Palm Oil traceability: Blockchain meets supply chain

by

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ABSTRACT

There is a current lack of visibility in the transfer of goods from farmers to oil mills, to manufacturers, to retail outlets and finally to the consumer in the palm oil industry. While leading brands have pledged to commit to a 100% sustainable certification, only 19% of global palm oil production is certified as sustainable. Emerging technologies, such as blockchain, a distributed ledger, can transform supply chain traceability as we know it and bring more transparency through the value chain, creating value to stakeholders. From a process perspective, the proposed solution leverages the mass balance, and book and claim traceability models that RSPO has defined. From a technology perspective, the proposed solution leverages blockchain, geospatial imagery classification, and IoT technologies to keep track of the flow of physical goods and sustainable palm oil certificates. From a people perspective, the proposed solution includes a set of incentive models that could be utilized in easing change management efforts.

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Contents

1. Introduction

Palm oil is the leading vegetable oil category in terms of production volume and consumption. In 2016/2017, worldwide palm oil production yielded roughly 65.5 million metric tonnes (“World vegetable oil production, 2018,”). Palm oil is used in food and for cooking, as well as for manufacturing soap, detergent, pharmaceutical products, cosmetics, biofuels and oleo products (DeCovny, 2017). Although the farming of palm trees for palm oil has a high growth rate and yield, growing palm trees is often considered an unsustainable effort because the land they grow on competes directly with rainforest and fauna. The production of palm oil has continued to reach new highs in recent years due to continuous high growth in its demand. (“Challenges in the production of palm oil,” 2016). Because of its environmental impact, and questions around the sustainability of its supply chain, there has been a surge in public scrutiny and awareness of palm oil.

Cultivation of oil palms has expanded more in the past ten years than cultivation of any other crop. Because oil palms grow only in a tropical climate, large areas of rainforest are often cut down to make way for palms – with greenhouse gases being released as a result of slash-and-burn. The changes in land use and the resulting environmental effects have sparked considerable debate among policy-makers, scientists, and the general public. The palm oil industry has been criticized for rainforest loss, CO2 emissions, and human rights violations (“Challenges in the production of palm oil, 2016).

Deforestation can be particularly seen in Indonesia and Malaysia, which are the biggest producers of the world’s palm oil. Around 85 per cent of palm oil is produced in these countries. In Indonesia some 1.7 million hectares of forests were chopped in 2015 alone. As a result, Indonesia is losing its rainforest faster than any other country in the world. (“Challenges in the production of palm oil”, 2016).

There is a current lack of visibility in the transfer of goods from farmers to oil mills, to manufacturers, to retail outlets and finally to the consumer in the palm oil industry. Several approaches to address the growing concerns regarding sustainability in the palm oil industry have been adopted. For example, the Roundtable on Sustainable Palm Oil (RSPO) (RSPO, 2018) has developed a set of environmental and social criteria with which companies must comply in order to produce Certified Sustainable Palm Oil (CSPO). While leading brands have pledged to commit to a 100% certification, only 19% of global palm oil production is certified as sustainable (“Impacts,” 2018.).

Due to the opaque nature of the palm oil supply chain, regulators, as well as customers have been unable to determine which producers are genuinely sustainable. Consumers, despite their growing concerns, are still in the dark on what products are sustainable.

Emerging technologies, such as blockchain, a distributed ledger, can transform supply chain traceability as we know it and bring more transparency through the value chain, creating value to stakeholders both upstream and downstream.

2. Literature Review

2.1 Process

The following section details the traceability efforts that are currently in place in the palm oil industry. First I will state what traceability means across multiple sources and pick the definition I am using throughout this research. Second, I will discuss stepwise traceability, an example of the traceability that is available in the palm oil industry. Third I will present the Traceability of RSPO- Certified Palm Oil.

2.1.1 Defining Traceability

In 2013, after a detailed investigation of all the existing definitions of traceability, Olsen and Borit came up with a detailed definition of traceability as “The ability to access any or all information relating to that which is under consideration, throughout its entire lifecycle, by means of recorded identifications”. (Olsen & Borit, 2013)
This definition does not suffer from the gaps outlined in Table 1 Selected traceability definitions (Olsen & Borit, 2013) According to Olsen and Borit, “There is a significant difference between having traceability (‘ability to access any or all information’) and verifying the claims in a traceability system” (Olsen & Borit, 2013). This claim is well adapted to the value proposition of blockchain technology, which allows access to any or all information but not necessarily the verification of the claims in a traceability system.

Table 1 Selected traceability definitions (Olsen & Borit, 2013)

Source	Definition of traceability	Trace what	Trace where	Trace how
International Standardization Organization (ISO) 8402	“ The ability to trace the history, application or location of an entity by means of recorded identifications.”	“An entity”	-	“By means of recorded identifications”
Codex Alimentarius Commission Procedural Manual	“ The ability to follow the movement of a food through specified stage(s) of production, processing and distribution”	“A food”	“Through specified stage(s) of production, processing and distribution”	-
EU General Food Law	“ The ability to trace and follow a food, feed, food producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution”	“A food, feed, food-producing animal or substance intended to be, or expected to be	“Through all stages of production, processing and distribution”	-

		incorporated into a food or feed”		
Moe, Tina. (1998) - scientific paper	“ Traceability is the ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales”	“A product batch and its history”	“Through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales or internally in one of the steps in the chain”	-
ISO 9000	“The ability to trace the history, application or location of that which is under consideration”	“Of that which is under consideration”	-	

2.1.2 Stepwise Traceability:

In the late 1990s, a series of food incidents drew attention to the need to establish a better baseline in food safety within the European Union. In 2002, the European Parliament and Council laid down the general principles and requirements under the General Food Law Regulation. As a requirement imposed by the European General Food Law, businesses within a supply chain are mandated to be able to identify at least the immediate supplier and the immediate consumer of the product in question, with exception of retailers to end consumers (European Commission, 2018). The requirements are applicable to palm oil and other food elements. The following is an example of the traceability that is available in the palm oil industry (van Duijn, 2013):

- The consumer can trace the product back to the retailer (where the product was purchased).
- The retailer has information about the consumer goods manufacturer, based on to whom the purchase order (PO) was made.
- The consumer goods manufacturer can trace back to the origin of their raw materials, which, in the case of palm oil products, would be the supplying refinery. They can also trace back their sales order (SO) to the retailer they supplied.
- The refinery can trace the palm oil back to the tanks and the shipment it came from based on their POs. It can also track which manufacturer it distributed to, based on their SOs.
- The ships can trace their oil tanks back to the oil mills and one step up to the refinery they supplied.
- The oil mills can trace the cans back to their group of suppliers, which can include many different wholesalers.
- The wholesaler of the shipments can trace back to the plantations and smallholder farmers from whom they collect their fruits.

- The plantations know who their main customers are, which could include wholesalers and oil mills. (van Duijn, 2013):

2.1.3 Traceability of RSPO- Certified Palm Oil

RSPO certified palm oil originates from plantations that have been certified against the principles and criteria for sustainable palm oil defined by the Roundtable Sustainable Palm Oil (RSPO). The unit of certification is the oil mill and its supply base. (Leegwater & van Duijn, 2012)

RSPO has four trading systems to link the sustainable production at the oil mill to claims made by the end user (Leegwater & van Duijn, 2012):

1. Identity Preserved (IP): Uniquely identifiable palm products from one certified oil mill and its supply base.
    - Oil is physically isolated from palm products originating from all other mills at any stage of the chain. Segregated transport and storage.
    - Expensive and only suited for low volumes.
    - Consumer goods manufacturers can label their products as RSPO certified sustainable palm oil.
2. Segregation: RSPO certified sustainable palm products are kept separate from non-certified material but will be mixed with a variety of certified sources. Consumer goods manufacturers can label their products as RSPO certified.
3. Mass Balance: RSPO certified palm products can be mixed with non-certified.
4. Book and Claim: Manufacturers and retailers can buy credits from RSPO-certified growers, crushers and independent smallholders.

2.2 Technology

In order for traceability to receive widespread adoption across the network, it must be simple and cost effective (Badia-Melis et al., 2015). The advancement of technology has introduced many tools to help increase the traceability and visibility in the supply chain. Technology such as:

Radio Frequency Identification	Automatic identification that uses electromagnetic waves to transfer data between the tag and the reader
Near Field Communication (NFC)	Designed to be a secure form of data exchange. An NFC device is capable of both being a reader and a tag
Internet of Things	Network that combines the data gathered from everyday smart devices in a network with the ability for them to identify and interact with each other
Blockchain	A shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. A decentralized database.

The following is a summary of these technologies to help expand the view of potential solutions that can be adapted to the palm oil industry to drive further traceability.

2.2.1 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a form of automatic identification that uses electromagnetic waves to transfer data between the tag and the reader (RFID Journal, 2018). RFID provides identification and tracking benefits similar to those of barcoding, but with the ability to store more information and to read tags without a line of sight.

