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Seafood traceability systems

Case Tracey – your traceability and trade data companion

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Acknowledgements

In words of Alan Moore, ”Knowledge, like air, is vital to life. Like air, no one should be denied it.”

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TIIVISTELMÄ:
Pilaantuvien tuotteiden kuten elintarvikkeiden jäljitettävyys on tärkeä osa elintarviketurvallisuutta ja toimitusketjujen toiminnallista tehokkuutta. Sääntely ja markkinoiden vaatimukset ovat olleet ajureina merenelävien jäljitettävyyden tietojärjestelmien kehittämiselle ja käyttöönotolle. Nämä informaatiojärjestelmät ovat suunniteltu ja toteutettu tukemaan eri sidosryhmiä datan keräämiselle, tallentamiselle ja jakamiselle jäljitettäville tuotteille arvo- ja toimitusketjuissa. Jäljitettävyyden informaatiojärjestelmien toteutus ja käyttö vaativat tyypillisesti resursseja ja tietopääomaa joka ei välttämättä ole aina saatavissa toimitusketjun alussa esimerkiksi pienimuotoisien kalastajien tapauksessa.
Pienimuotoisille kalastajille suunnitellut informaatiojärjestelmät ja työkalut ovat harvassa. Vastatakseen tähän tarpeeseen uusi informaatiojärjestelmä projekti nimeltään Tracey on aloitettu. Tracey projektin tavoitteena on suunnitella ja kehittää työkaluja pienimuotoisille kalastajille. Tracey on lohkoketjuja hyödyntävä IT artifakti, informaatiojärjestelmä konsepti jonka tavoiteena on kannustaa pienimuotoisia kalastajia tuottamaan ensimmäisen mailin kauppa ja jäljitettävyys dataa merenelävien tuotteista esimerkiksi kalasaaliista.
Tässä lopputyössä käydään lävitse jäljitettävyyden käsitteet, jäljitettävyyden ajurit ja hyödyt sekä jäljitettävyyden informaatiojärjestelmien konseptit. Case-tutkimusosuudessa esitetään Tracey informaatiojärjestelmä konsepti pienimuotoisten kalastajien kannustamiseksi tuottamaan todennettua jäljitettävyys ja kaupankäynti dataa, jota tutkitaan DSRM tutkimusmenetelmällä. Lopputyön tavoitteena on luoda yleiskuva ja näkemys merenelävien jäljitettävyyden hyödyistä ja haasteista, reflektoida Tracey konseptia tietojärjestelmien tutkimusmenetelmien avulla ja tuottaa ehdotuksia Tracey konseptin parantamiseksi kirjallisuuskatsauksen ja case-tutkimuksen myötä.

Avainsanat: Merenelävien jäljitettävyys, lohkoketjutekniikka, tietojärjestelmien suunnittelu

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ABSTRACT:
Traceability of perishables such as food products is important for end-consumer food safety and operational efficiency of supply chains. Regulatory and market requirements have been driving the development and adoption of seafood traceability information systems. These Information systems are designed and built to support different stakeholders throughout the supply and value chain to collect, store and disseminate data about traceable products or resource units to form end-to-end traceability solutions. Implementation and use of traceability information systems typically require resources and know-how which may not always be available for the stakeholders in the beginning of the supply chain e.g. small scale fishers.
There aren't many information system solutions or tools that are targeted towards small scale fishers and fisheries. To answer to this need an information systems project, Tracey, was established to design and develop tooling for small scale fishers. Tracey is a blockchain based novel IT artifact, an information systems concept, that attempts to incentivize small scale fishers to provide first mile trade and traceability data of fish product from e.g. fish catch and fish landing. In this thesis the concepts of traceability, its drivers and benefits as well as traceability information systems are explored. In the case study, Tracey - a concept to incentivize small scale fishers to produce verifiable traceability and trade data, is presented and examined with information science research methods. The objectives for this study are to create a general understanding of benefits and challenges relate to seafood traceability, reflect Tracey with IS research methods, and suggest how to improve Tracey concept on basis of previous literature and research. Recommendations to improve Tracey IT artifact are provided on basis of analysis of Tracey with DSRM framework and further research is recommended on using blockchains in traceability information systems.

Keywords: Seafood traceability, blockchain technology, fisherfolk, information system design

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Abbreviations

ABI Application Binary Interface. 60

API Application Programming Interface. 60

BSE Bovine Spongiform Encephalopathy. 11

DS Design Science. 48

DSRM Design Science Research Methodology. 50

EU European Union. 11, 12

FAO Food and Agriculture Organisation. 12

FBO Food Business Operator. 34

FIP Fisheries Improvement Project. 54

GDST Global Dialogue on Seafood Traceability. 43

GLN Global Location Number. 44

GTIN Global Trade Item Number. 44

IS Information Systems. 12

ISO International Organization for Standardization. 16

IT Information Technology. 12

IUU Illegal, Unreported, and Unregulated. 18, 24

JSON JavaScript Object Notation. 60

KDE Key Data Element. 43

NGO Non-governmental organization. 25

RFID Radio-frequency identification. 29, 30

TRU Traceable Resource Unit. 30, 34

TU Trade Unit. 33

US United States. 11, 12

WHO World Health Organization. 16

1 Introduction

The topic of this thesis arises from an actual project need to develop an information systems concept, design and a proof-of-concept implementation of a traceability information system to incentivize small scale fishers in different pilot locations in South-East Asia to produce European Union (EU) and United States (US) market compliant traceability data of different tuna fish species e.g. yellow-fin tuna. In addition collection of trade data between small scale fishers and fish buyers is explored in this project.

The project has been ongoing since 2019 and has lately entered proof of concept implementation phase. This master's thesis aims to explore and summarize the theoretical background related to traceability and seafood traceability information systems, touching the topics of why traceability systems are required, what are the drivers and benefits of them and what types of challenges and gaps are related to them. On the case study part of this thesis the concept and design of the IT artifact developed under the project is reflected and expanded.

1.1 Motivation and justification

Almost half of the world's fish catch comes from the developing countries, but there aren't many traceability solutions that are aimed at small scale fishers and fisheries in there. In addition, the smaller operations may not have sufficient resources to purchase or implement traceability systems thus new types of solutions are required (Greene, 2010; Sterling & Chiasson, 2014)

Traceability information systems are integral pieces in tracking food products in global supply chain networks. There are multiple different drivers for implementing food traceability but one of the main ones has been the concern for the food safety, which has been driven by the numerous food product scandals in 1990s and early 2000s such as Bovine Spongiform Encephalopathy (BSE) or mad cow disease in the United Kingdom, Hudson food recalls in the United States, dioxin contamination of chicken feed in Belgium and melamin milk scandal in China (Olsen & Borit, 2013; Pei et al., 2011).

Multiple different definitions exist for Traceability (Olsen & Borit, 2013). For example, Food and Agriculture Organisation (FAO) of the United Nations has defined traceability as "...the ability to discern, identify and follow the movement of a food or substance intended to be or expected to be incorporated into a food, through all stages of production, processing and distribution" (FAO, 2017).

Correct and suitable implementation of traceability can bring many benefits (Mai, Bogason, Arason, Árnason, & Matthíasson, 2010) such as reduction of risks and costs associated with food borne disease outbreaks (Hobbs, 2003), reduction in costs associated with product recalls (Agriculture & Canada, 2007), increase production efficiency (Moschini, 2007), expand sales of high-value products (Golan et al., 2004).

For example, In developing countries, implementation of traceability systems may enable small scale fishers and fisheries to comply with export regulatory requirements set by foreign markets such as EU and US, and bring higher price for fish catch (Marttila, Nousiainen, Sheppard, Malka, & Karjalainen, 2019).

However, there are costs involved in implementing traceability solutions and these costs are not equally shared with the ones who gain benefit out from them (Agriculture & Canada, 2007). Bigger players may have the luxury of considering the cost of implementing a traceability system as investment, where as smaller ones may see implementing traceability systems as a financial liability. (Greene, 2010; Sterling & Chiasson, 2014).

In this thesis, an Information Technology (IT) artifact Tracey (Marttila et al., 2019), a blockchain based concept design aimed at incentivizing small scale fishers in the Philippines to produce and share traceability data is introduced and explored with Information Systems (IS) research methodologies.

1.2 Research problem and objectives

This thesis has two purposes: to review and summarize the challenges and benefits of seafood traceability systems; and to reflect a novel concept solution - Tracey that is aimed to solve first mile traceability with small scale fishers with design science methods.

Following research questions are set for this study:

Research Question 1: **What kind of challenges are related to seafood traceability ?**

Research Question 2: **How can Tracey be tied to rigor and relevance of design science and where does it fit in design science research methodology ?**

Research Question 3: **How can the concept IT solution be improved by reflecting it to information systems research framework ?**

1.3 Scope and structure of the thesis

Traceability and food traceability are complex topics and the empirical studies of food traceability span over several different scientific fields as portrayed on Figure 1. This thesis touches both of the social science and natural science aspects of it.

