure 5.6 shows how to launch and connect MetaMask with local blockchain. Chain ID and RPC URL should be the same with the Ganache to connect the blockchain with MetaMask. Figure 5.7 shows once the blockchain network in the MetaMask (in this use case, the network name is test) and Figure 5.8 shows once the account relates to the local blockchain.

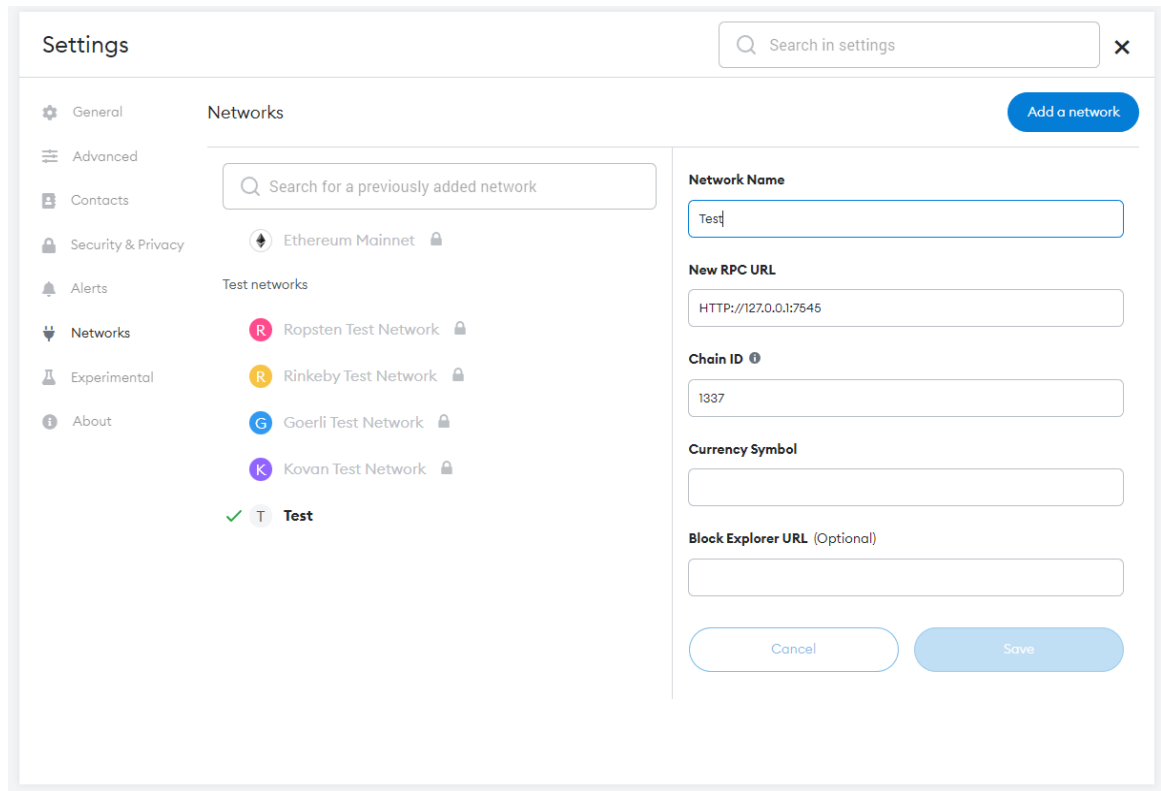


Figure 5.6: Add network interface.

Figure 5.6 shows the page for adding the local blockchain network into MetaMask. RPC URL and Chain ID are provided by the local blockchain Ganache to be used in the MetaMask to connect the local blockchain with the wallet. RPC (Remote Procedure Call) URL is an endpoint that enables an application (SongketChain) to communicate with a blockchain network (Ganache). A chain ID is a unique identifier that represents a blockchain network. It is used to distinguish different blockchain networks from each other and to ensure that transactions and messages are sent to the correct network.

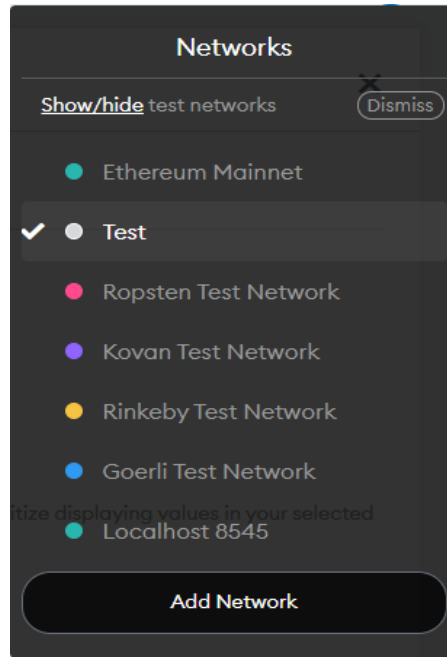


Figure 5.7: Added network.

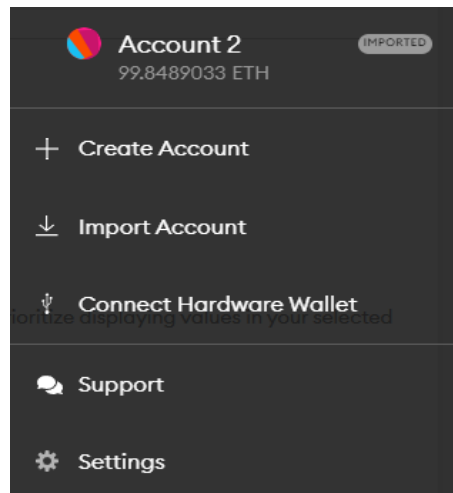


Figure 5.8: Connected account

Next, before running the system, certain codes need to be compiled in Remix IDE to get the contract ABI and contract address. The Contract Application Binary Interface (ABI) is the standard way to interact with contracts in the Ethereum ecosystem, whether off-chain or between contracts. A contract address is an address on the Ethereum blockchain that hosts a collection of code that performs a function. These functions of a

contract address are performed when a transaction with associated input data (contract interaction) is executed at the contract address. Figure 5.9 shows the page for Remix IDE and the tab for contract ABI. Once compiled, the code needs to be deployed within the Remix IDE by using InjectedWeb3 to get the contract address. Figure 5.10 shows the tab for deploy and contract address option.