An RFID system consists of a reader and a tag. The reader is equipped with an antenna that sends out electromagnetic signals to the tags. The tags, which consists of a microchip and antenna, are tuned to receive these signals and to emit an electromagnetic response for the reader to convert into digital data (RFID Journal, 2018).

The introduction of combining Internet of Things with RFID is the innovative way of implementing RFID for traceability purposes called “intelligent food logistics” and is described in more detail in section 2.2.3.

2.2.2 Near Field Communication (NFC)

NFC is an extension of the concept of RFID. NFC is designed to be a secure form of data exchange, and a NFC device is capable of both being a reader and a tag; this unique feature allows NFC devices to communicate in a peer-to-peer fashion (Chandler, 2012). In addition, NFC features are embedded in most smartphones nowadays, making them easily accessible. Similar to RFID, the main advantage of NFC technology over barcode and QR is that it does not require a line of sight between the tag and the reader (Badia-Melis et al., 2015). In the near future, consumers can use the NFC reader on their smartphone to scan grocery products and read information regarding the item they are purchasing (Chen et al., 2014). MIT engineers have also recently developed a NFC tag that can detect the gas in the air, which can help detect whether food is spoiled (Trafton MIT, 2014).

2.2.3 Internet of Things (IoT)

The Internet of Things (IoT) is a network that combines the data gathered from everyday smart devices in a network, enabling them to identify and interact with each other. There are three main pillars to this system: information items, independent networks, and intelligent applications (Badia-Melis et al., 2015). IoT can leverage other technologies, such as RFID, to create an intelligent food logistics. RFID is used to track the items as they move through the supply chain, and the information is tracked on a network of information systems.

2.2.4 Blockchain

Blockchain is a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network (Gupta, 2017). There are many challenges in a traditional transaction, such as over reliance on the trust of a central entity, high transactional cost and time, susceptibility to fraudulent activities, and overall accessibility.

One of the first successful implementation of blockchain is bitcoin, which created a digital currency that is self-governing, cost effective, efficient, and safe and secure. Using blockchain within a financial transactional context is only one use case. There are many other potential use cases. According to Deloitte, the primary potential benefits of blockchain in supply chain management is to increase traceability of material supply chain and ensure corporate standards are met. Blockchain can enable more transparent end-to-end tracking in the value chain: Companies digitize material assets and create a decentralized immutable record of all transactions, allowing them to track assets from production to delivery or use by end user (Deloitte, 2017). Blockchain can improve supply chain through 6 elements as shown in Figure 1: develop, plan, source, make, deliver and return (Deloitte, 2017).

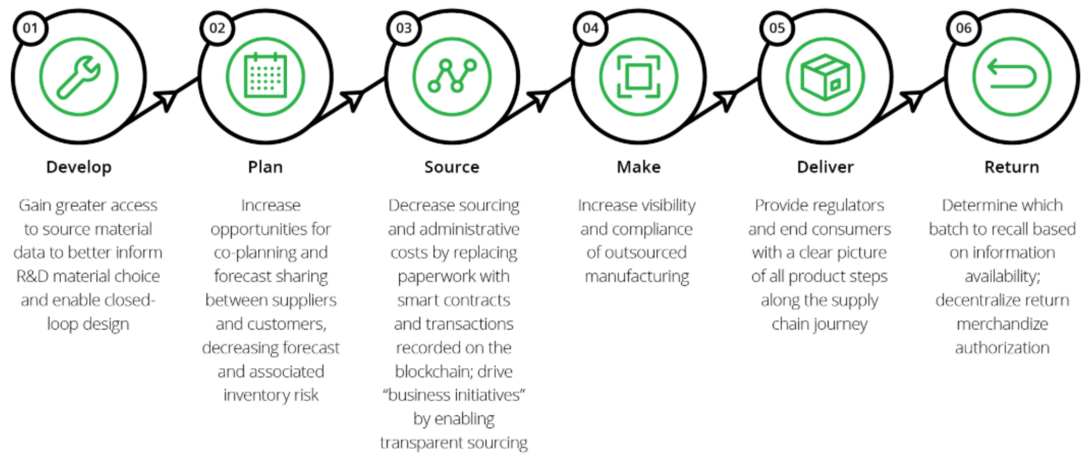


Figure 1 6 elements of blockchain (Deloitte, 2017).

Blockchains can be distinguished by who is allowed to participate in the network, maintain a shared ledger or execute the consensus protocol. Three types of Blockchains have been developed: public, private and permissioned. Table 2 describes the differences between these types of Blockchains. (Wald & Brock, 2017)

Public	Private	Permissioned / Consortium/ Federated
Anyone can read the chain, make legitimate changes, and write new blocks into the chain developed as an alternative for centralized trust	Invitation-only. New nodes must either be validated by the person or people who started the network or by a set of rules those people put in place.	Hybrid between public and private Blockchains
Usually an incentive mechanism to encourage more people to join.	The ability to write information and validate transactions is limited to one organization,	Transactions are visible only to the parties with permission to view them — not the whole network
Developed as an alternative for centralized trust	Read permissions can be public or restricted.	

Require a substantial amount of computational power to maintain a distributed ledger at scale	Groups and participants verify transactions internally: risk of security breaches just like in a centralized system	
Low cost for transactions	Provide solutions to problems in highly regulated industries	
	Transaction cost agreed to by the consortium	Transaction cost dictated by one entity

Table 2 Types of Blockchains (Wald & Brock, 2017)

Different blockchain platforms exists on the market in 2018. Different platforms serve different needs. The most prominent platforms are listed in Table 3.

Platform name	Description	Advantage	Disadvantage
Ethereum	Open-source, public blockchain platform for smart contracts	Turing completeness, Vision, Fault tolerance, Corporate backers	Transaction speed, Pace of change, Steep learning curve
Hyperledger Fabric	Hyperledger is an open source projects led by The Linux Foundation. Initially built as a project within IBM. It is meant to be a foundation for developing blockchain applications	Enterprise backing, Relative maturity, Private channels, Modular architecture, Smart contracts	Lack of public chain, Lack of cryptoeconomics, Enterprise backing (some see it as a disadvantage)
Hyperledger Sawtooth	Developed by Intel, utilizes a modular platform for building, deploying, and running distributed ledgers	Distributed state agreement, Adapters for transaction logic, Versatility, Scalability, Transaction families	Lack of maturity, therefore other disadvantages haven't been fully explored
Hyperledger Burrow	Permissioned Ethereum smart contract blockchain system	Lower barrier to entry, Use of the Ethereum Virtual Machine (EVM)	Lack of maturity, No key management system
Hyperledger Iroha	Originated with developers in Japan who built their own blockchain	Mobile libraries	Lack of maturity, therefore other disadvantages

	technology for mobile use cases		haven’t been fully explored
Hyperledger Indy	Developed by a nonprofit group called the Sovrin, provides tools, libraries, and reusable components for providing digital identities	Identity management	Lack of maturity, therefore other disadvantages haven’t been fully explored
Quorum	Created and open sourced by JPMorgan, Quorum is a permissioned implementation of Ethereum	Transaction-level privacy	Scalability/privacy concerns, Lack of cryptoeconomics

Table 3 Blockchain platforms (Wald & Brock, 2017) and (Deloitte, 2017).

2.3 People

This section reviews the different people-oriented challenges that come with implementing a traceability solution.

2.3.1 Change Management - Incentives for Change

Increasing visibility and traceability is not a new subject in the area of supply chain. From an operational perspective, the benefits of having a more visible and traceable supply chain are easy to see. However, there are many challenges from a ‘people’ perspective.

From a financial perspective, some managers believe their ‘source’ is a strategic advantage of the firm and thus are hesitant to share this information, much less to make it public. From a supply chain perspective, if a competing firm knows the source of supplies or customers, they may target these companies and out-compete from a price or service perspective.

From a human nature perspective, people are resistant to change, because it is an additional workload that is added to their day-to-day responsibilities. Some may also feel that keeping important information ‘off the grid’ and preserving it as tribal knowledge may protect their own individual value within a firm.

In order to make sweeping changes across many separate organizations, it is important to understand what each stakeholder within the value chain values and then find ways to incentivize them to make these changes (Interview, 2018).

3. Methodology

This thesis analyzed the problem using the framework shown Figure 2.