Literature review of this thesis builds from the standards of food traceability towards a more holistic picture of what drives seafood traceability as a whole and what kind of challenges are related to implementing seafood traceability systems.

Literature review begins with defining the terminology as there is ambiguity in the definitions of food traceability. This is followed by brief background of seafood traceability to understand the motivation of it. On the following chapters drivers, benefits and challenges for seafood traceability and traceability systems are explored, after which the systems concepts for seafood traceability systems are introduced at conceptual level.

An introduction to blockchain or distributed ledger technologies and their application on food sector are briefly elaborated to equip the reader to understand basic concepts behind the Tracey case study.

Theoretical framework used to explore and evaluate Tracey is introduced on chapter 3. On chapter 4 the background, reasoning and IT artifact of Tracey are introduced. On chapter 5 this IT artifact is analyzed with design science research methodology and recommendations are offered on how to improve the artifact. Chapter 6 is reserved for discussion of the results of analysis and Chapter 7 concludes the thesis and suggest directions for further research.

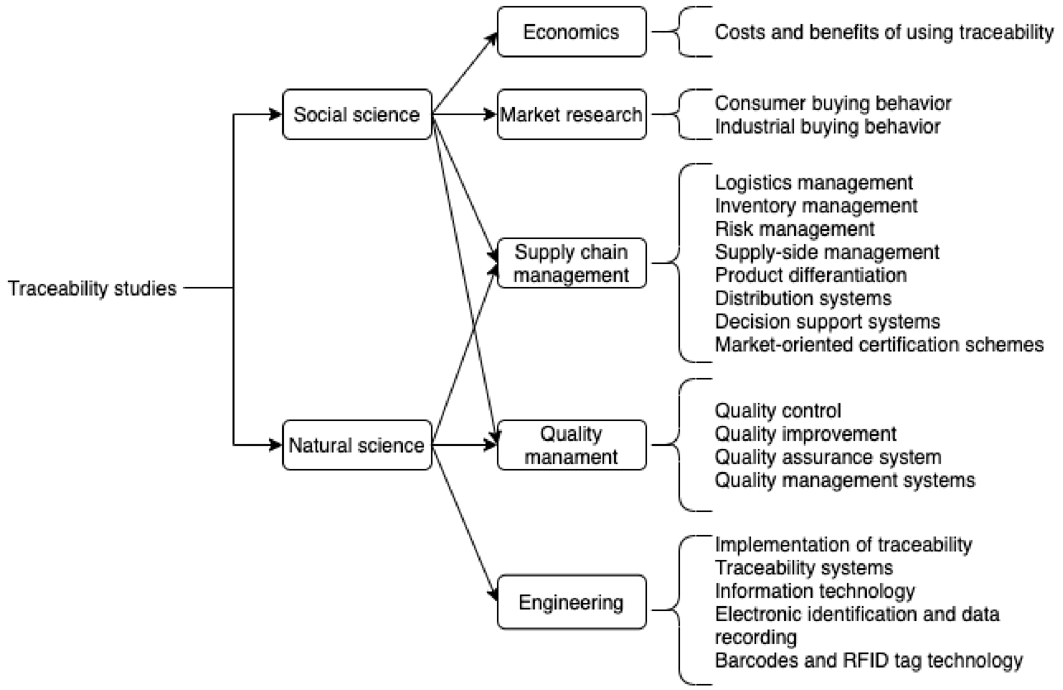

Figure 1. Scientific fields in empirical studies of food traceability, adapted from (Karlsen et al., 2013).

2 Literature review and prior research

According to (Montet & Ray, 2017) food industry has had many scandals in the past. Food scares are not always associated with micro-organisms such as bacteria and viruses but also with technology such as use of chemicals, pesticides, glass and plastics; or environmental pollution such as radiation from nuclear fallouts, mercury or dioxin accumulation in food chain; or changes in co-product management. The recorded history of food scares and alterations span from consumption of fungal infected grains used on rye bread in the middle-ages to modern times.

Historical aspects of food traceability span also from the middle ages to modern day. According to (Montet & Ray, 2017) the first recorded event of treaceability of food relates to traceability of an epizootic event, sheep pox and mange crisis in Europe at 1275.

This chapter continues with the themes traceability, food traceability and traceability systems by exploring the definitions of traceability, the contemporary background, drivers, benefits, challenges and gaps of seafood traceability, traceability systems, technologies and its applications.

2.1 Definition of food traceability

It is important to establish and define common terminology to be able to communicate effectively. When traceability is discussed in different literature there is no single definition for it in the context of food traceability nor is there a clear consensus on what the term ”traceability” means (Olsen & Borit, 2013). Besides having different traceability definitions there are also different types of traceability definitions (Lindvall & Sandahl, 1996).

International standards, scholars, dictionaries and academic papers define traceability in different ways. These definitions of traceability can be conflicting and lacking by themselves and failing to capture the complexity of what traceability is and what does it consist of (Olsen & Borit, 2013). In the following sub chapters, some of the well used definitions of traceability are introduced.

2.1.1 ISO standards

International Organization for Standardization (ISO) has a few different definitions for traceability. ISO 8402 quality standard defines traceability as ”the ability to trace the history, application or location of an entity by means of recorded identifications” (ISO, 1994). A newer ISO 9000 quality standard defines traceability as ”the ability to trace the history, application or location of that which is under consideration” (ISO, 2004).

ISO 9000 standard further states that when relating to products, traceability may refer to “the origin of materials and parts, the processing history, and the distribution and location of the product after delivery (ISO, 2004).

The newest version of ISO 9000 standard adds that ”...records can be used, for example, to formalize traceability and to provide evidence of verification, preventive action and corrective action (ISO, 2015).

2.1.2 Food code standards

The Codex Alimentarius Commission, body that is responsible for all matters regarding the implementation of the Joint FAO and World Health Organization (WHO) Food Standards Programme defines traceability as ”the ability to follow the movement of a food through specified stage(s) of production, processing and distribution” (C. A. Commission et al., 2006).

2.1.3 Governing laws

The EU General Food Law defines traceability as ”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” (E. Commission, 2002).

2.1.4 Academia

Given the fact that different entities such as standardisation organisations, special agencies and regulatory bodies define traceability in different ways there are also different types of traceability.

According to literature review by (Karlsen et al., 2013), the definition of traceability can be divided into three different types: horizontal, vertical and chain traceability. Horizontal traceability having the ability ”...to trace correspondent items between different models”. Vertical traceability having the ability ”...to trace dependent items within a model” (Lindvall & Sandahl, 1996) and chain traceability having 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.” (Moe, 1998)

In this thesis the following definition for traceability coined by Olsen and Borit (2013) is used which combines the commonly used definitions such as ISO, FAO and EU Law definitions. According to (Olsen & Borit, 2013) traceability is ”...the ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications”.

What is noteworthy about when traceability is discussed is that ”... traceability is based on systematic recordings and record-keeping” but ”...there is no guarantee that the recordings are true” (Olsen & Borit, 2013). Olsen and Borit (2013) distinguish traceability and verifiability as two distinctly different topics. In practice, the ability to verify recorded data is crucial but by definition they should not be mixed.

2.2 Background of seafood traceability

People are consuming more fish than ever and over three billion people rely on aquacultured or wild caught fish based protein as their source of nutrition. Fish consumption has been on upward trend since second half of the 20th century, and in the period of 1961 to 2016 the average annual increase in global seafood consumption has been 3.2 percent outpacing the population growth. (FAO, 2018)

Trade of fish and fish products have played a key role in increasing fish consumption, providing employment and generating income for millions of people globally, particularly in developing countries. Exporting fish and fish products is essential to economies of many countries and in the South-East Asia seafood industry forms an economic backbone for many developing countries and communities. (FAO, 2018)

Besides the historical increase in fish consumption, there has been also an upward trend in seafood production, see figure 2. The global fish production including fish, crustaceans and mollusc peaked 171 million tonnes in 2016, aquaculture produce representing 47 percent and captured produce representing 53 percent. According to FAO (2018) "...the total first sale value of fisheries and aquaculture production in 2016 was estimated at USD 362 billion, of which USD 232 billion was from aquaculture production."

Seafood traceability has multiple different drivers, some of which are explored more in-depth in the following chapter in the literature review, such as consumer attitudes, production management, regulatory requirements, market requirements, Illegal, Unreported, and Unregulated (IUU) fishing and seafood fraud (Sterling & Chiasson, 2014).