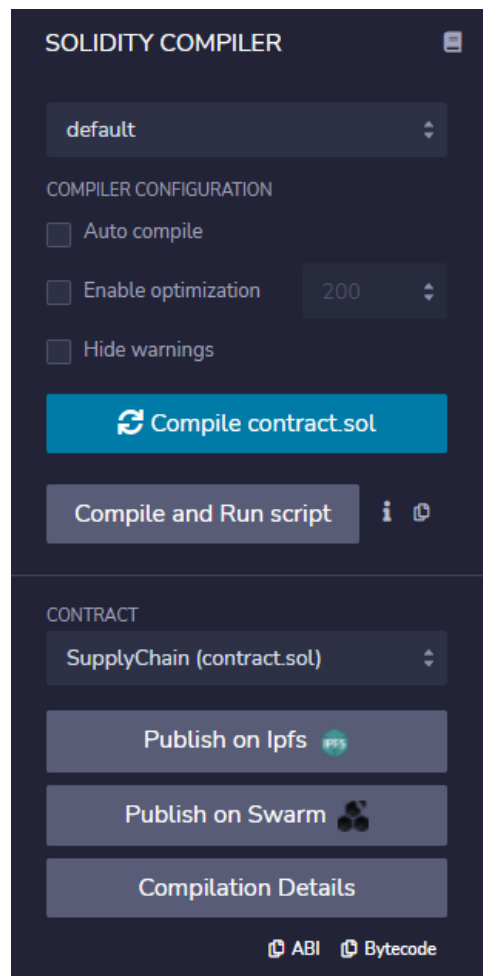


Figure 5.9: Compile tab in Remix IDE

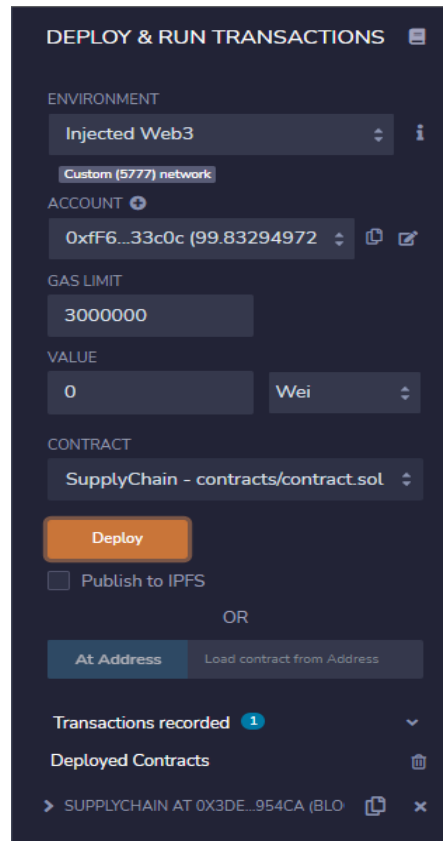


Figure 5.10: Deploy tab in Remix IDE

Once the contract address and contract ABI have been obtained, respective contract address and contract ABI are used in the app.js file in the root folder. This is important for the system to run normally since the contracts that have been compiled and deployed are used in the system. Before running the system, the database of the system needs to be online (XAMPP) to register a new user. Then, the system should run normally at the local host. Figure 5.11 shows the homepage for the system which consists of two buttons which are login and register. For new users, they need to register first before they can use the system.

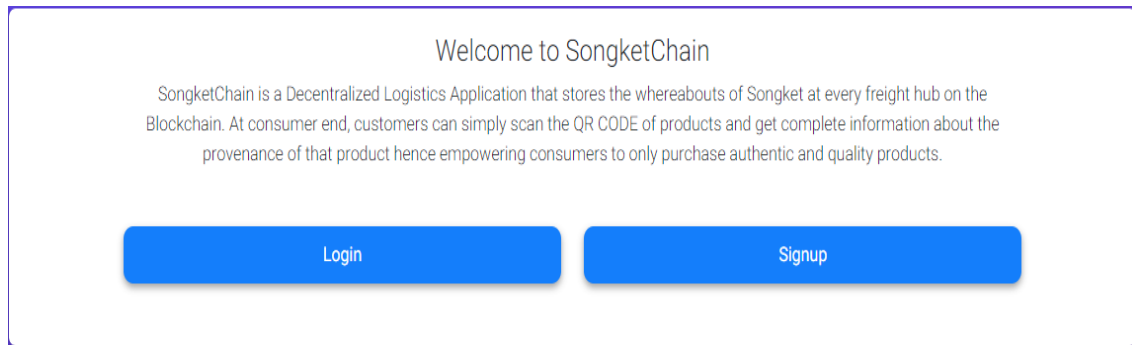


Figure 5.11: Home page for SongketChain

During the registration process, the user needs to register themselves according to their role to ensure smooth user experience while using the system. Figure 5.12 shows the registration page for new users. All the details gained will be stored in the local database (XAMPP).

Figure 5.12: Registration page for SongketChain

Once logged in, the system will detect whether the logged user is a songket manufacturer, distributor, retailer, or customer. Only songket manufacturers can create a new product (songket) in the system. Before creating a new product, songket manufacturers need to upload the image of the songket into the IPFS by using the upload

image button. Figure 5.13 shows the IPFS upload file page and Figure 5.14 shows the product creation page of a new songket.