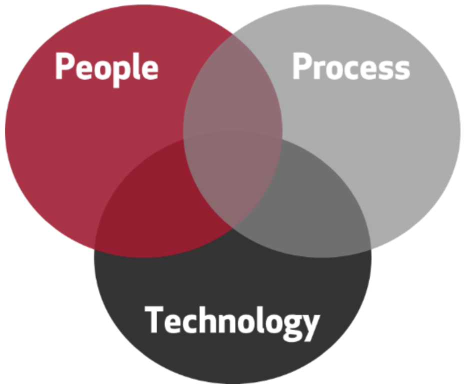


Figure 2: People, Process, Technology Framework

1) Process
2) People
3) Technology

This framework was used to perform a content analysis of the current traceability issues in the palm oil industry, and to assess the feasibility of using emerging technologies (e.g. blockchain, IoT) to improve transparency and traceability of palm oil from farm to consumer, the accompanying process, and the changes in human behavior to adopt this implementation. The activities that performed include:

- reviewing existing traceability models and solutions
- mappin out how emerging technologies can increase traceability
- highlighting existing barriers to implementation
- identifying roadmap for potential next steps.

The study engaged in a multi-method approach (Figure 3) from a multi- and interdisciplinary perspective:

1. A comprehensive literature review of current traceability models in the palm oil industry, identifying key technological solutions and reviewing different people-oriented challenges that arise with implementing a traceability solution.
2. A gap analysis of the status quo of the palm oil industry. The analysis is based on NGO reports, company sustainability reports, and industry interviews.
3. Content analysis of selected cases
4. Development of proposed solution.

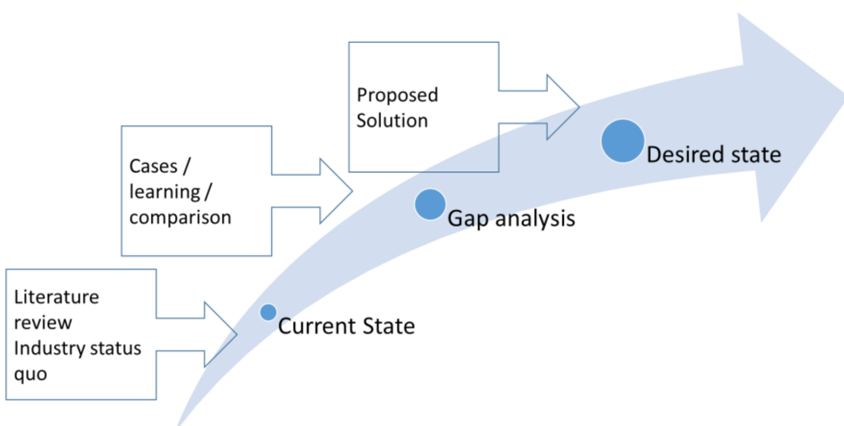


Figure 3 Analysis approach

This study used data gathered by reviewing past literature from both academic and industry sources, analyzing case studies, and interviewing experts from a Fortune 500 CPG company (sample questions of interviews can be found in the Appendix A)

Content analysis involved analysing 5 cases of traceability from different industries: tracking tuna on a public blockchain, tracking pig meat using NFC Technology, tracking beef using a distributed RFID-based network, tracking oats using a private blockchain, and tracking deforestation caused by palm oil plantations through near real-time satellite imagery.
The 5 cases were chosen because they represented 5 different technologies and processes and yielded different results. The learning derived from these cases, along with a comparison of the status quo of the palm oil industry and the knowledge generated by industry interviews allowed me to select and then map out a process that can improve the traceability level of the palm oil value chain.

4. Gap Analysis

4.1 Industry Status Quo

This section offers a meta-analysis of current industry standards and a description of the status quo. Table 4 Leading brands buying PO shows the score card of leading brands and buyers of palm oil. Greenpeace's report on assessing the brands was based on three criteria. (Greenpeace, 2016)

- Responsible sourcing: Practical steps companies are taking to ensure that the palm oil bought is not linked to deforestation.
    - Strong: A company's efforts are labeled as strong if it is making significant progress towards tracing its palm oil to the plantation where it was sourced. The firm must obtain third-party auditing that their suppliers are adhering to its 'no deforestation' policy. The company must also purchase physically certified oil. (Greenpeace, 2016)
    - Decent: The company's main sourcing is mass balance palm oil, and it is tracing the majority of its palm oil to the mill and using this data for mill-based risk assessments. (Greenpeace, 2016)
    - Failing: A company is considered to be failing if it is making slow progress towards tracing palm oil to the mill. The firm relies on GreenPalm certificates and RSPO certification as verification of their 'no deforestation' procedures. (Greenpeace, 2016)
- Transparency: Companies' level of openness about their palm oil suppliers, and how they tackle suppliers that breach their 'no deforestation' policy. (Greenpeace, 2016)
    - Strong: Transparent about all or some of their suppliers
    - Decent: Do not publish their supplier information but willing to share it with civil society actors
    - Failing: Refuse to provide information about their suppliers (Greenpeace, 2016)
- Industry reform: How companies are supporting wider industry reform. (Greenpeace, 2016)
    - Strong: Participation in these "industry-wide initiatives that [Greenpeace] believe have some potential to transform the palm oil sector: The New York Declaration on Forests (NYDF), membership of the Tropical Forest Alliance, membership of the UNDP Sustainable Palm Oil Initiative, or taking a leadership role in the Consumer Goods Forum's palm oil working group." (Greenpeace, 2016)
    - Decent: Participating in more than two of these multi-stakeholder bodies
    - Failing: Little or no participation

WWF's report indicates that no company had reached a perfect score, and only Ferreo was able to trace back their palm oil back to the plantation. There is a considerable amount of work to be done before companies have deforestation-free supply chains. (Greenpeace, 2016)

Table 4 Leading brands buying PO (WWF Palm Oil Scorecard, 2016) and (Greenpeace, 2016)

Company name	Responsible sourcing	Transparency	Industry reform	Total palm oil used (t)
Unilever	Decent	Decent	Strong	1,513,265

P&G	Decent	Decent	Strong	493,677
Pepsi	Failing	Decent	Strong	452,743
Nestle	Strong	Strong	Decent	417,834
Mondelez	Decent	Failing	Strong	289,255
Ferrero	Strong	Decent	Strong	181,000
Colgate-Palmolive	Failing	Failing	Failing	174,328
Johnson and Johnson	Failing	Failing	Strong	86,686
Mars	Decent	Strong	Strong	82,456
General Mills	Decent	Strong	Decent	67,724
Kellogg Company	Decent	Strong	Failing	50,313
Danone	Strong	Failing	Strong	34,457

4.2 Limitations of current RSPO processes

While leading brands have pledged to commit to 100% certification, only 19% of global palm oil production is certified as sustainable (“Impacts,” 2018.). One-third of certified sustainable palm oil (CSPO) sales in 2016 were “book and claim” and cannot traced back to the plantation/smallholder (“Impacts,” 2018.).

The key obstacle to traceability in the palm oil value chain lies in its first component, the smallholders/plantations. Tracing back palm oil to the smallholder using current certifications such as the RSPO process has not proven to be efficient. According to Shukla and Tiwari, smallholders find it extremely challenging to participate in the RSPO process due to “absence of information in the right form and medium, lack of understanding of the certification system, age-old farming practices that are difficult to change [and] inability to quantify the importance of the certification” (Shukla & Tiwari, 2017a)

Today, there is a need to introduce traceability solutions that “can reduce the smallholders’ burden for data collection, reduce the dependency on auditors, reduce the long wait to find an auditor and the results of the audit process, and can make the entire process transparent for the buyers”. (Shukla & Tiwari, 2017a)

The key limitations that constrain the adaptation of smallholders and scalability of current RSPO are summarized in Table 5.

Table 5 Limitation of RSPO certification in relation to smallholders and buyers (Shukla & Tiwari, 2017a)

Limitation	Smallholders	Buyers
Intensive data requirements	Huge time and efforts to collect and maintain data	Buyers have no visibility of the data

Scope for data alteration (misreporting)	High motivation to alter or misreport the data	Buyers have no visibility of on-farm activities
Change in behavior	Extremely difficult to change smallholders perception and farming practices	Difficult to evaluate if the behavioral changes are temporary or permanent
Lack of transparency		Buyers have no visibility in the overall process.
Huge cost of certification	Uncertainty about the cost and premium for certification	Buyers not sure about smallholders/ end-consumers' willingness to pay

This gap analysis has identified the current state of the industry's leading brand names: no CPG company achieved a deforestation-free supply chains. The analysis has also identified the limitation of the current RSPO certification model. The next step is to analyze, compare and contrast the 5 traceability case studies using different processes, technology, and people approaches.

5. Content Analysis

5.1 Case Study 1: Tracking Tuna on a public Blockchain

Many supply chain management systems exist, but most are expensive enterprise resource planning (ERP) systems that run on internal servers or on private cloud databases.