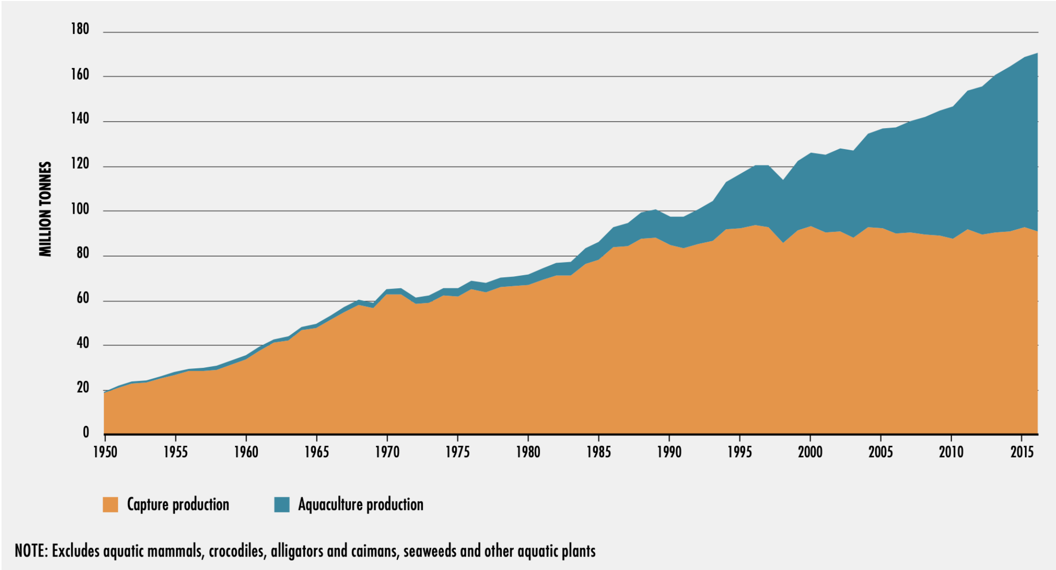

Figure 2. Global capture production and aquaculture production (FAO, 2018).

However, one of the most important drivers that has affected the food traceability as a whole has been food safety, and it is still a major concern, and a critical component in ensuring food and nutrition safety globally. (Ryder, Iddya, & Ababouch, 2014).

The growth of international fish trade has raised concerns of seafood safety. International fish trade has expanded in span of 35 years from approximately USD 8 billion in 1976 to USD 102.5 billion in 2010. Developing countries have played a major role in the international fish trade. In 2010, exports from developing countries represented 49 percent (USD 42.5 billion) of world fish exports in value and 59 percent (31.6 million tonnes live weight equivalent) in volume. (Ryder et al., 2014)

As supply and demand for international fish trade have expanded the international trade has created complex value and supply chains for fish and fish products. For example farmed Norwegian salmon is flown to be consumed in fine restaurants as sushi in Japan and Yellow-fin tuna caught in the Philippines is processed, canned and shipped to be consumed in Europe. According to Sterling and Chiasson (2014) and Pramod, Nakamura, Pitcher, and Delagran (2014) "...seafood often moves very long distances, in and out of multiple ports, and changes hands among various brokers, wholesalers, processors, and retailers before reaching the consumer".

Tveterås et al. (2012) have estimated that 77.7 percent of the global seafood consumption is exposed to international trade. According to Pauly and Zeller (2017) supply and demand dynamics for different fish species are becoming increasingly global. Fish product producers are joining together, increasing supply and operating in multiple countries while fish product processing is being pushed to lower cost countries.

To visualize the complexity of seafood value chain a depiction of it is presented on Figure 3. On the figure, seafood product travels through multiple different actors and it may change its form as it travels from the ecosystems resource pool to end consumers plate. This complexity of the supply chain has a significant impact on the complexity to provide seafood traceability systems. Rombe, Mubaraq, Hadi, Adriansyah, and Vesakha (2018) have claimed that some seafood products may be transferred between different parties up to 10 times before reaching the end consumer.

2.3 Drivers for food and seafood traceability and traceability systems

Some overlap and variance exist between drivers of food traceability and seafood traceability. Food traceability drivers provide general context for what kind of phenomenons are pushing the traceability of food products forwards. Seafood traceability drivers introduce and include the context of fisheries and seafood production to drivers of food traceability and extend them in the context field. The drivers for traceability systems are influenced by drivers of food and seafood traceability. In the following sub sections each of these categories are explored.

2.3.1 Food traceability drivers

Karlsen et al. (2013) have identified 10 different drivers, depicted on Figure 4, that affect food traceability. Besides affecting directly food traceability, several of these drivers

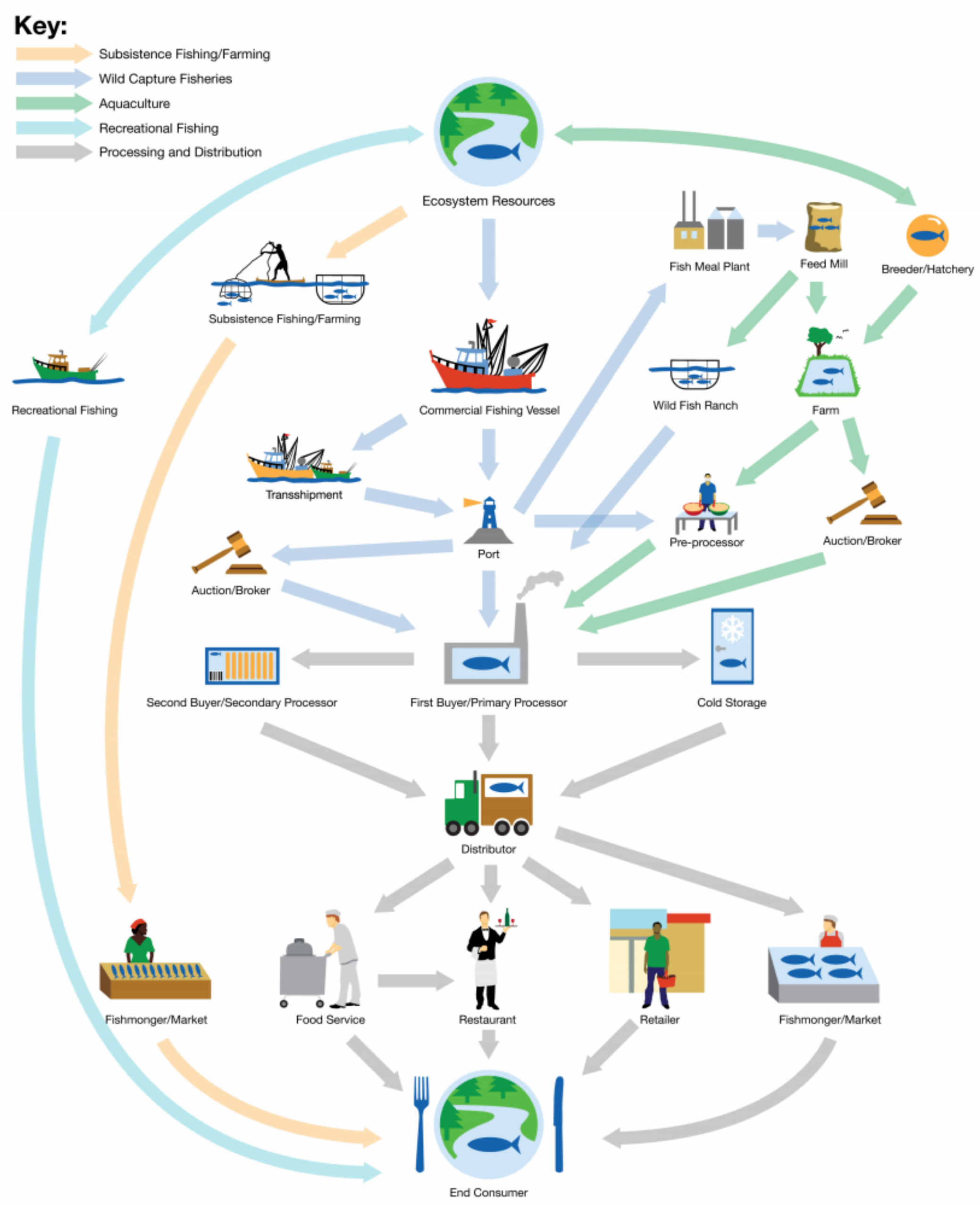

Figure 3. Depiction of seafood value chain (FishWise, 2018).

can also affect each other. For example, certification can be a requirement to enter new markets, such as EU and North America in case of seafood, and being able to produce certified fish products can produce competitive advantage. (Karlsen et al., 2013; Manos & Manikas, 2010)

However, only some of these drivers have studies with empirical evidence, such as food safety, quality, competitive advantages, chain communication and production optimization (Karlsen et al., 2013).

Figure 4. Drivers for food traceability (Karlsen et al., 2013).

2.3.2 Seafood traceability and seafood traceability systems drivers

Based on seafood traceability studies done in the US and Canada, the market requirements drive the seafood traceability (Hanner, Becker, Ivanova, & Steinke, 2011; Sterling & Chiasson, 2014; Thompson, Sylvia, & Morrissey, 2005). According to (Sterling & Chiasson, 2014) the destination market and its requirements for seafood products play an important role in driving businesses and companies to adopt traceability. Destination market's influence on treaceability can be tied to other drivers such as regulatory requirements on destination market, health and safety regulations, consumer demand for certified products and product differentiation (Sterling & Chiasson, 2014).

Sterling and Chiasson (2014) have identified six different drivers for implementations of seafood traceability systems from previous literature: consumer attitudes, production or management tool, regulatory requirements, market requirements, illegal fishing and mislabelled products.