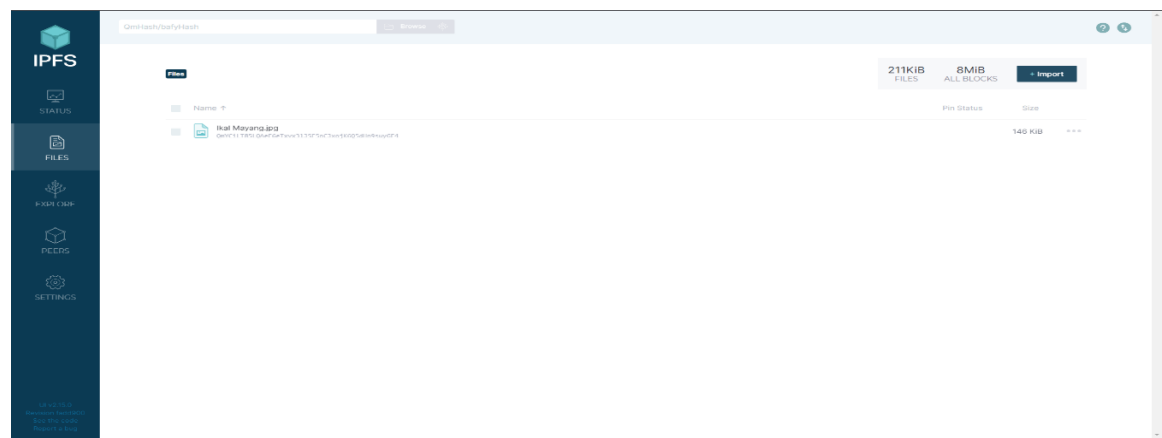


Figure 5.13: Image upload in IPFS

Please fill product details

Songket Name

Ikal Mayang

Distributor Name

Encik Zamarul

Retailer Name

Puan Hidayah

Place of Origin

Bau, Lundu

Batch Number

0001

Motive Link

<https://ipfs.io/ipfs/QmYCiLT85LQAeF6eTxvx31JSF5nCxojK6Q5dHn9>

Register Item

Figure 5.14: Create product page

Once the product is created, a QR code will be generated for each respective product. QR code can be used to scan the product shipment location and gain product information. Only songket manufacturer, distributor and retailer can update the location of

the product whereas customers can only check the product information in the system. Figure 5.15 shows QR code scanner to update shipping location information and Figure 5.19 shows checked product by using QR code scanner.

In the blockchain ledger, a new block is created when a new product is added into the system by the weaver. This block contains the transaction details such as transaction hash and block hash which can be used to trace the flow of the product in the supply chain. Figure 5.15 shows the representation of the block in the blockchain ledger.

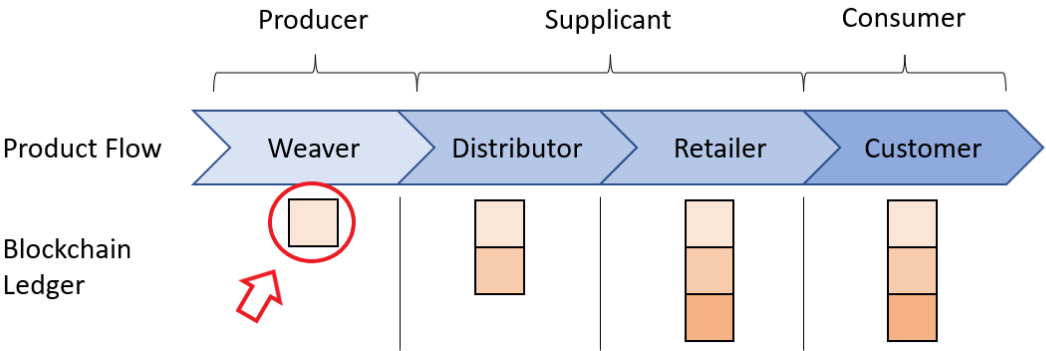


Figure 5.15: First Block of Data Creation

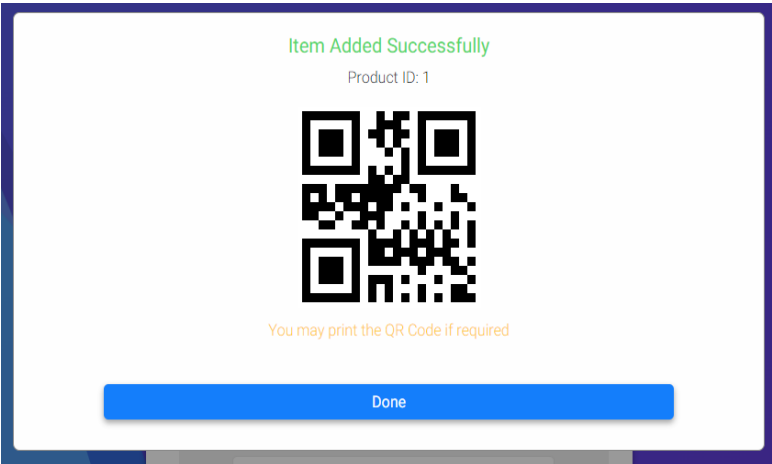


Figure 5.16: Product created success

Once the product is created with the details included, the system will prompt a success message stating that the product is successfully created. The system will include an image of QR code for the users (manufacturers, distributors, and retailers) to use it for location update.