A recent six-month pilot performed by the British startup, Provenance, has demonstrated how using mobile technology, blockchain and smart tagging can track fish caught by fishermen with a verifiable social sustainability claim. Figure 4 provides an overview of the traceability process. The pilot's objective was "to aid robust proof of compliance to standards at origin and along the chain" and was successful "in tracking responsibly-caught fish and key social claims down the chain to export". They were also able unlock the premium fish market that has proven compliance of standards and traceability back to source. (Provenance.org, 2016

In a report published on 15 July 2016, Provenance demonstrated the capabilities of a blockchain-based system tracing yellowfin and skipjack tuna fish in Indonesia from catch to consumer. They performed the implementation through three phases (Provenance.org, 2016):

Pilot Phase 1: The "First Mile"

- The first mile includes setting up the local fishermen with the blockchain system and implementing the framework that connects fishermen to suppliers.
- Local NGOs verify the social and environmental conditions of the fishermen at the point of capture.
- Fishermen send SMS messages to register their catch. Each SMS issues an asset onto the blockchain system.
- The assets are transferred from fishermen to supplier along with the catch, both physically and digitally on the blockchain. The assets transferred have permanent, unique IDs that are immutable.

Pilot Phase 2: Integration with Existing Systems

- The blockchain traceability system is further integrated downstream with the processing firms and other organizations.
- Records of the catch are held on the blockchain, which is identified by the unique identifier that is attached to items, such as a QR code or a RFID tag.
- Standards by GS1 are enforced and allowed separate and independent systems to "communicate using the same language, structures and identifiers" (Provenance.org, 2016)

Pilot Phase 3: End Consumer Experiences

- Creating the end consumer experience and build an interface that assures consumers of the permanence of the tuna. Integrate the Provenance system into physical retail outlets.
- Consumers can use their smartphones to track an item's provenance

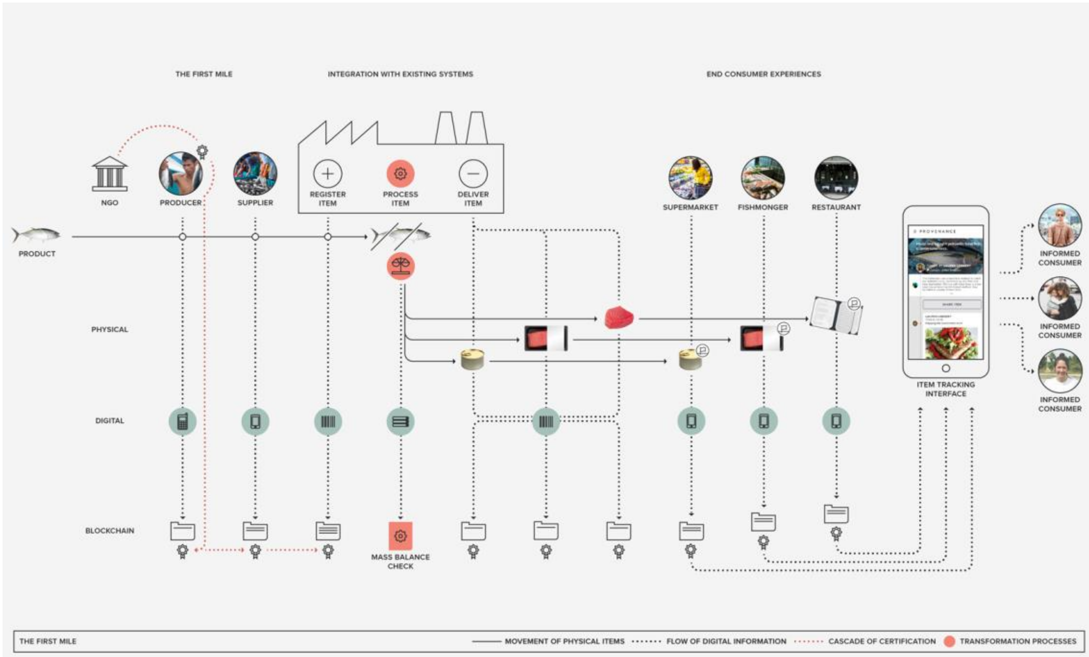


Figure 4 Traceability of Tuna fish using a public blockchain

5.2 Case Study 2: Tracking Pig Meat using NFC Technology

An NFC-based traceability system was implemented by Università Politecnica delle Marche on pig meat from the Marche Region in Italy. Six entities were involved in the value chain: farmers that provide food for the animals, breeders, slaughterhouse, distributers, retailers, and consumers.

They implemented the following process (see Figure 5).

1. Pig arrives at the slaughterhouse
2. Data on meat processing is written on an NFC tag that is applied to the half-carcass and the data is automatically stored in the online database.
3. The half-carcass is then transferred to the cutting plant, where it is further divided into various cuts.
4. Contents of the “father” tag is copied and saved in all the “children” tags that are applied to related cuts.
5. New processing data is added to the “children” tags.
6. Meat is processed and packaged.
7. The data relating to the meat processing is always saved on the database and on the corresponding tag.
8. Once packaged, the product arrives in the store, where the consumer can read all the information gathered throughout the supply chain by scanning the NFC tag with his smartphone. (Pigini & Conti, 2017)

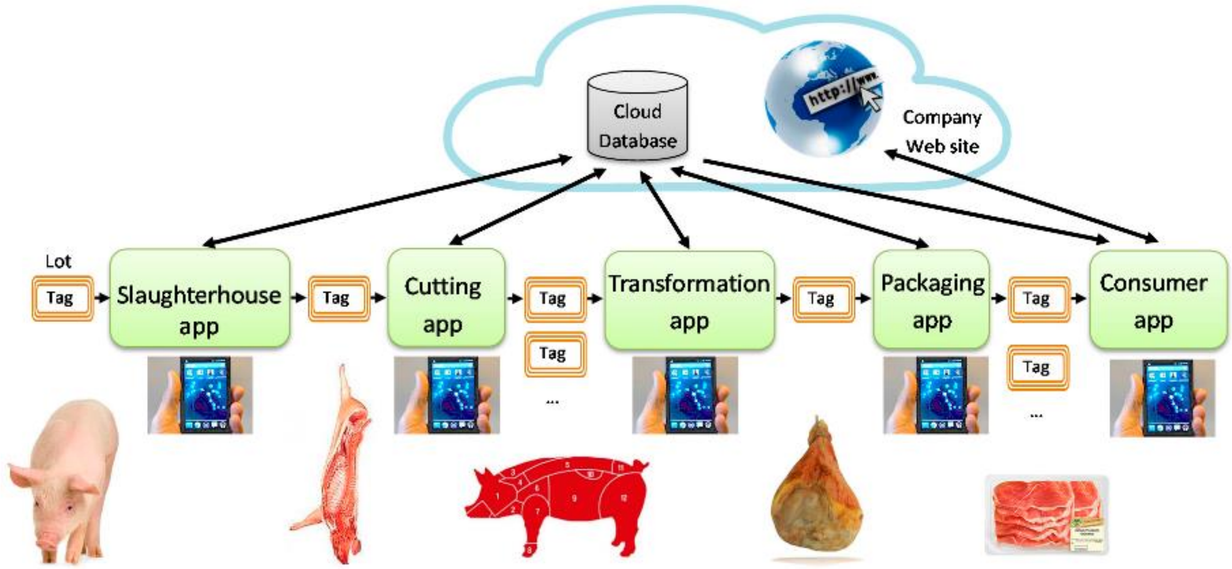


Figure 5: Pig Meat Process Diagram (Pigini & Conti, 2017)

This implementation relied on a MySQL database and android applications. Refer to Figure **5** for additional details. Six different Android application were developed. One app for each stakeholder: slaughterhouse app, cutting app, transformation app, packaging app, consumer app. (Pigini & Conti, 2017)

5.3 Case Study 3: Tracking Beef using a Distributed RFID-Based Network

This traceability system was conducted by Jiangsu Academy of Agricultural Sciences on Liangfeng cattle farm, a farm with 3000 cattle, located in Zhangjiagang, a city in southeastern China. The system proposed in this study provides a comprehensive framework for cattle/beef supply chain identification and traceability from cattle breeding to the end consumer. Sensors were developed to monitor environmental factors such as slaughter, processing, and transport as well as storage factors, such as temperature, ammonia content, moisture and lighting. The data from the sensors are identifiable by the RFID on the batch. (Liang, Cao, Fan, Zhu, & Dai, 2015). Figure 6 and Figure 7 illustrate the system architecture of the solution. The first provides an architecture overview of the software, while the second provides an overview of the hardware. (Liang et al., 2015)

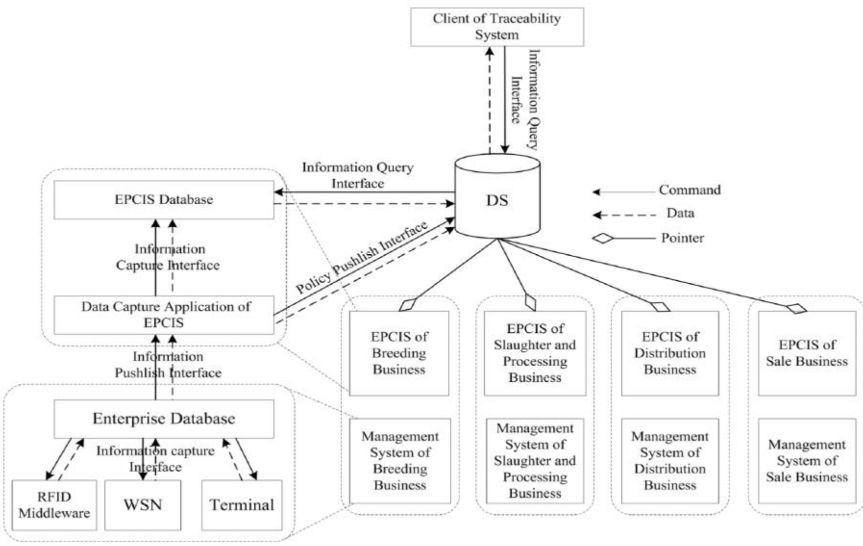


Figure 6 Interface of traceability system (Liang et al., 2015).