Consumer attitudes

Consumers have become aware and concerned about the sustainability of seafood. They are demanding a change from the industry in relation to overfishing and environmental degradation. Concerns about the state of fisheries, declining fish population and production of sustainable food has positively affected peoples interests towards third party certifications such as eco-labels promoting sustainable and organic seafood products. (Sterling & Chiasson, 2014)

Production or management tool

Another driver for seafood traceability and its systems comes from seafood businesses and sectors. For example aquaculture sector relies on traceability to be able to optimize production against the market demand (Sterling & Chiasson, 2014). The innate driver for businesses to utilize traceability comes from the potential effect it has on the bottom line, either in form of increased revenue or decreased costs.

Regulatory requirements

Certain market areas demand fulfilment of regulatory requirements to be able to access them. According to (Sterling & Chiasson, 2014) traceability systems enable seafood companies to fulfil general production, export regulatory and species-specific regulatory requirements.

Market requirements

Some high volume buyers such as importers, exporters and retail and wholesale companies that apply traceability standards also demand the same standards from their suppliers causing a push of traceability requirements to upstream of supply chain. (Sterling & Chiasson, 2014)

Illegal fishing

Illegal activities related to fishing such as IUU fishing is a global problem. Illegal, unreported and unregulated fishing compromises ecosystems, food security and livelihoods. IUU fishing can happen by fishing vessels ignoring domestic and international fishing laws, fishing in closed or commercially restricted fishing areas, targeting endangered or at risk species or by using illegal fishing gear. (Sterling & Chiasson, 2014)

Mislabelled products

Fraud is persistent problem in seafood supply chains. It can happen through intentional mislabeling of lesser value seafood for a higher value. There are multiple reasons why this type of fraud happens such as "...high demand with limited supply, high profit incentive and an increase in international trade of processed foods, and lack of regulatory enforcement." (Sterling & Chiasson, 2014)

In addition to these drivers, Borit and Olsen (2016) have outlined safety, security, regulatory quality, non-regulatory quality and marketing, food chain trade and logistics management, plant management and documentation of sustainability as drivers for traceability systems.

2.4 Benefits of seafood traceability and traceability systems

Ideally seafood traceability and traceability systems provide many benefits: access to markets that require provenance of fish products, seafood product safety in case of product recalls, combating Illegal, unreported and unregulated fishing with information produced by traceability systems, provision of information for Non-governmental organizations (NGOs) and governmental actors to better understand the state of the fisheries, supporting sustainability targets and goals, reduction of costs and added productivity due to better oversight and understanding of product management and flows.

Mai et al. (2010) have studied quantitatively estimated and qualitatively perceived benefits of traceability from the companies' perspectives. In the study of 24 companies, they perceived the benefits differently depending on which step of the fish supply chain they were.

Related to qualitatively perceived benefits of traceability, the improvement of supply chain management was expected as the most important benefit of traceability. Other perceived benefits were increased customer retention, increase in product quality, product differentiation and reduction of customer complaints (Mai et al., 2010).

Quantitatively estimated benefits of adopting new traceability solutions were expected to come from following areas: market growth, labour savings and process improvements, and reductions in product recalls, liability claims and lawsuits, (Mai et al., 2010).

Despite the multitude of potential benefits of seafood traceability and implementation of seafood traceability systems for companies, the costs and benefits in fish supply chains may not go hand in hand. Mai et al. (2010) notes that there's an argument on "...costs shifting among the stakeholders in a supply chain" and there's a need "...for open discussion between different actors in a food supply chain on the distribution/redistribution of costs and benefits of implementing traceability" (Agriculture & Canada, 2007; Mai et al., 2010).

2.5 Challenges and gaps in seafood traceability standards and regulations

Borit and Olsen (2016) have identified and analyzed gaps and inconsistencies related to current traceability standards and regulations while taking into account; how integrity of product tracking is maintained with consideration towards developing countries and small-scale fisheries . In their study, gap analysis was performed to understand the current state of seafood traceability and the wanted future state of seafood traceability. The findings of this study are of importance as they portray the complexity and the general issues related to seafood traceability systems through different dimensions.

According to Borit and Olsen (2016) literature review there are six general fields where gaps may appear:

- **Awareness**, where the stakeholders need to be interested and aware in their specific contexts about e.g. the advantages of traceability systems.
- **Knowledge or research**, where the stakeholders need to have the correct facts and information related to their situation e.g. what kind of traceability related information should be collected and stored by a traceability system.
- **Commitment**, which is it's own field but it relates also to the awareness. Awareness and commitment are required in relation to the use of standards and norms in traceability systems. They should be the same as used by the policy-makers and the industry, and they shouldn't be circumvented.
- **Implementation**, where the principles of traceability and the implementation of traceability systems bring value when they are implemented effectively through standards and norms.

- **Technology** which is also related to the implementation. The necessary tools and technologies should exist and they should be available to support effective traceability.
- **Standards**, which is also related to implementation. The terms and concepts related to traceability should be harmonized and both implementation and certification of traceability should be available and accepted.

Out of the six general fields Borit and Olsen (2016) have found five to have traceability related gaps. These gaps are summarized in the following paragraphs.

2.5.1 Awareness Gaps

According to Borit and Olsen (2016) there's a lack of understanding on basic terminology and the benefits related to traceability. For example, what does traceability mean, how it should be defined, and how does it differ from similarly viewed concepts like chain of custody or catch and trade documentation schemes.

There's unclarity on what can traceability do to improve companies' internal processes and financial performance as well as where the problems related to adoption of traceability arise from. Many of the issues related to adoption of traceability in seafood stem from the culture and organization rather than from the technology. (Borit & Olsen, 2016)

Organizations that wish to implement traceability may not fully grasp that traceability needs to capture the entire seafood chain from the source of origin to the final destination e.g. from fish catch via transporter to processor to exporter to retailer and finally to consumer. This is related to lack of understanding the difference between internal and chain traceability and it applies for both governmental and to private sector levels. (Borit & Olsen, 2016)

Governmental and private sector level entities do not always understand the importance of documenting transformation which occur to the fish product. These transformations are essential if one wants to trace a product backwards or forwards in a supply chain. (Borit & Olsen, 2016)

2.5.2 Commitment Gaps

Borit and Olsen (2016) argue that the commitment gap related to implementing seafood traceability is significant. There are challenges related to availability of technology, solutions and standards, however most companies have less traceability than they could have and should have given their strategy, priorities and economic interests (Borit & Olsen, 2016).

One of the major commitment gaps is that companies do not understand the economic benefits of traceability despite the evidence and research showing that traceability systems can reduce operating costs, fulfil legislative and commercial requirements and provide a competitive edge. (Borit & Olsen, 2016)

According to Borit and Olsen (2016) typically companies invest in traceability only when they have to e.g. to enter a market that requires fulfilling legislative or commercial requirements.

Companies are not aware of all positive effects of improved traceability systems. One of the reasons may be that it is difficult to perform a cost-benefit analysis of investments related to improving traceability systems and in practice ”...many of the benefits related to improved traceability were not anticipated by the companies” (Borit & Olsen, 2016).

2.5.3 Implementation Gaps

Implementation gap relates to gap between regulatory requirements and feasibility of industry implementation (Borit & Olsen, 2016). Global food system is a complex system and developing regulations and guidance to improve traceability practices across the entire food industry is a challenge (Zhang & Bhatt, 2014). There's a need for standardized and harmonized requirements across all food sectors but there is no single standard to cover them all.

Several regulatory and industry initiatives have proposed frameworks for solving the challenge of having standardized and harmonized requirements. However, most of these initiatives have focused on solving the problem on their specific food product categories instead of across the food industry. (Zhang & Bhatt, 2014)

This may lead to a situation where standardization and harmonization derived from regulatory requirements work only in a specific food sector for a specific food product e.g. fisheries related guidance may not work for other food sectors such as beef and poultry.

Additionally, there is a "...lack of robust fishery control-based catch certificate; inadequate document security for split consignments, insufficient maintenance of batch integrity." (Borit & Olsen, 2016)

2.5.4 Technology Gaps

According to (Borit & Olsen, 2016; Sterling & Chiasson, 2014) there is a lack of verification procedures that integrate with monitoring of food authenticity leading to a situation where one is able to trace the product throughout the supply chain without knowing the authenticity of it. The absence of integration of verification procedures to food authenticity monitoring can expose food products to be mistakenly or maliciously mislabeled.

There is a lack of affordable, functional and robust technologies for automatic data capture and electronic tagging of products e.g. Radio-frequency identification (RFID) tags. Manual labour and tasks cause significant costs for running traceability systems e.g. actions that are performed frequently such as data entry and reading of bar codes. These costs could potentially be decreased by utilizing remotely readable electronic tags e.g. RFID tags which could also enable introduction of smaller granularity Traceable Resource Units (TRUs). (Borit & Olsen, 2016)

2.5.5 Standards Gaps

Standards and norms have series of inconsistencies ”...both between the standards/norms issued by the same institution and those issued by different institutions but referring the same topic” (Borit & Olsen, 2016).