Figure 5.17: QR code scanner page

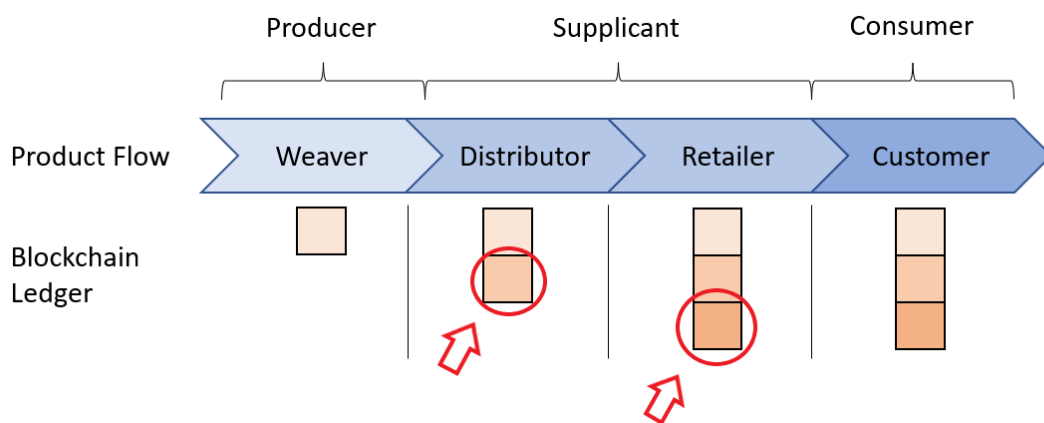


Figure 5.18: Second and Third block of Data Creation

Figure 5.18 shows the block creation by updating the location of the product in the system. Each supplicant that updates the location of the product will create a transaction that will create a new block in the blockchain ledger. The distributor and the

retailer will add a new block into the ledger except for customers since there is no data needed to be added from the customers.

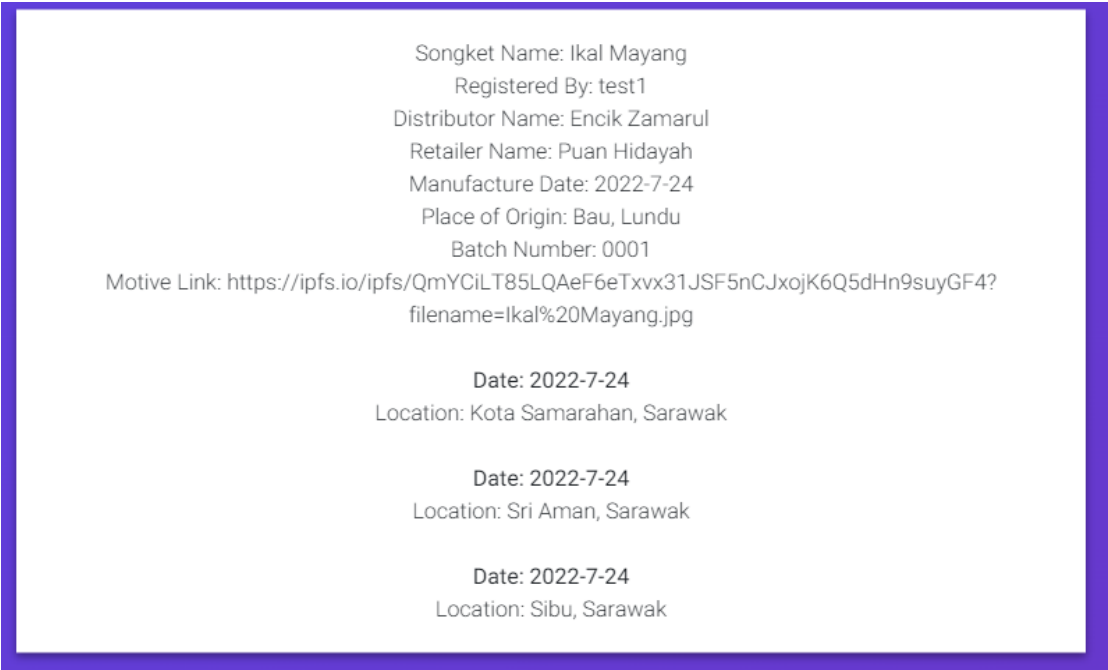


Figure 5.19: Checked product information

Every time the location of the product is updated, a new transaction block will be added to the local blockchain Ganache. With this feature, each transaction can be traced within the blockchain. Figure 5.20 shows one of the transaction details in the block.

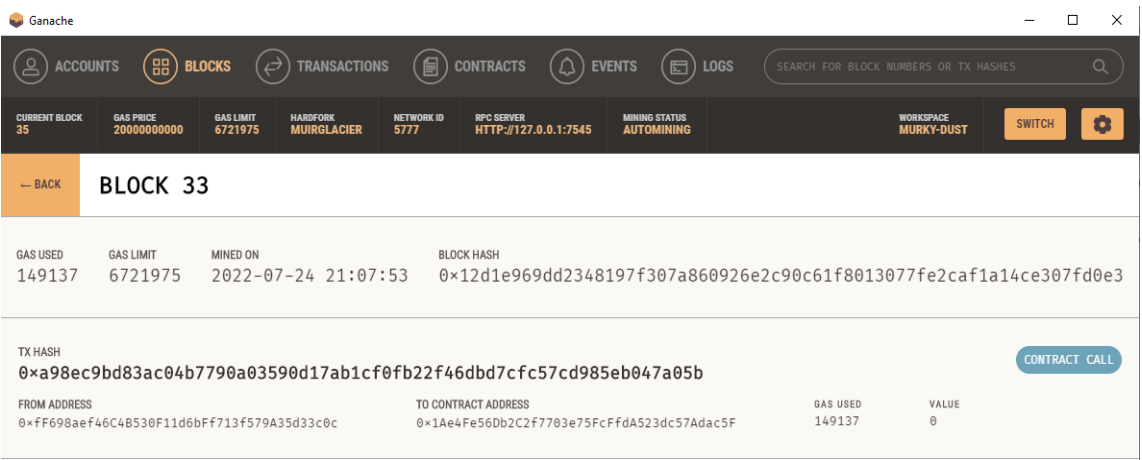


Figure 5.20: Transaction block Data

5.3 Analysis of SongketChain

The analysis of SongketChain will be using the data from the SongketChain. Figure 5.21 shows the data for each transaction is available to the weaver, distributor, retailer and customer. Based on the steps to find supply chain transparency and traceability in Section 2.2 (page 24), a subset of data of supplier (Weaver) and transaction data (Songket) is disclosed as shown in Figure 5.21. Each transaction will create a new block in the local blockchain (Ganache) and can be traced based on the block hash and parent hash.