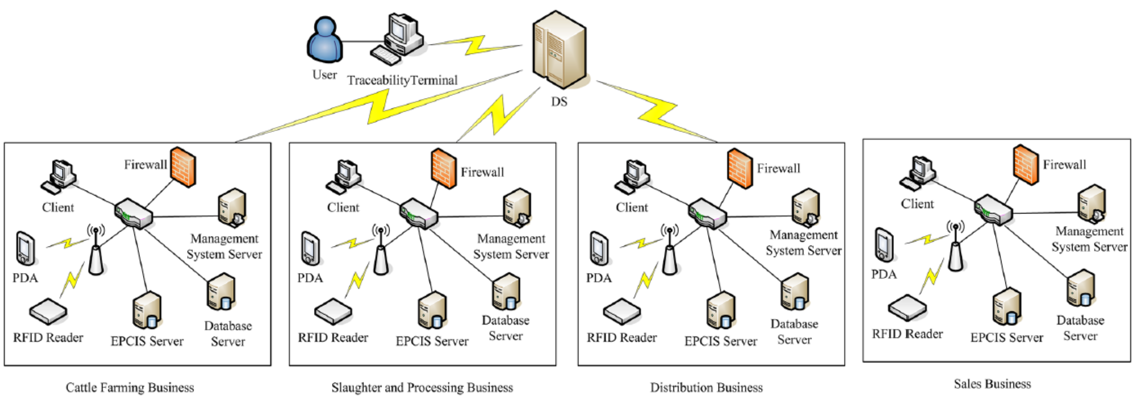


Figure 7 Architecture of the traceability system (Liang et al., 2015).

After the implementation, 38 surveys were sent to the stakeholders. As shown in Figure 8 and Figure 9, the stakeholders considered the system to be user friendly, and with good usability, scalability, and stability. However, the cost was considered to be high, due to the initial investment and the ongoing costs to replace damaged RFID tags. (Liang et al., 2015)

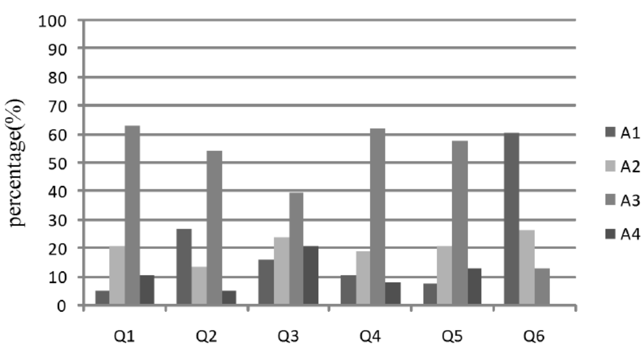


Figure 8 Analysis of results obtained from system users (Liang et al., 2015)

No	Question	Answer1	Answer2	Answer3	Answer4
Q1	System usability	Poor	Acceptable	Good	Excellent
Q2	System stability	Poor	Acceptable	Good	Excellent
Q3	System scalability	Poor	Acceptable	Good	Excellent
Q4	User interface	Poor	Acceptable	Good	Excellent
Q5	Ease of use	Difficult	General	Ease	Very Ease
Q6	Cost	High	Acceptable	Low	Can be ignored

Figure 9 System user questionnaire (Liang et al., 2015).

This case study demonstrated that traceability was improved throughout the beef supply chain, but mistrust still exists around the authenticity of the traceability information. The team recommended the introduction of a third party to authenticate or audit the process (Liang, Cao, Fan, Zhu, & Dai, 2015)

5.4 Case Study 4: Tracking Oats using a private blockchain

In 2017 AgriDigital, a commodity management platform, and CBH Group, Australia's largest exporter of grain, partnered to pilot use cases for blockchain in the Australian grain industry. Blue Lake milling, a CBH subsidiary and oat processor, was chosen for the pilot. The pilot's objective was to solve two key challenges ("AgriDigital and CBH Blockchain Pilot Report.pdf," 2017):

1. Matching title transfer of the grain asset to payment
2. Supply chain traceability and provenance

AgriDigital and CBH used a private Quorum blockchain to trace the movement of a batch of organic oats from origin through milling and production and until it reached the end consumer. Data on the provenance, movement and treatment of the batch of oats was stored and analyzed on a Quorum network. The organic status of the oats was monitored closely; this was done though a range of physical data points that were captured at various stage of the value chain. An analytics model was used to determine whether the oats were organic at the farm gate, and by checking off pre-identified business processes through the supply chain, the model produced a binary true/false statement as to whether the organic status had been retained through the movement. The pilot concluded that data integrity is still an issue and that removing human data input and increasing automation increases the integrity of the blockchain overall ("AgriDigital and CBH Blockchain Pilot Report.pdf," 2017).

5.5 Case Study 5: Tracking deforestation through near real-time satellite imagery

Google Earth Engine (GEE) is a cloud computing platform which hosts publicly available satellite images and allows for land cover classification using inbuilt algorithms. A group of researchers, Janice Ser Huay Leea, Serge Wichb, Atiek Widayatid and Lian Pin Kohe, explored the potential of Google earth engine's imagery classification system as a low-cost, accessible and user-friendly oil palm detection tool. The study was made on the Tripa, a region in Aceh province, Indonesia. Since 1990 the region's ecosystem has seen a rapid deforestation due to oil palm agricultural expansion at the scale of industrial and smallholder plantations. (Lee, Wich, Widayati, & Koh, 2016)
Using classification and Regression Trees (CART) and Random Forests (RFT) algorithms, the study produced and classified land cover maps that had high overall accuracies. Their algorithm

was able to distinguish the following land cover classes: immature oil palm, mature oil palm, non-forest non-oil palm, forest, water, and clouds. (Lee et al., 2016)
The study showed that Google Earth Engine has the potential to be an accessible and low-cost for palm oil stakeholders to detect and monitor the expansion of oil palm plantations in the tropics in near real time. (Lee et al., 2016)

5.6 Case study meta-analysis

The case studies provided key insights into this thesis's goal of improving the sustainability across the palm oil value chain, by increasing transparency and creating incentives to the different stakeholders. Key learnings were derived from the cases and are listed in Table 6.

Table 6 Cases key learning

Case	Key learning 1	Key learning 2	Key learning 3
Tracking Tuna on a public Blockchain	Integration of blockchain with mobile technology, QR codes and RFID tags to trace batches – Using a mass balance check once the fish is processed	The public blockchain allows traceability of fish from fishermen to end user - unlock the premium fish market	Blockchain traceability system is integrated downstream with the processing firms and other organizations.
Tracking Pig Meat using NFC Technology	Consumer can read all the information gathered throughout the supply chain by scanning the NFC tag with his smartphone.	Process begins at slaughterhouse and ends with the consumer	Enabling Wholesalers, Resellers and Retailers Optimization their inventory levels
Tracking Beef using a Distributed RFID-Based Network	Mistrust still exists around the authenticity of the traceability information – recommendation of third party physical auditors	Monitoring of environmental factors affecting the product from cattle breeding to the end consumer	Integration of RFID sensors with ERP systems and centralized databases
Tracking Oats using a private blockchain	Private Quorum blockchain to trace the movement of a batch of organic oats from the origin to end consumer	Analytics model to determine whether oats were organic at the farm gate. Followed by binary true/false statement whether the organic status had been retained through the movement	Data integrity is still and issue and that removing human data input and increasing automation increases integrity of the blockchain overall

Tracking deforestation through near real-time satellite imagery	Low-cost for palm oil stakeholders to detect and monitor the expansion of oil palm plantations	Algorithm is able to distinguish (with high overall accuracies) the following land cover classes: immature oil palm, mature oil palm, non-forest non-oil palm, forest, water, and clouds.	Near real-time tracking at point of origin

Extending the earlier gap analysis, Table 7 contrasts the limitations of the current processes and status quo with the target model.