Naming and seafood attribute list conventions vary from country to country. Different countries often have different seafood attribute lists and in some cases the same fish species can be named differently depending on a country. (Borit & Olsen, 2016)

Traceability related information gathering requirements and standards differ from country to country. There is no universal standard for what kind of information should be gathered and shared to have effective and interoperable traceability. (Borit & Olsen, 2016)

The lack of uniform traceability information inhibits the interoperability of seafood traceability systems and increases business related risks and costs when choosing and adopting traceability information systems. (Borit & Olsen, 2016)

2.6 Challenges of small scale traceability in developing countries

Challenges and gaps discussed by (Borit & Olsen, 2016) apply also for small scale fishers from developing countries and should be considered to be taken into account when implementing solutions for small scale traceability. Besides challenges discussed by (Borit & Olsen, 2016), there are further challenges related to developing traceability solutions for developing countries.

Duggan and Kochen (2016) have studied challenges and opportunities related to fisheries certification of Indonesian small-scale tuna fisheries. Findings of Duggan and Kochen (2016) in rural Indonesia are particularly interesting in the context of this thesis as they portray similar issues as found on the case study Marttila et al. (2019) in the rural Philippines. Duggan and Kochen (2016) has identified multiple challenges but to understand these challenges better, a picture needs to be painted of the environment where the fishing activities occur.

Typically small-scale tuna fishery operations occur in remote and small communities where ”...accessibility, education, socioeconomic conditions etc. are variable at best and poor at worst”. (Duggan & Kochen, 2016)

Location of these communities lack of developed transport links creating difficulties in reaching them and transporting products produced in them to market. These communities suffer from the lack of continuous electrical supply, having limited access to ice and fuel and minimal landing facilities, often being only simple beach landing without dedicated facilities further impede maintaining the quality of the fish product. (Duggan & Kochen, 2016)

Typically the level of education is low in rural areas such as in Eastern Indonesia making the fisheries improvement projects, guidelines and the need for fisheries certification difficult for small-scale fishermen to grasp and often the fishers do not see any immediate benefits of participation to long term improvement projects. (Duggan & Kochen, 2016).

Conversely, ”...many small-scale fishermen fish on short-term basis i.e. they are concerned about their daily income/subsistence rather than having any long-term vision for the fishery, participation in trainings, capacity building and co-management initiatives” (Duggan & Kochen, 2016).

On the fishing communities the fishermen have to rely and deal with middlemen, actors in value chain whom sell the fishermens’ catch to local processors. These middlemen

”...enjoy a powerful and often highly respected role in the community and can have a large influence on the financial status of fishermen” (Duggan & Kochen, 2016).

If the fishermen wish to be able to export to EU and US, they and their ”...associated supply chains, will have to conform to the requirements of both, possibly placing normative burdens on actors, creating confusion and barriers to compliance” (Duggan & Kochen, 2016). However, the lack of governmental seafood traceability guidelines, infrastructure and electronic traceability systems and use of hand-written coding systems e.g. for catch logging cause challenges.

International demand exists for sustainably produced tuna fish but to be able to meet it ”...more sophisticated, reliable and updated traceability systems may be required in comparison to any existing ones, placing pressure and costs to supply chains” (Duggan & Kochen, 2016), but key challenge exists with the split of the costs and benefits of such systems.

Besides splitting the costs of traceability systems, implementing them requires extra human and financial resourcing, training and incentives for participation. Implementing traceability systems can be a challenge for small-scale fisheries due to lack of guidance in regards of what level of traceability is required and due to nature of production lots i.e. ”...volumes from individual small-scale vessels may be too low to process separately”. (Duggan & Kochen, 2016)

As a whole, a strong need exists for improving small-scale fisheries activities to enable them to improve and export products internationally. This comprises of process digitalization of fishermens activities e.g. creation of digital tools for electronic catch logging and supply chain management, education of use and benefits of aforementioned tools, incentive building, piloting and testing, certification and potentially supply chain restructuring such as removing middlemen.

2.7 Seafood traceability systems concepts

To understand seafood traceability and seafood traceability systems, some seafood traceability context dependant concepts and definitions need to be established. There are many definitions for food traceability but seafood traceability in general means the ability to "...fully trace a product from the point of sale back to its point of origin, with information available about all transactions and movements in between" (SeafoodSource, 2012).

2.7.1 Batches and Trade Units

In seafood supply chains, several different terms exist for batches e.g. production batches, raw material batches and ingredient batches. Batch is an internal term in a company and it identifies "...the quantity of material prepared or required for one operation" (Farlex, 2020). Batches usually have their own identifiers which are generated in the company and they do not adhere to any standards. (Olsen & Borit, 2013)

Trade Unit (TU) is a quantity of material such as fish product which is sold by one trading partner to another. " Incoming TUs are often merged or mixed into raw material or ingredient batches, e.g. when captured fish is sorted by size and quality before processing". Production batches are usually large and split into numerous outgoing TUs. These TUs "...must be explicitly labelled and identified by the producing/selling company so that the receiving/buying company can identify the content". (Olsen & Borit, 2013)

It is not uncommon for TUs to share same identification number e.g. production batch, making traceability more difficult and less effective. Conversely, using unique identification numbers on TUs requires extra work but it also makes traceability easier for example in cases of product recalls. (Olsen & Borit, 2013)

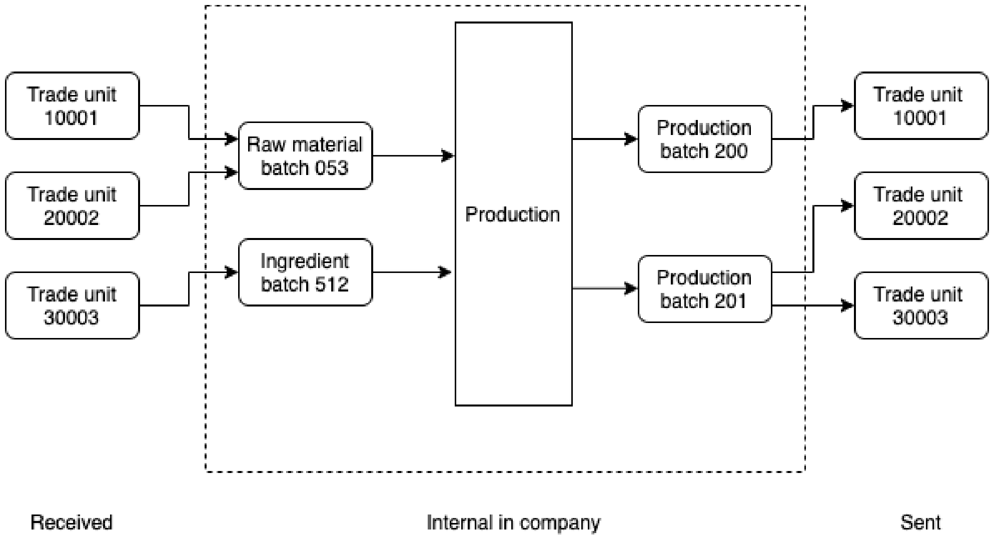

Figure 5. Example of batches and trade units in supply chain of company. Adapted from Olsen and Borit (2013); Tracefood.org (2008).

2.7.2 Traceable Resource Unit

In (Olsen & Borit, 2013) definition of traceability, they refer to information that can be traced which relates to something that is under consideration throughout the entire life-cycle. This ’something’ in seafood industry is typically ”...a batch (i.e. a unit of food or material used or produced by a Food Business Operator (FBO)) or a tradeunit (i.e. a unit of food or material sold by one partner, transported to, and received by another FBO)” (Borit & Olsen, 2016).

These batches and tradeunits are commonly called as TRUs (Borit & Olsen, 2016; Kim, Fox, & Grüninger, 1999). TRUs are the smallest unique traceable items that are wanted to be traced and which information is recorded in traceability systems (Borit & Olsen, 2016).

2.7.3 Granularity

Granularity of TRUs determines the accuracy of traceability systems and granularity itself is affected by the physical size of the TRU. For example, ”...processing company can typically choose whether they assign a new production batch number every day, every shift (e.g. 2–3 times per day) or every time they change raw materials (e.g. 1–20 times per day)" (Borit & Olsen, 2016). Lower granularity increases the amount of TRUs and work related to them but it also increases the accuracy of traceability systems.

2.7.4 TRU identifiers

TRUs are codified numeric or alphanumeric identifiers assigned by the company that generates TRUs or they can be mutually agreed between trading partners with references to standards. The TRU identifiers "...must be unique in their context so that there is no risk of the same identifier accidentally being assigned twice". Ensuring uniqueness of TRUs is important and typically most convenient solution is to use globally unique identifiers constructed for example from by combining country codes with company codes that are unique within the country.

In practice, the creation and management of uniqueness of TRU identifiers may be externalized by companies by utilizing 3rd party services such as GS1 global trade item numbers (GTIN) see figure 6 for examples of GS1 GTIN standard.