Songket Name	Suppliers Data (Transparency)
Weaver Name	
Distributor Name	
Retailer Name	
Manufactured Date	
Place of Origin	Transaction Data (Traceability)
Batch Number	
Motive Link	
Date	
Location	

Figure 5.21: Suppliers and Transactions data from Weaver to Distributor

5.3.1 Overall Supply Chain Transparency

Table 5.2: Overall Supply Chain Transparency

SongketChain System	Supply Chain Transparency (%)		
	Weaver to Distributor	Distributor to Retailer	Retailer to Customer
SongketChain	$\frac{8}{8} \times 100\% = 100$	$\frac{9}{9} \times 100\% = 100$	$\frac{10}{10} \times 100\% = 100$

	Weaver to Distributor	Distributor to Retailer	Retailer to Customer
	Songket Name	Songket Name	Songket Name
	Weaver Name	Weaver Name	Weaver Name
	Distributor Name	Distributor Name	Distributor Name
	Retailer Name	Retailer Name	Retailer Name
	Manufactured Date	Manufactured Date	Manufactured Date
	Place of Origin	Place of Origin	Place of Origin
	Batch Number	Batch Number	Batch Number
	Motive Link	Motive Link	Motive Link
	Date	Date	Date
	Location 1	Location 1	Location 1
		Location 2	Location 2
			Location 3
Number of Data	10	11	12
Increment of Data	0	1	1
Total Number of Data	10	11	12

Figure 5.22: Supply Chain transparency of SongketChain

Figure 5.22 shows the addition of new data based on Table 5.2. The number of data obtained from Weaver to Distributor, Distributor to Retailer, and Retailer to Customer is 1. Each added data is the updated location of the songket product from each party in SongketChain.

Table 5.2 shows the result of overall Supply Chain Transparency. At the first stage (weaver to distributor) of the result, there are a total of 10 data. Second stage from distributor to retailer, there is an increment of 1 data which consists of updated location and date which consist of 11 data. On the last stage of the supply chain (retailer to customer), the retailer will update the location and time. Increment of 1 data in the supply chain and present the data updated to the customer which will have 12 data in total by the end of the supply chain.

5.3.2 Overall Supply Chain Traceability

Table 5.3: Overall Supply Chain Traceability

SongketChain System	Supply Chain Traceability (%)		
	Weaver to Distributor	Distributor to Retailer	Retailer to Customer
SongketChain	$\frac{2}{2} \times 100\% = 100$	$\frac{3}{3} \times 100\% = 100$	$\frac{4}{4} \times 100\% = 100$

Table 5.3 shows the result of overall Supply Chain Traceability. At the first stage (weaver to distributor) of the result, there are a total of 2 blocks in the local blockchain (Ganache). At the second stage (distributor to retailer) of the result, there is an increment of a block which is one block added to the local blockchain. At the final stage (retailer to customer) of the result, another block is added to the local blockchain. For each transaction in the SongketChain, a new block is created and added to the local blockchain. The main reason for the created block in the first stage is because of creation of the songket product and updated location of the songket product. Each block is related to the previous block and can be traced by using the block hash and parent hash.

5.4 Summary

This chapter mainly discusses the analysis and the implementation of the SongketChain. Technical requirements and specification of the framework are listed before the implementation of the system. Implementation of the framework is then discussed step by step according to the flow of the transaction in the implemented framework by applying the supply chain concept. The analysis section discusses the transparency and traceability of the supply chain in the SongketChain as a performance indicator for the system and the results of the analysis are put into the table view for better understanding of the performance. Overall, SongketChain has proved a great transparency and traceability features to the user that uses the system for buying authentic songket from an authentic weaver.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Blockchain technology, initially launched 15 years ago as the backbone of Bitcoin, has matured significantly and expanded into various industries, including manufacturing, healthcare, and finance. Early studies on blockchain highlighted its ability to enhance transparency and traceability in the supply chain, offering significant potential for improving operational efficiency and trust. These studies have shown positive impacts, especially in supply chain management, by eliminating centralized control and providing real-time, immutable data. However, despite the promise, challenges remain, as blockchain solutions often struggle to meet the demands of real-time business use cases.

One of the key areas where blockchain can have a profound impact is in improving transparency and traceability. Blockchain can remove the need for centralized third parties by decentralizing control, which can fundamentally transform business, communication, and even governance systems. In this research, blockchain's capacity for enhancing transparency and traceability is specifically explored within the context of the **songket industry**, a traditional textile industry with complex supply chain processes.

6.2 Achievements

Ganache by Ethereum (private blockchain environment) was implemented in the supply chain use case in the songket industry. Aim of this research is to

design, implement and analyze the usage of blockchain technology in the songket industry by implementing supply chain management framework, complying with traceability and transparency which has been achieved successfully.

This study proves that Ethereum public blockchain is the most suitable implementation for Songketchain. Ganache provides an easy setup that could bind with the Songketchain framework which includes the usage of smart contracts that contains songket information. Smart contract offers customization that can store information based on the use case scenario, while Ganache provides local blockchain that could be traced on the hash number.

Songketchain has successfully achieved the objective of evaluating the transparency and traceability of blockchain technology. With the formulation of supply chain transparency and traceability metrics that derive from OTIF and based on the definition of supply chain transparency and traceability introduced by Tsai (2018); Ethereum has been successfully assessed.