Table 7 Contrast between Current and Target traceability model

Current status	RSPO certified		Target solution	
Limitations	Smallholders	Buyers	Smallholders	Buyers
Intensive data requirements	Huge time and efforts to collect and maintain data	Buyers have no visibility of the data	Digitally audited in real time.	Permissioned and secure data visibility
Scope for data alteration (misreporting)	High motivation to alter or misreport the data	Buyers have no visibility of on-farm activities	Motivation to misreport high. Ability to misreport is drastically decreased	Near real time visibility of farm activities
Change in behavior	Extremely difficult to change smallholders perception and farming practices	Difficult to evaluate if the behavioral changes are temporary or permanent	Minimal change in behavior. Minimal training needed	Data driven decisions to evaluate behavioral changes
Lack of transparency	N/A	Buyers have no visibility in the overall process.	N/A	Full (permissioned) visibility of value chain, starting from plantation to end user
Huge cost of certification	Uncertainty about the cost and premium for certification	Buyers not sure about smallholders/ end-consumers' willingness to pay	Faster payments. Premium for certification	Cost decreased by more efficient process.

Using blockchain in case 1 and 4 was effective from a dependability, performance and practicality perspective. However, four of the case studies dealt mainly with products that were discrete and larger. The palm fruit would be similar to these items in that it is identifiable, but as soon as the palm fruit is milled into oil, the oil itself would be impossible to identify individually. Palm oil is similar in this respect to oats in case 4. One take-away from case 3 is that it is important to keep the cost low and dependability high throughout the implementation to maintain stakeholder interests.

It is important to note that the authenticity of the traceability information is a key issue.

To identify the need for a blockchain (or not) in increasing transparency in the value chain, I have created a decision tree (Figure 10) that I applied to the palm oil industry. The database needs were acknowledged: Stakeholders have different incentives and a need for a strict immutability of records; the business logic is simple and the records should be kept private. As a result, a permissioned database is recommended.

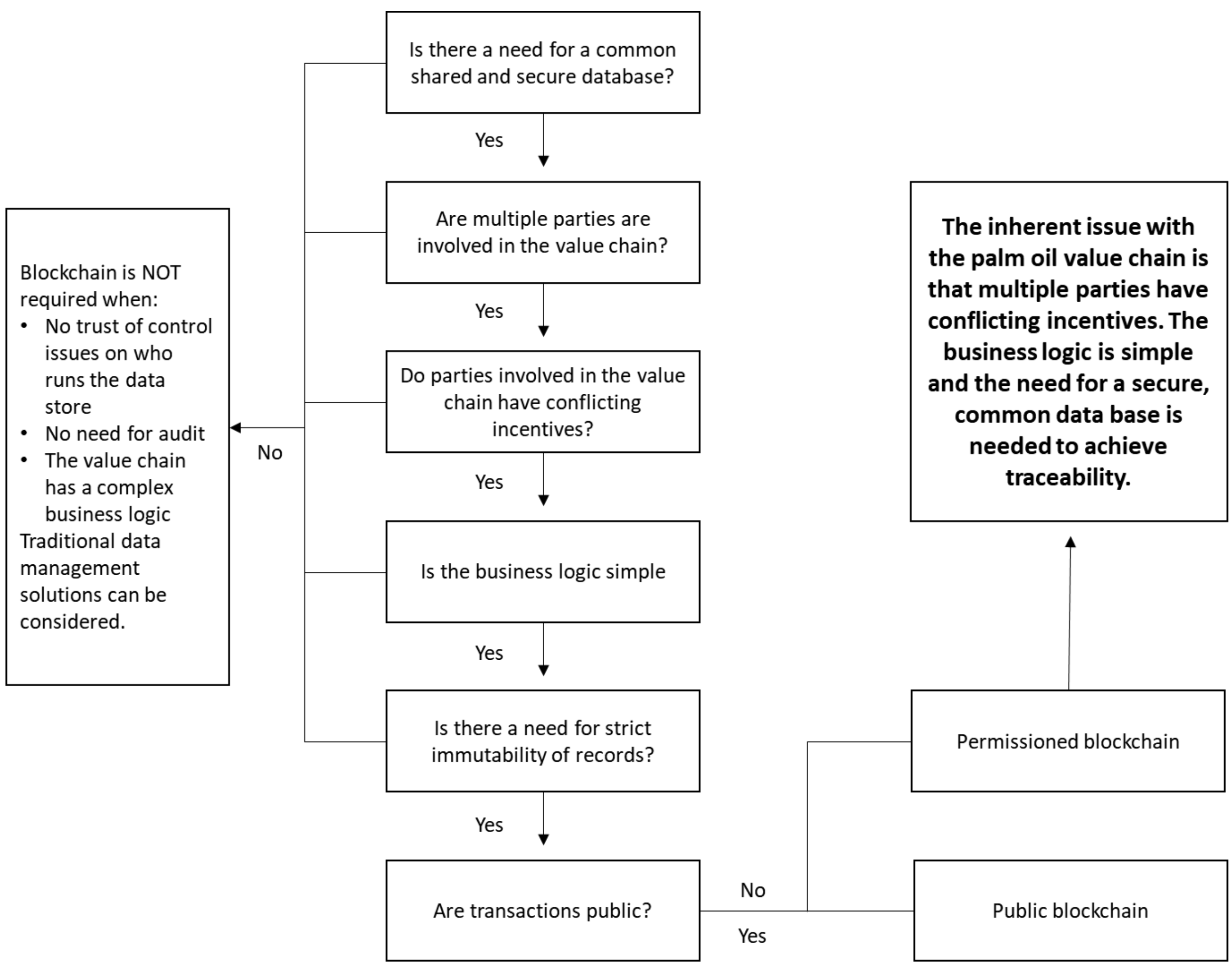


Figure 10 Blockchain decision model for the palm oil value chain

No single case provides a comprehensive and full solution for the palm industry. I have opted for a combination of technologies and processes as a potential solution and adapted the learning from the different cases to the palm oil industry.

6. Proposed Solution Traceability of Palm Oil

Taking into account the lessons learned from the different case studies presented in this thesis (section 5.1), a future-state traceability process was developed to monitor palm oil. This future-state process takes into account the analyses in section 2 from a Technology, Process, and People perspective. From a process perspective, the proposed solution leverages the mass balance, and book and claim traceability models that RSPO has defined. From a technology perspective, the proposed solution leverages blockchain, geospatial imagery classification, and IoT technologies to keep track of the flow of physical goods and sustainable palm oil certificates. From a people perspective, the proposed solution includes a set of incentive models that could be useful in easing change management efforts.

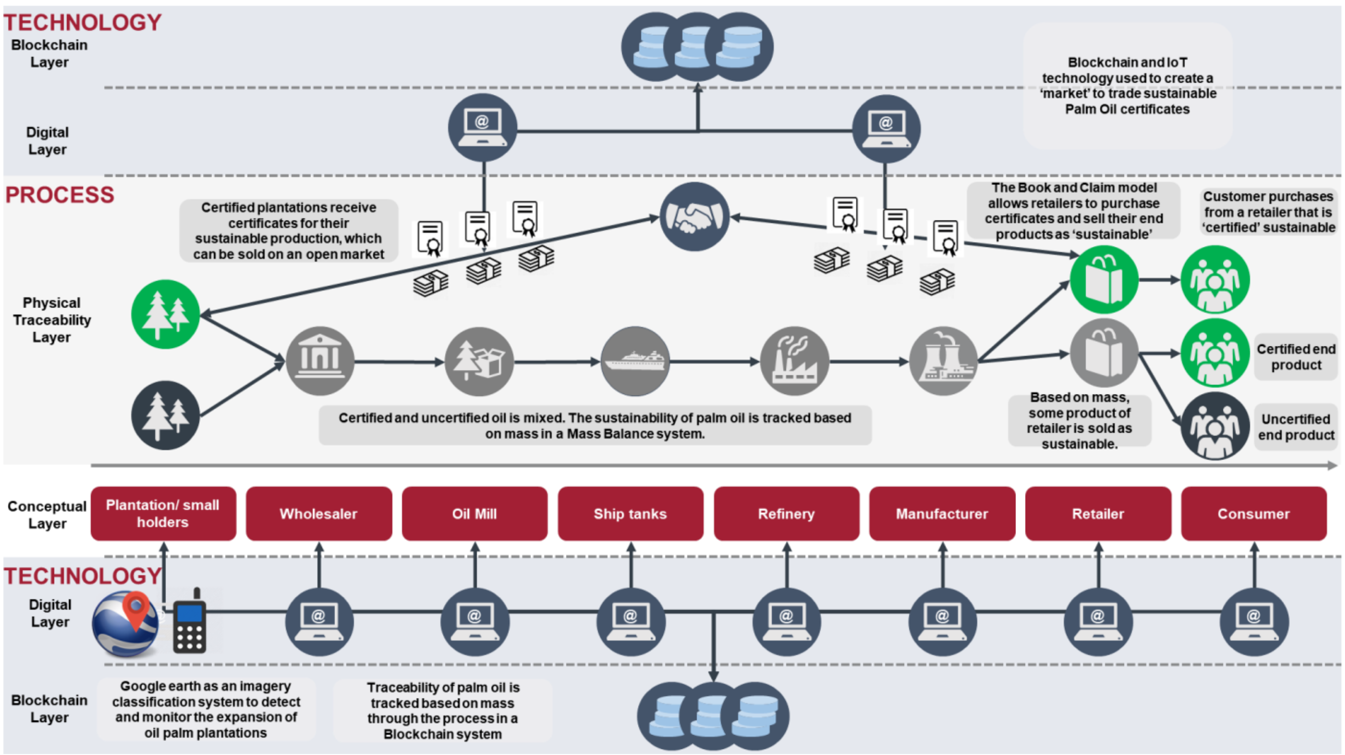


Figure 11 Proposed Solution for Palm Oil

6.1 Overall Flow

The overall flow of the Palm Oil process (from plantation to consumer) is mapped below (Dujin, 2013; RSPO, 2018).