EAN/UPC
9 501101 021037

GS1 DataMatrix
(01)09504000059118
(17)141120
(10)7654321D

GS1 DataBar
(01) 0 9501101 02103 7

GS1-128
(01) 0 0614141 98765 8 (11) 120715 (10) ABC123

Figure 6. Example of unique GTINs displayed with different barcodes for unique traceable resource units. (GS1, 2017).

2.7.5 Internal and External Traceability

Traceability is divided into internal traceability and external traceability or chain traceability. ”Internal traceability refers to the ability to keep track of what happens to a product, its ingredients and packaging within a company or production facility” (Petersen & Green, 2005) and it is the backbone of traceability in general (Borit & Olsen, 2016).

External traceability or chain traceability ”...refers to the ability to keep track of what happens to a product, its ingredients and packaging in the entire or part of a supply chain” (Petersen & Green, 2005). It is the ”...traceability between links and companies, and it depends on the data recorded in the internal traceability system” being exchanged to next link in traceability chain (Borit & Olsen, 2016).

On Figure 7 the relationship between internal and external traceability is illustrated. For example, on the figure a simplified seafood products traceability chain is portrayed. From left to right the traceable resource unit is carried through as it goes under transformations. First the fish is caught on sea, put on batches, sent to processors, processed, and finally sold to and consumed by a customer. Along the way the product is traced and information of changes to the TRU is recorded.

In this illustration internal traceability is considered to include all the events that happen to the product inside a single processor. Transformations, merges, splits or mixes of products are recorded and stored to processors traceability system. External traceability is sharing this information between supply chain parties. Chain traceability can be seen as sharing the traceability information to next processor in line.

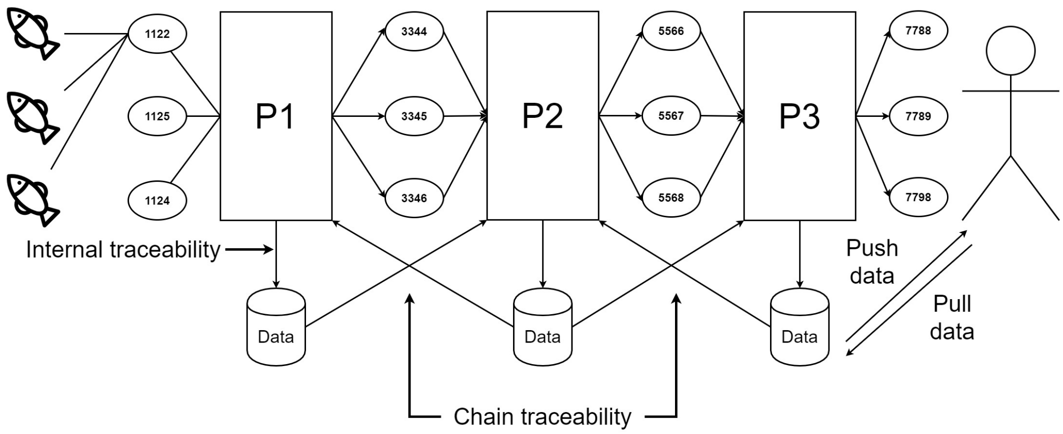

Figure 7. Internal versus chain traceability.

2.7.6 Transformations

Transformations are events where new TRUs are generated on basis on existing ones. Typically, transformations are merges, splits and mixes of fish products, see Figure 8 e.g. batches of fish or raw materials used to produce a certain product batch at certain day to fill a container of outgoing product of certain weight. ”To document a transformation, one needs to document exactly which existing batches or TUs were used to create a new batch or TU”. (Borit & Olsen, 2016)

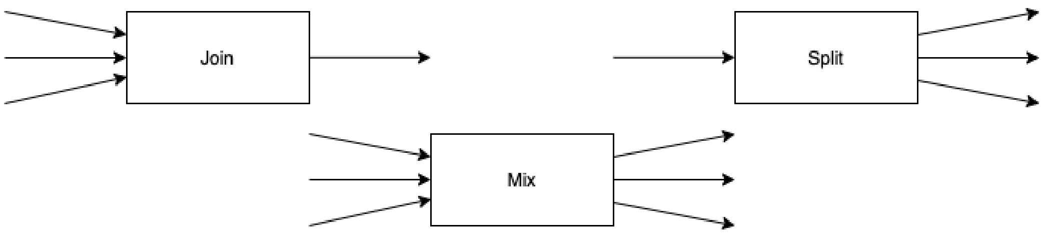

Figure 8. Trade Unit transformation types Adapted from Olsen and Borit (2013); Tracefood.org (2008).

2.7.7 Referential integrity

Referential integrity relates to practice of maintaining TRUs uniqueness within its context. When unique identifiers are assigned to only one TRU instead of multiple TRUs, the practice is called as referential integrity. When referential integrity is present ”…each TRU will have its own unique identifier, not to be shared with any other TRU”. If the referential integrity is absent, the effectiveness of traceability system is limited as it is neither longer possible to distinguish between TRUs nor to record further properties related to each TRU e.g. when TRUs come from the same vessel and were caught and processed at the same time. (Borit & Olsen, 2016)

2.8 Seafood traceability systems

According to Borit and Olsen (2016) ”…traceability systems are constructions that enable traceability”. These systems do not have to be digital information systems. They can be paper based which are still commonly used in South-East Asia. Generally speaking, a golden rule for traceability system is that ’you can do anything’ as far as the traceability system is concerned but you must document what you are doing (Olsen & Borit, 2018).

However, there are certain requirements for traceability systems. Traceability systems should be able to provide access to all properties related to a food product and the related ingredients to all the actors in the supply chain, and facilitate backwards and forwards traceability of the food product to ascertain where did the food product come from and to where did it go next. (Borit & Olsen, 2016; Olsen & Borit, 2013)

To achieve the above, traceability system should have following properties (Borit & Olsen, 2016):

- Ingredients and raw materials must somehow be grouped into units with similar properties e.g. as traceable resource units.
- Identifiers or keys must be assigned to these units. Ideally these identifiers should be globally unique and never reused.
- Product and process properties must be recorded and either directly or indirectly

linked to these identifiers.

- A mechanism must exist to get access to these properties.

2.8.1 Garbage in, garbage out

The traceability system is only as good as the data that has been inserted to it. Traceability system is like a filing cabinet, it enables systematic storing and retrieval of data but it doesn't care about what types of data are being stored. According to Borit and Olsen (2016) most of the data in traceability systems should not be taken as a single truth but to be considered as a claim. Someone e.g. a supply chain stakeholder is claiming that an inserted point of data about a TRU in traceability system to be truthful. If verification cannot be connected to this claim there is no certainty that the data is correct and true.

2.9 Blockchain technology

According to (Bashir, 2018) "...blockchain is a peer-to-peer, distributed ledger that is cryptographically secure, append-only, immutable, and updateable only via concensus or agreement among peers". Technically blockchain "...refers either to a distributed data infrastructure or a method for recording data using cryptoanalytic hash function" (Wang et al., 2019).

Blockchain can be perceived as another application layer that runs on top of the internet protocols enabling economic transactions between relevant parties. It can also be used as a registry and inventory system for recording, tracing, monitoring and transacting tangible, intangible and digital assets. (Wang et al., 2019)

In practice, a blockchain is an encoded digital ledger that is stored on multiple computers in a public or private network comprising of data records or blocks. As each transaction occurs, it is placed into a block. Each block is then connected to the one before and after it. Each block is added to the next in an irreversible chain and transactions are blocked together forming a blockchain. Once the blocks have been added to the chain they cannot be overwritten and users will always have access to a comprehensive trail of activity. On figure 9 a generic structure of a blockchain string is presented. (Wang et al., 2019)

Ideally in a blockchain, no single party controls the data and the entire data infrastructure is visible to all parties where every party member can verify the records of its transactions directly from each other without an intermediary or a distributed consensus mechanism. (Wang et al., 2019)

Different types of blockchains exist: permissioned and permissionless. These two main types are ”...distinguished in terms of access control - who can read a blockchain, submit transactions to it and participate within the consensus process” (Wang et al., 2019). In public blockchains, every transaction is public or permissionless and users can be pseudonymous. In private blockchains or permissioned blockchains ”...participants need to obtain an invitation or permission to join. Access is controlled by a consortium of members (consortium chain) or by a single organisation (private blockchain)”. (Wang et al., 2019)

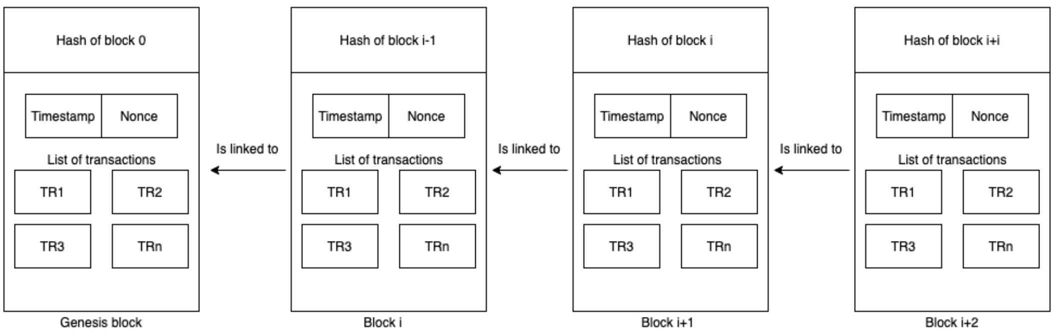

Figure 9. Generic structure of a blockchain, adapted from (Wang et al., 2019).