6.3 Significance of Contributions

The core motivation of this research is to explore how blockchain technology affects supply chain transparency and traceability, especially in industries like songket where authenticity and craftsmanship are crucial. While numerous studies have shown the general benefits of blockchain in supply chain management, the novelty of this research lies in the application of blockchain to the songket industry, with a specific focus on **traceability metrics**.

Several key contributions include:

1. **Transparent Supply Chain:** Blockchain's inherent transparency helps eliminate the need for third-party verification, ensuring that all stakeholders have access to immutable and verifiable data at every stage of the supply chain.
2. **A New Metric for Traceability:** Unlike traditional supply chain systems, which rely on centralized authorities, this research introduces a metric for transparency and traceability based on **OTIF**, providing clearer insights into the performance of blockchain in real-world supply chains.

This study contributes to the growing body of literature on blockchain's potential in improving supply chain management, particularly in industries where product authenticity is of utmost importance.

6.4 Limitations

Despite the promising results and the successful implementation of the Songketchain framework, this research has several limitations:

- **Trust Among Consumers:** One of the primary challenges in adopting blockchain for supply chain management is consumer trust. While blockchain can ensure transparency and traceability, consumers must be educated about the technology and how to use it to verify product authenticity. In industries like songket, where counterfeiting is a concern, convincing consumers to trust the blockchain system and adopt it may require significant time and effort. The challenge lies in ensuring that consumers feel comfortable with the new technology and that they have the tools to verify the authenticity of the products they purchase.
- **Real-Time Implementation:** While this research demonstrated blockchain's potential in supply chain transparency and traceability, the adoption of blockchain in real-world, fast-paced supply chains requires overcoming issues such as system scalability and real-time transaction verification. Blockchain technology, particularly Ethereum, may not yet fully meet the demands of high-speed, real-time supply chains, and this could hinder its broader adoption.
- **Blockchain Adoption Challenges:** Blockchain is still in its early stages of adoption in many industries, and the technology must mature further before it can be implemented effectively at scale. The integration of blockchain into traditional industries such as songket requires overcoming regulatory hurdles, industry resistance, and the challenge of transitioning from legacy systems.

6.5 Proposed Framework (Abolishing Monopoly)

A key feature of this research is the Songketchain framework, which proposes a decentralized supply chain system that eliminates monopolistic control by central authorities. Traditional supply chain systems often rely on intermediaries and centralized organizations to validate transactions, which can introduce inefficiencies and trust issues. The Songketchain framework, based on Ethereum's public blockchain, abolishes the need for such centralized entities by creating a decentralized network where all stakeholders (artisans, manufacturers, retailers, and consumers) have equal access to transparent and immutable data.

By using smart contracts and a decentralized ledger, the framework ensures that all participants can track the product's history, verify its authenticity, and ensure that it complies with ethical production practices. This abolition of monopoly empowers smaller players in the supply chain and democratizes access to data, which can be particularly beneficial for artisanal industries like songket, where small-scale producers may be at a disadvantage in traditional supply chains.

6.6 Future Works

While the objectives of this research have been successfully achieved, there are several areas for future improvement and exploration:

- **Evaluation of Other Blockchain Frameworks:** While this research focused on Ethereum, other blockchain frameworks, such as Hyperledger Fabric or Hyperledger Sawtooth, should be evaluated to determine which platform best suits supply chain applications for traceability and transparency.

- **Refinement of Traceability Metrics:** The traceability metric based on OTIF should be reviewed and possibly refined in future studies. As blockchain technology continues to evolve, new metrics for assessing transparency and traceability may emerge that offer a more comprehensive evaluation of supply chain performance.
- **Non-Functional Aspects:** Future research could explore non-functional aspects of blockchain, such as performance, scalability, and security. As supply chains grow and become more complex, these factors will become increasingly important in ensuring the successful adoption of blockchain technology.

6.7 Summary

Blockchain technology has enormous potential to transform a variety of industries, including supply chain management. However, challenges remain, particularly in terms of adoption and real-world implementation. The key to successful blockchain adaptation lies in eliminating trust from centralized third parties and fostering consumer confidence in the technology.

This research demonstrates that Ethereum blockchain, through the Songketchain framework, can improve supply chain transparency and traceability, offering a viable solution for industries like songket that require robust systems for ensuring authenticity. Despite the current limitations, such as trust among consumers and real-time scalability issues, blockchain's role in the future of supply chain management is promising. As the technology matures, it is likely to

accelerate the transformation of traditional industries and offer more transparent and efficient systems for tracking products across their lifecycle.

REFERENCES

- Angeles, R. (2005). RFID technologies: Supply-chain applications and implementation issues. *Information Systems Management*, 22(1), 51-65.
<https://doi.org/10.1201/1078/44912.22.1.20051201/85739.7>
- Ab. Aziz, A. (2019). Malay songket motif: A design and acumen of weavers. *International Journal of INTI*, 23(2), 91-98.
<https://doi.org/10.1080/01265822.2019.1585012>
- Bambrough, B. (2021). What is going on with Bitcoin rival Stellar? *Forbes*.
<https://www.forbes.com/sites/billybambrough/2019/09/18/what-is-going-on-with-bitcoin-rival-stellar/#6da230a63d25>
- Björk, A., Erlandsson, M., Häkli, J., Jaakkola, K., Nilsson, Å., Nummila, K., Puntanen, V., & Sirkka, A. (2011). Monitoring environmental performance of the forestry supply chain using RFID. *Computers in Industry*, 62(8), 830-841. <https://doi.org/10.1016/j.compind.2011.08.001>
- Cachin, C. (2016, July). Architecture of the Hyperledger blockchain fabric. In *Workshop on distributed cryptocurrencies and consensus ledgers* (Vol. 310, No. 4, pp. 1-4).
- Chen, J., Cai, T., He, W., Chen, L., Zhao, G., Zou, W., & Guo, L. (2020). A blockchain-driven supply chain finance application for the auto retail industry. *Entropy*, 22(1), 95. <https://doi.org/10.3390/e22010095>