Figure 12 overall flow of the palm oil process

Plantations and smallholders of palm oil plants harvest the fruits, typically manually, using a harvesting team. The number of bunches harvested per day depends on the height of the palm

trees. Harvesters typically mark the fruit bunches after harvesting them by writing a unique code on the fruit.
An oil mill is typically supplied by hundreds of harvesters and runs throughout the entire day until all the fruit bunches delivered for that day are processed. At this point, the fruits are no longer segregated. The oil is stored in tanks before being moved to the refinery. The tanks may be transferred directly to the refinery or after being stored in large shore tanks. The shore tanks usually serves many oil mills and may move from port to port.
The refineries receive the crude palm oil in feeding tanks. The refined palm oil is then sent to manufacturers, like CPG companies, for use in end products and sold by retailers.

Sections (6.2, 6.3 and 6.4) describe in further detail the proposed solution for the pam oil industry

6.2 Process

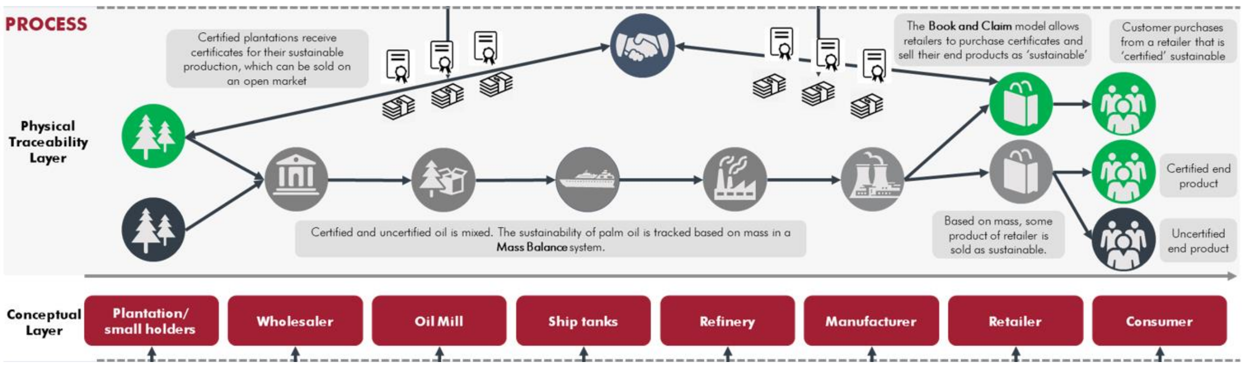


Figure 13 Process section

This section dives into further detail on the process section of the proposed solution for palm oil as shown in Figure 11. The standalone process section can be found in Figure 13.
The proposed solution will leverage mass balance and book and claim traceability models to put the overall value chain in a position to certify the different sustainability certificates (as listed in section 2.1.3). The mass balance model is used because it is the least costly (from time and money perspectives) to implement and can thus attract the most adopters. The book and claim model, which provides sustainability certificates, can attract additional adopters by creating a market in which certificates can be traded. By creating a trading market, organizations that are not directly part of the supply chain can also participate in the traceability process and thus increase the demand for sustainable products.

6.3 Technology

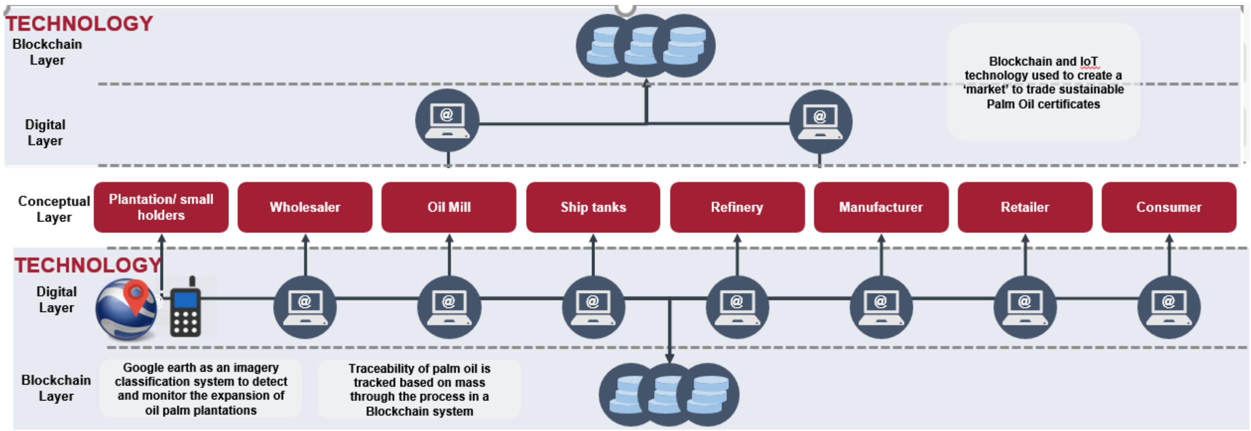


Figure 14 Technology section

This section dives into further detail on the technology section of the proposed solution for Palm Oil diagram as shown in Figure 11. The standalone technology section can be found in Figure 14.

The proposed solution leverages blockchain and IoT technologies to enable the traceability of palm oil. IoT technologies can be used to input the data and to provide online visibility of the information. For example, plantation farmers can use their phones (or computers) to scan in the number of palm fruits harvested per day and the destination they were shipped to. Each stakeholder in the process will also use scan in the batch number into the system as well. Using near real-time satellite imagery, a low cost solution, discussed in section 5.5, the farmers can be localized though GPS and their plantation. Therefore, it could be determined whether the plantation has been planted on deforested land.

The traceability is performed under a mass balance model, meaning that companies will have to keep track of the mass/quantity of sustainable palm oil goods throughout the supply chain starting from plantation/smallholders.

Blockchain is proposed as a data management system for two purposes. The first is to provide traceability to sustainable palm oil products throughout the value chain. The second is to provide a way to keep track of the sustainable certificates and allow traders to trade on a blockchain-backed platform and to support the book and claim model. The book and claim model will help draw additional participants into the palm oil sustainable cause and provide farmers in developing countries with an additional revenue stream.

6.4 People

This section dives into further detail on the people section of the proposed solution for Palm Oil diagram as shown in Figure 11 As discussed in section 2.3, one of the main challenges in implementing a traceability program is in change management. Specifically, how does one entice users to adopt and use the program over time, especially when a full traceability model may conflict with their own personal and organizational goals?

Table 8 lists the different types of incentives that should be provided to engage the users in using the proposed model.

Table 8 Stakeholder incentives

Stakeholders	Incentives
Plantation	• Make sustainable farmers more competitive on the market • Additional revenue stream in selling sustainable certificates • Mitigates risk from future regulatory ramifications
Small Holders	• Make sustainable farmers more competitive on the market • Additional revenue stream in selling sustainable certificates • Mitigates risk from future regulatory ramifications
Oil Mills	• Provides additional value to their customers (refineries) to distinguish themselves from competitors. • Can improve operational effectiveness with the technology implementation • Additional revenue stream in selling sustainable certificates
Wholesaler	• Can improve operational effectiveness with the technology implementation, but loses out on their core value linking customers to their suppliers
Ship Tanks	• Provides additional value to their customers (refineries) to distinguish themselves from competitors. • Can improve operational effectiveness with the technology implementation
Refinery	• Provides a way for refineries to keep their major cpg manufacturing clients satisfied.
Manufacturer	• Provides retailers with a way to unlock additional market potential by being in a position to provide assurance to consumers that the goods come from a sustainable source. • Provides retailers with way to improve their branding and public image • Allows manufacturer to differentiate itself from competitors • Additional revenue stream in selling sustainable certificates

Retailer	• Provides retailers with a way to unlock additional market potential by being in a position to provide assurance to consumers that the goods come from a sustainable source. • Provides retailers with way to improve their branding and public image. • Allows retailer to differentiate itself from competitors
Consumer	• Provides assurance for consumers that the goods that are buying come from a sustainable source
Independent Traders	• Traders may join the certificate trading market and create derivatives for the certificates. Once critical mass of traders is reached, the demand will drive the certificates up and enticing additional sustainable farmers to join the system, and thus creating a reinforcing loop.