There are different types and implementations of blockchains but they all share some key characteristics: consensus, provenance, immutability and finality. For a transaction executed in a blockchain to be valid, all participants must agree on its validity by forming a consensus. There are different types of governance (Karjalainen, 2020) and consensus mechanisms, though Proof of Work and Proof of Stake are more common ones.

Participants in blockchain know where the asset came from and how its ownership has changed over time forming provenance. No participant can tamper with a transaction after it has been recorded to the ledger. If a transaction is in error, a new transaction must be used to reverse the error, and both transactions are then visible, forming immutability. A single, shared ledger provides one place to go to determine the ownership of an asset or the completion of a transaction, forming finality. (IBM, 2017)

2.10 About application of blockchain on food sector

According to Olsen, Borit, and Syed (2019) since 2015, there have been relatively many tests and trial applications of blockchain in food chains addressing specific issues such as traceability of fish, chicken, beef and coffee.

Enterprises and organizations have tested, trialed and piloted use of blockchain in different contexts but why haven't they adopted it? Are decentralized solutions inferior to centralized ones?

According to Olsen et al. (2019), comparing individual implementations of e.g. centralized seafood traceability solutions to a decentralized seafood traceability solution may not be meaningful due to anecdotal evidence that this comparison would provide.

A better approach to compare the choice of implementation technology should come from analysing attributes and implementation options separately and by indicating pros and cons of each option. (Olsen et al., 2019)

Olsen et al. (2019) have identified eight different attributes against which the choice of centralized or decentralized technologies should be weighted against.

- **Suitability of database**: Blockchains and relational databases operate differently. Traditional database stores the current value or the state of data but blockchains store transactions. As transformations in supply chains are similar to transactions blockchains are well suited for storing data related to product traceability.
- **Data quality and veracity**: The quality of data cannot be guaranteed on either type of database systems. However, deliberate fraud may be less likely in blockchain-based systems as the provider of the fraudulent statement can be unambiguously identified as all transactions to blockchain are stored and linkable to an identity.
- **Immutability, integrity and transparency**: In traditional databases, data elements can be overwritten. In blockchain, data is never overwritten but updated via new transactions where the latest transaction would represent the newest state of data element in chain.
- **Confidentiality**: Blockchains can provide a level of confidentiality e.g. through private blockchains but they are not designed for it. Confidentiality and tiered data access protocols are designed externally for blockchains. Confidentiality and transparency are to a degree mutually exclusive qualities. If one needs high level of confidentiality, blockchain implementations may not be as good as traditional databases.
- **Trust**: In traditional traceability systems, one is asked to trust the owner of the system and if anything turns out to be wrong, the reputation of the owner of the system suffers. Blockchains are designed to work without trusting any particular organization, the trust is built in the blockchain system by design through veracity of the data. However, Olsen et al. (2019) note that "...the inherent blockchain quality of not needing to trust any single organisation is not really applicable in the food sector" as brand owners to provide data and safe food products.
- **Speed and efficiency**: Having data integrity comes at a cost and blockchain implementations will always be slower than traditional implementations due to verification of signature or identities using cryptographic methods and need to execute consensus algorithms to decide how new blocks are added to the chain.

- **Robustness**: Indicates how sensitive the data and database are to mistakes, errors or incidents. In traditional systems, robustness is provided by external processes which may vary by implementation effort and quality. In blockchain-based systems, a degree of robustness is inherent in the system for both state of the data which can be recreated by traversing the recorded transactions and for the database which can be duplicated many times.
- **Interoperability**: How well different systems are able to exchange information with each other. The capability of interoperability could be seen as independent factor from the choice of traditional databases or blockchain technology. However, in practice there are a number of implementation options for traditional electronic traceability systems whereas blockchain implementations are for now more homogenous. Olsen et al. (2019) claim that the homogenous nature of blockchain systems makes them more interoperable, and that many of the reported success stories related to using blockchain in supply chains come from the improvements in interoperability and data sharing due to homogenous nature of blockchain than from other attributes of blockchain. Whereas the interoperability of traditional traceability systems depend on adoption of standards for Electronic Data Interchange and for data content, but since there are too many competing standards, the current level of interoperability remains low.

2.11 Traceability data standards

In context of this thesis, two traceability data standards are explored and utilized in the Tracey IT artifact: GS1 and Global Dialogue on Seafood Traceability (GDST). Both standards define Key Data Elements (KDEs) that should be captured about the fish product which is to be traced.

GS1 is a not-for-profit organisation that develops global standards for business communication. GS1 standard for seafood traceability aims to capture KDEs defining Who, What, When, Where and Why over Critical Tracking Events where physical events occur to tracked goods. (GS1, 2019)

An example of use of GS1 standard could be following. To define KDEs of a tuna fish that has been sold between fisher and a buyer; **Who** would be defined by the standard as a Global Location Number (GLN) of the party that did the first sale and to identify buyers and sellers of fish further downstream. **What** would be defined by a Global Trade Item Number (GTIN) to uniquely identify the trade item with Batch/lot number, serial number, quantity and weight of the trade item. **Where** would be defined by GLN of physical location identifying production and inventory locations e.g. first landing. **When** would be defined by date and time of critical tracking event e.g production, shipping or receiving. And lastly, **Why** would be defined by the process context of the critical tracking event e.g. shipping.

GDST is an international business-to-business platform for companies and organizations that engage in activities in the seafood supply chain. Goal of GDST is to advance the interoperability in the seafood supply chain through definition of commonly used key data elements, technical specifications for interoperable traceability systems and benchmarks for data validity. (GDST, 2020)

GDST has defined internationally agreed key data elements that are routinely associated with seafood products. Version 1.0 of GDST standard for wild capture fish consist of 35 key data elements over seven different critical tracking events, from catch to landing to processing.

Both GS1 and GDST seafood traceability standards contain some overlap but they capture information at different scopes. In simplified terms, GS1 captures information about the fish product in the supply chain whereas GDST captures information in addition about how the fish was captured e.g. which gear type was used and what kind of working conditions applied e.g. use of human welfare policy standards.

2.12 Centralized vs decentralized traceability systems

Traceability systems are built to store and manage business critical information related to products that need to be traced. Traditionally, these electronic traceability systems are built as centralized systems, where a single party controls and manages the solution and the stored information. An alternatively approach to implement traceability systems is to make them decentralized. Blockchains provide a technological approach to support creation of decentralized traceability systems utilizing a distributed approach where multiple parties participate on managing and hosting the stored information.

Various blockchain applications and implementations exist for food traceability but in the scope of supply chain implementations it has been scarcely applied to it (Galvez et al., 2018; Olsen et al., 2019). Some of the challenges related to adopting blockchain to supply chains has been the complexity associated with implementing blockchain systems and the fact that blockchain technology is still in stage of development and there is a lack of standards for traceability system implementations (Galvez et al., 2018).

But how does use of blockchain on decentralized traceability systems compare to traditional centralized systems. Galvez et al. (2018) has attempted on illustrating the differences on abstract level as see on the Figure 10. In general, Olsen et al. (2019) summarize that the difference between centralized and decentralized systems is the structure of underlying database. While there are inherent differences between individual implementations of traceability systems, these differences are fairly small and relate to the immutability and inherently consistent nature of the blockchain data structure.

Blockchain provides some inherent advantages due to the nature of it such as: transparency, efficiency ,security and safety (Galvez et al., 2018). But blockchain based systems are going to be always slower than centralized systems due to the nature of replicating information. Olsen et al. (2019) note that if speed is not of paramount importance for a

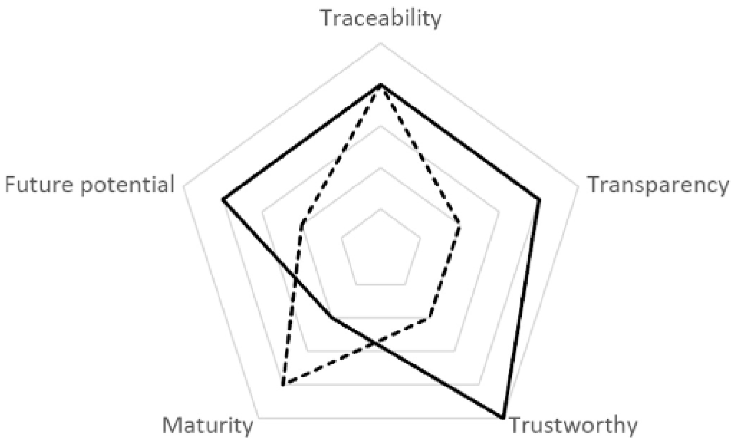

Figure 10. Spider chart of blockchain (solid line) versus a centralized system (broken line). (Galvez et al., 2018).

traceability system, then blockchain technology can provide a good solution.