- Chen, T., Li, Z., Zhu, Y., Chen, J., Luo, X., Lui, J. C., Lin, X., & Zhang, X. (2020). Understanding Ethereum via graph analysis. *ACM Transactions on Internet Technology*, 20, 1-32. <https://doi.org/10.1145/3381036>
- Chong, Y. Y. (2022). The two masters of the calligraphy, Peng Qingqin and Wang Jia. <https://caotangmen.org/wjqpqq/>
- Costa, C., Antonucci, F., Pallottino, F., Aguzzi, J., Sarriá, D., & Menesatti, P. (2012). A review on agri-food supply chain traceability by means of RFID technology. *Food and Bioprocess Technology*, 6, 353-366. <https://doi.org/10.1007/s11947-012-0958-7>
- Coyler, A. (2021). Practical Byzantine fault tolerance. *The Morning Paper*. <https://blog.acolyer.org/2015/05/18/practical-byzantine-fault-tolerance/>
- Egels-Zanden, N., Hulthen, K., & Wulff, G. (2015). Trade-offs in supply chain transparency: The case of Nudie Jeans Co. *Journal of Cleaner Production*, 107, 95-104. <https://doi.org/10.1016/j.jclepro.2014.04.074>
- Ethereum. (2023). Proof-of-stake. <https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/>
- Figorilli, S., Antonucci, F., Costa, C., Pallottino, F., Raso, L., Castiglione, M., & Menesatti, P. (2018). A blockchain implementation prototype for the electronic open source traceability of wood along the whole supply chain. *Sensors*, 18(9), 3133. <https://doi.org/10.3390/s18093133>
- Gardner, T. A., Benzie, M., Börner, J., Dawkins, E., Fick, S., Garrett, R., Godar, J., Grimard, A., Lake, S., Larsen, R. K., Mardas, N., McDermott, C. L., Meyfroidt, P., Osbeck, M., Persson, M., Sembres, T., Suavet, C.,

- Strassburg, B., Trevisan, A., ... Wolvekamp, P. (2018). Transparency and sustainability in global commodity supply chains. *World Development*, 112, 1-10. <https://doi.org/10.1016/j.worlddev.2018.05.025>
- Hammerschmidt, C. (2017). Consensus in blockchain systems. *Medium*. <https://medium.com/@chrshmmmr/consensus-in-blockchain-systems-in-short691fc7d1fefe>
- Hayes, A. (2019, September 15). Is Ethereum more important than Bitcoin? *Investopedia*. <https://www.investopedia.com/articles/investing/032216/ethereum-more-important-bitcoin.asp>
- Hu, B., Xie, H., Ma, Y., Wang, J., & Zhang, L. J. (2018, June). A robust retail POS system based on blockchain and edge computing. In *International Conference on Edge Computing* (pp. 99-110). Springer, Cham.
- Holland, M., Stjepandić, J., & Nigischer, C. (2018, June). Intellectual property protection of 3D print supply chain with blockchain technology. In *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)* (pp. 1-8). IEEE.
- Hyperledger Foundation. (2018). Hyperledger Fabric. <https://www.hyperledger.org/use/fabric>
- Ibrahim, Z. (2020). Melestari seni sulaman keringkam. *Kosmo!* <https://www.kosmo.com.my/2020/12/15/melestari-seni-sulaman-keringkam/>

- Isa, I., Zulkifli, A., & Suhani, N. (2021). Songket asli bakal berkubur. *Harian Metro*. <https://www.hmetro.com.my/utama/2019/11/513725/songket-asli-bakal-berkubur>
- Jain, P. (2021). The ABCs of Kafka in Hyperledger Fabric. *Medium*. <https://codeburst.io/the-abcs-of-kafka-in-hyperledger-fabric-81e6dc18da56>
- Jamaluddin, I. H. (2019). Songket rajang mengagumkan. *Harian Metro*. <https://www.hmetro.com.my/hati/2019/04/443379/songket-rajang-mengagumkan>
- Kaul, C. (2010). Auto-ID in timber supply chain—Identifying single logs using RFID tags. In *Proceedings of the FORMEC Conference*, Padova, Italy, 11–14 July 2010 (pp. 1-7).
- Kim, S. K., Ma, Z., Murali, S., Mason, J., Miller, A., & Bailey, M. (2018, October). Measuring Ethereum network peers. In *Proceedings of the Internet Measurement Conference 2018* (pp. 91-104).
- Khan, A., Balan, K., Javed, Y., Tarmizi, S., & Abdullah, J. (2019). Secure trust-based blockchain architecture to prevent attacks in VANET. *Sensors*, 19(22), 4954. <https://doi.org/10.3390/s19224954>
- Kheng, J. N. S., & Ngo, J. (2010). Sustaining the magnificent craft of songket weaving in Malaysia. In *Proceedings of the 12th Biennial Textile Society of America Symposium* (pp. 1-12).
- Kumar, P. (2021). Understanding consensus algorithm. *Medium*. <https://medium.com/@pravindia/understanding-consensus-algorithm-ee73162f6c50>