Wholesalers are the most difficult to entice. Their value added under status quo supply chains is to act as a facilitator and a connector. Their core value is in their knowledge of the plantation and small holders. Increasing the traceability of palm oil would effectively diminish their core service. The proposed solution goes against their current interests and will be marginalized if the proposed model is implemented.

7. Conclusion

Many additional challenges must be considered prior to the implementation of such a solution.

Firstly, the global value chain of palm oil is a complex environment that requires different stakeholders to comply with the different regulations in different countries. There will be challenges during the implementation in getting all stakeholders to comply while the implementation team operates within this complex setting of established laws, customs, and institutions.

Secondly, the implementation of the suggested model is contingent on the participation of all the different stakeholders. These stakeholders have different capabilities, interest and objectives. They are highly geographically distributed, with no regular interaction among them.

Thirdly, blockchain can provide a robust traceability system, but the physical/digital separation cannot be easily overcome. The gap between the physical and virtual worlds can still provide an opportunity for human mistakes at best or fraudulent activities at worst.

Fourthly, the technology required might become a barrier for some stakeholders in developing countries. Without their participation, it is not possible to reach the full potential of the suggested traceability model.

Lastly, in contrast to the many well-known public blockchain applications such as bitcoin, "…corporate-designed Blockchain lack one of the main elements that made bitcoin a success: the decentralized structure." (Kshetri, 2018). Only a limited set of participants can have access to a corporate designed blockchain system, which increases the vulnerability of the system to hacking (Kshetri, 2018).

Blockchain technology alone will not solve traceability challenges companies face. However, it provides an ideal base layer upon which architectures for robust traceability systems can be built and participated in without ownership by the biggest value chain participant.

There are many potential roadblocks to the implementation. The first would be to find an owner for the implementation. Should the retailer/CPG companies enforce this implementation on upstream suppliers? Should NGOs take ownership of such a project, and, if they do, will they have the authority to implement it?

Secondly, although such an implementation may benefit many stakeholders in the value chain, there will be stakeholders that will be harder to persuade, since they stand to benefit less from such an implementation. For some stakeholders, it may even be the case that they lose their strategic advantage from such an implementation. Finding a way to entice all stakeholders to adopt this implementation in specific situations will be a major obstacle.

The next steps:

- Identify owner of the implementation
- Identify whether to implement from downstream to upstream or vice versa
- Find ways to scale up the RSPO certification system and introduce it to a free market
- Financial feasibility study to get industry buy in
- Develop detailed incentive model

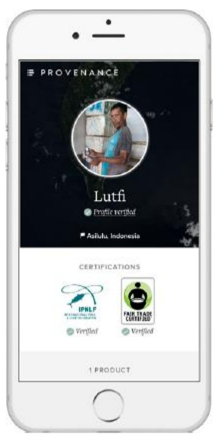
Appendix

A - Interview questions

Where do you see a burning need for traceability in “CPG”? Can existing technologies and database solutions provide the solution? What are the potential advantages of blockchain?
How would you determine is blockchain is needed in your company? What are the metrics?
What do you look for in a feasibility study?
How do you see blockchain being applied to increase transparency in blockchain?
What are the costs of a traceability initiatives? How can operational efficiencies offset these costs?
Is there any training for different stakeholders of the supply chain? (smallholders, mills, suppliers)
How close did CPG work with the government and NGO in this process?
How do you facilitate that in inter farmer connection?
How does it empower you to manager your supply chain when you know the farmer?

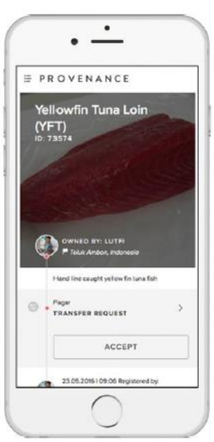
B- Key steps for yellowfin tuna

1. Registration of fisherman by NGO.

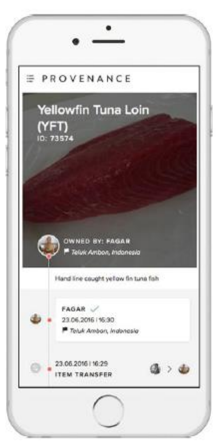


2. Item attribute confirmation by NGO. Attributes tested include Fair Trade USA, Pole and Line Foundation Association Member, GPS (working with Seatracker data).

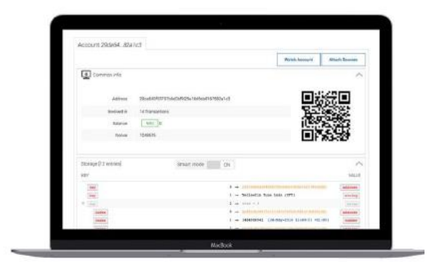
3. Fisherman issues item.



4. Fisherman transfers the item to supplier.



5. Supplier receives the item.



6. Checking item on blockchain explorer.

C- Stepwise Traceability

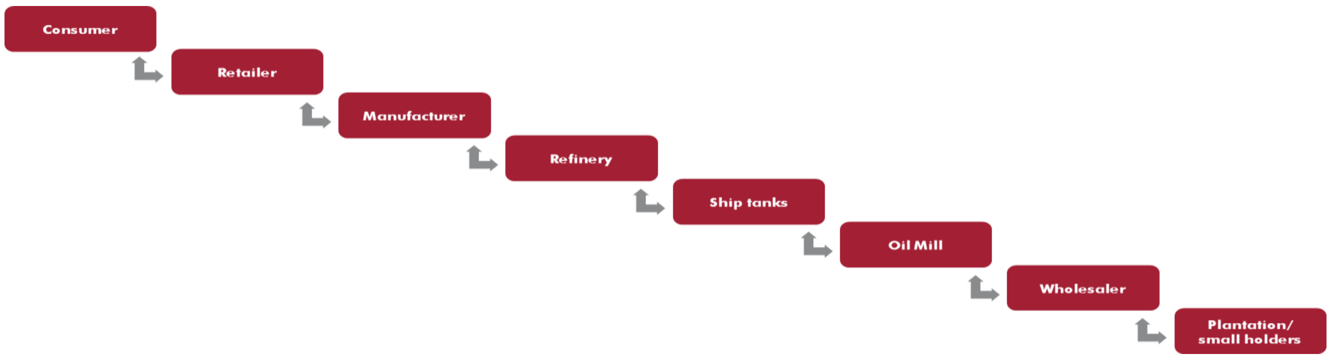


Figure 15: Example of Stepwise Traceability

D- Traceability assessment criteria

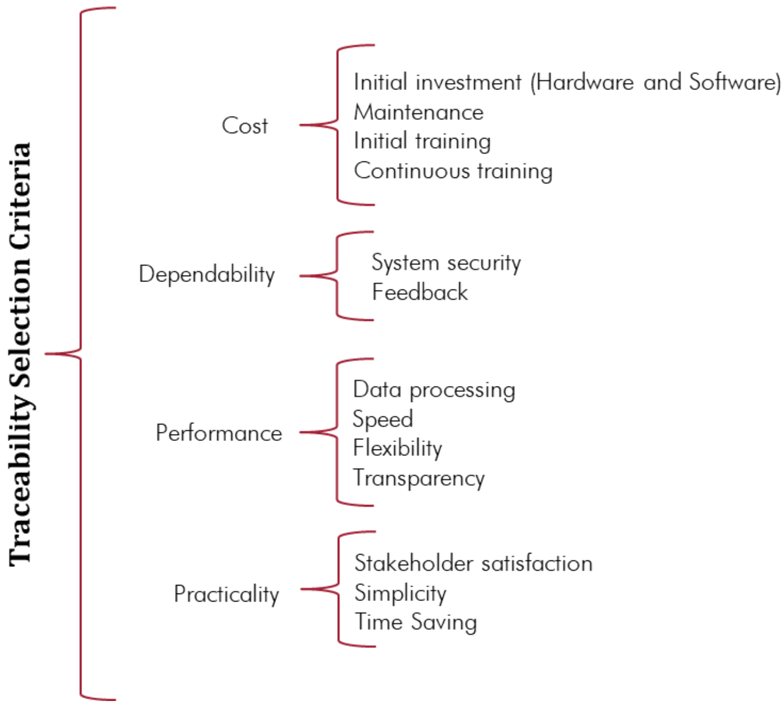


Figure 16: Traceability Assessment Criteria

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