- Li, M., Shao, S., Ye, Q., Xu, G., & Huang, G. (2020). Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail. *Robotics and Computer-Integrated Manufacturing*, 65, 101962. <https://doi.org/10.1016/j.rcim.2020.101962>
- Lucas, B., & Rafael, P. V. (2019). Consensus algorithm for a private blockchain. In *2019 IEEE* (pp. 978-1-7281-1190-2/19).
- Malaysian Handicraft Development Corporation. (2016). *Laporan Tahunan 2016*. <https://www.kraftangan.gov.my/en/info/annual-report/laporan-tahunan-2016>
- McDermott, C. L. (2014). REDDuced: From sustainability to legality to units of carbon—The search for common interests in international forest governance. *Environmental Science and Policy*, 35, 12-19.
- Ministry of International Trade and Industry. (2018). *MITI Report 2018*. https://www.miti.gov.my/miti/resources/MITI%20Report/MITI_Report_2018.pdf
- Mol, A. P. J. (2009). *Environmental reform in the information age: The contours of informational governance*. Cambridge University Press.
- Mol, A. P. J. (2015). Transparency and value chain sustainability. *Journal of Cleaner Production*, 107, 154-161. <https://doi.org/10.1016/j.jclepro.2013.11.012>
- Randall, M. (2018). Blockchain consensus algorithms: An early days overview. *Medium*. <https://medium.com/coinmonks/blockchain-consensus-algorithms-an-early-days-overview-2973f0cf49c6>

- Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system.
<https://bitcoin.org/bitcoin.pdf>
- Nawawi, N. Md., Aziz, A., Legino, R., Ahmad, N. H., & Ismail, N. H. (2015).
The nature of Malay songket textile patterns. *Business and Management
Quarterly Review*, 6(2/3), 41-56.
[https://www.researchgate.net/publication/315685841_THE_NATURE_OF
_MALAY_SONGKET_TEXTILE_PATTERNS](https://www.researchgate.net/publication/315685841_THE_NATURE_OF_MALAY_SONGKET_TEXTILE_PATTERNS)
- Picchi, G., Kühmaier, M., Marques, D., & de Dios, J. (2015). Survival test of
RFID UHF tags in timber harvesting operations. *Croatian Journal of
Forest Engineering*, 36, 165-174.
- Pizzi, A., Despres, A., Mansouri, H. R., Leban, J. M., & Rigolet, S. (2006). Wood
joints by through-dowel rotation welding: Microstructure, ¹³C-NMR, and
water resistance. *Journal of Adhesion Science and Technology*, 20, 427-
436.
- Politou, E., Casino, F., Alepis, E., & Patsakis, C. (2019). Blockchain mutability:
Challenges and proposed solutions. *IEEE Transactions on Emerging
Topics in Computing*, 1-1. <https://doi.org/10.1109/tetc.2019.2949510>
- Sabrina, S. (2023). This Sarawakian started a handmade sape brand at 22 that's
still going strong 6 years in. *Vulcan Post*.
[https://vulcanpost.com/839011/shape-sape-handmade-wooden-traditional-
kuching-sarawak-malaysia/](https://vulcanpost.com/839011/shape-sape-handmade-wooden-traditional-kuching-sarawak-malaysia/)
- Scott, J. C. (1998). *Seeing like a state: How certain schemes to improve the
human condition have failed*. Yale University Press.

- Sigurdsson, V., Larsen, N. M., Pálsdóttir, R. G., Folwarczny, M., Menon, R. G. V., & Fagerstrøm, A. (2022). Increasing the effectiveness of ecological food signaling: Comparing sustainability tags with eco-labels. *Journal of Business Research*, 139, 1099-1110.
<https://doi.org/10.1016/j.jbusres.2021.10.052>
- Szabo, N. (1994). Smart contracts. <http://szabo.best.vwh.net/smart.contracts.html>
- Treiblmaier, H., & Garaus, M. (2022). Using blockchain to signal quality in the food supply chain: The impact on consumer purchase intentions and the moderating effect of brand familiarity. *International Journal of Information Management*, 68, 102514.
<https://doi.org/10.1016/j.ijinfomgt.2022.102514>
- Tsai, K. (2018). Transparency vs. traceability: What's the difference?
<https://www.transparency-one.com/transparency-vs-traceability-whats-the-difference/>
- Tzoulis, I., & Andreopoulou, Z. (2013). Emerging traceability technologies as a tool for quality wood trade. *Procedia Technology*, 8, 606-611.
- Wan Abdul Kadir. (1993). *Perspektif Sosio-Budaya Melayu*. Masfami Enterprise.
- Wethey, E. (2004). Creative commodification of handicrafts, the encounter between the export market and the indigenous weaver: Comparisons of Latin American weaving communities. *Lambda Alpha Journal*, 35, 2-28.
- Wust, K., & Gervais, A. (2021). Do you need a blockchain? *IEEE Xplore*.
<https://ieeexplore.ieee.org/document/8525392>

- Viriyasitavat, W., & Hoonsoon, D. (2019). Blockchain characteristics and consensus in modern business processes. *Journal of Industrial Information Integration*, 13, 32-39. <https://doi.org/10.1016/j.jii.2018.12.001>
- Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2018). *NISTIR 8202 blockchain technology overview*. National Institute of Standards and Technology, U.S. Department of Commerce. <https://doi.org/10.6028/NIST.IR.8202>
- Yang, C. (2019). Maritime shipping digitalization: Blockchain-based technology applications, future improvements, and intention to use. *Transportation Research Part E: Logistics and Transportation Review*, 131, 108-117.
- Yurnida, L., Riviyusnita, R., & Utoyo, M. (2020). Perlindungan hukum terhadap produk lokal tenun songket Palembang. *Disiplin: Majalah Civitas Akademika Sekolah Tinggi Ilmu Hukum Sumpah Pemuda*, 26-38. <https://doi.org/10.46839/disiplin.vi.32>
- Zhang, M., Sas, C., Lambert, Z., & Ahmad, M. (2019). Designing for the infrastructure of the supply chain of Malay handwoven songket in Terengganu. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-14). <https://doi.org/10.1145/3290605.3300716>
- Zhao, W., Yang, S., & Luo, X. (2019, March). On consensus in public blockchains. In *Proceedings of the 2019 International Conference on Blockchain Technology* (pp. 1-5).