3 Theoretical framework

Traceability is an interdisciplinary field spanning from natural sciences to social sciences. Different scientific methods have been utilized in past studies, see figure 11, to define the problems or questions and to argue why a specific approach to solve the problem is feasible. (Karlsen et al., 2013)

In general there's no common or agreed framework for implementing food traceability (Karlsen et al., 2013). As the focal point of this thesis is to study and develop an IT artifact, information systems research methodologies are utilized.

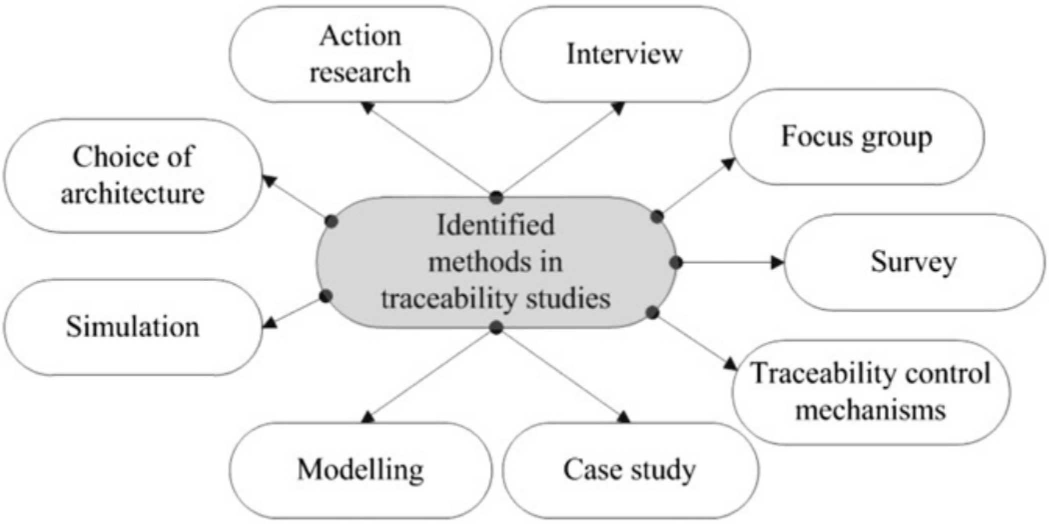

Figure 11. Common methods used to study traceability (Karlsen et al., 2013).

3.1 Design Science

According to Peffers et al. (2007) "...Information Systems is an applied research discipline". IS discipline has two major research paradigms: behavioral research paradigm and design research paradigm. The former "...seeks to develop and verify theories that explain or predict human or organizational behavior" and the latter "...seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts". (Hevner et al., 2004).

These paradigms differ from each other and they have different roots; "behavioral-science paradigm has its roots in natural science research methods" which seeks to develop and justify theories whereas "…design-science paradigm has its roots in engineering and the sciences of the artificial (Simon 1996)" being a problem solving paradigm seeking to create innovations. (Hevner et al., 2004).

In Information Systems science research, technology and behavior are inseparable. Truth and utility are "…two sides of the same coin and that scientific research should be evaluated in light of its practical implications". (Hevner et al., 2004)

When Design Science (DS) research is compared to other fields of sciences; Design science research "…focuses on creating and evaluating innovative IT artifacts that enable organizations to address important information-related tasks" (Hevner et al., 2004).

Hevner et al. (2004) have combined behavioral-science and design-science paradigm as a conceptual framework that represents the information systems research framework for understanding, executing, and evaluating IS research. This framework is depicted in Figure 12 (Hevner et al., 2004)

Hevner et al. (2004) have established seven guidelines "…to assist researchers, reviewers, editors, and readers to understand the requirements for effective design-science research".

1. Design as an artifact. The result of design science research should be "…a purposeful IT artifact created to address an important organizational problem". The artifact can be a construct, model, method or an instantiation.

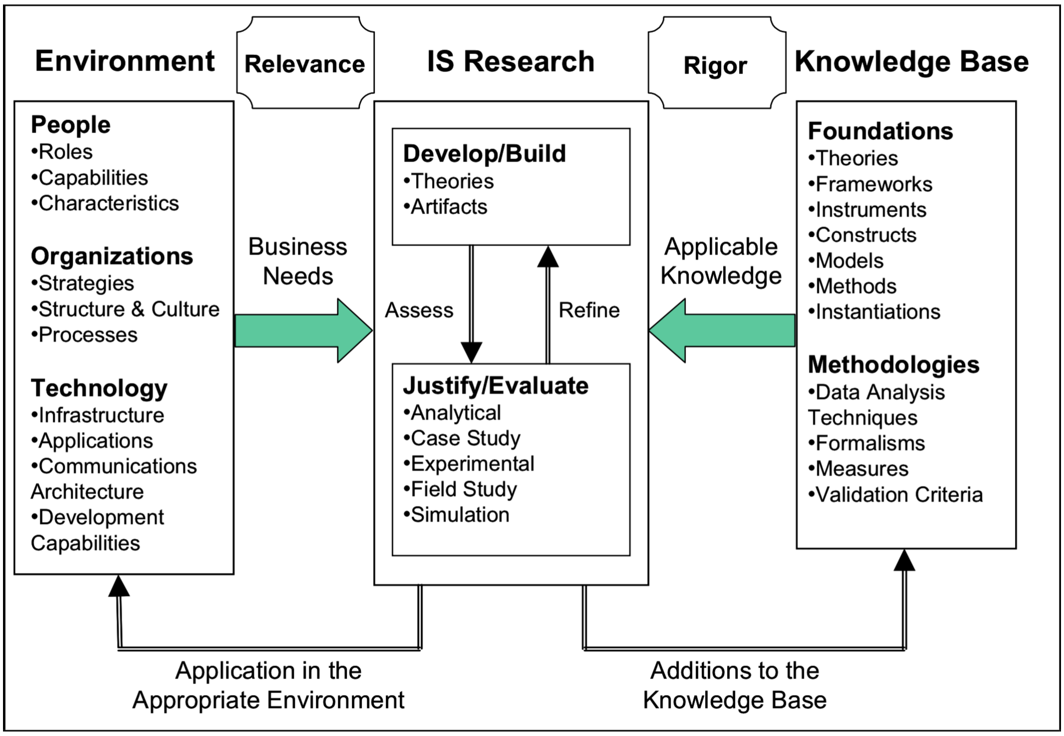

Figure 12. Information systems research framework (Hevner et al., 2004).

2. Problem relevance - “The objective of design-science research is to develop technology-based solutions to important and relevant business problems.”

3. Design evaluation - “The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.”

4. Research contributions - “Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.”

5. Research rigor - “Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.”

6. Design as search process - “The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.”

7. Communication of Research - “Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.”

3.2 Design Science Research Methodology

Peffers et al. (2007) have develop a methodology for design science research in information systems by "...introducing a DS process model, which, together with prior research on DS, provides DS research with a complete methodology".

The design of this conceptual process seeks to meet three objectives: to provide a nominal process for the conduct of DS research, to build upon prior literature about DS in IS and reference disciplines, and to provide researchers with a mental model or template for a structure for research outputs. Design Science Research Methodology (DSRM) "...provides a nominal process model for doing DS research, and it provides a mental model for presenting and evaluating DS research in IS". Peffers et al. (2007)

DSRM process can be mapped in different ways, but typically it is presented as a table or as a sequential process model as shown in Figure 13. DSRM process consists of six steps (Peffers et al., 2007):

- Problem identification and motivation. Where specific research problem and justification for the value of a solution are defined.
- Defining the objectives for a solution.
- Designing and development of the artifact. Creation of the artifact which could be e.g. constructs, models, methods or instantiations.
- Demonstration of the use of artifact to solve one or more instances of the problem.
- Evaluation by observing and measuring how well the artifact supports a solution to the problem.
- Communication by communicating "...the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate".

Though the process of DSRM is structured as sequential, there is no expectation that research should proceed in sequential order through the first activity to the last activity. Application of DSRM can happen through any of the first four process steps and move outward creating four different entry points for design science research and application of design science research method to an IT artifact. (Peffers et al., 2007)

These four research entry points are problem-centered approach, objective-centered approach, design and development centered approach and client/context-initiated solution approach, see figure 13 for research entry points. As an example, the problem-centered approach starts with the first activity of DSRM ”…if the idea for the research resulted from observation of the problem or from suggested future research in a paper from a prior project”. (Peffers et al., 2007)

An objective centered solution approach starts with the second activity and ”… it could be triggered by an industry or research need that can be addressed by developing an artifact”. Design and development centered approach would start with the third step of DSRM process and it could be started as a ”…result from the existence of an artifact that has not yet been formally thought through as a solution for the explicit problem domain in which it will be used”. Client and context initiated approach starts with the fourth step of DSRM process and it ”…may be based on observing a practical solution that worked”. (Peffers et al., 2007)

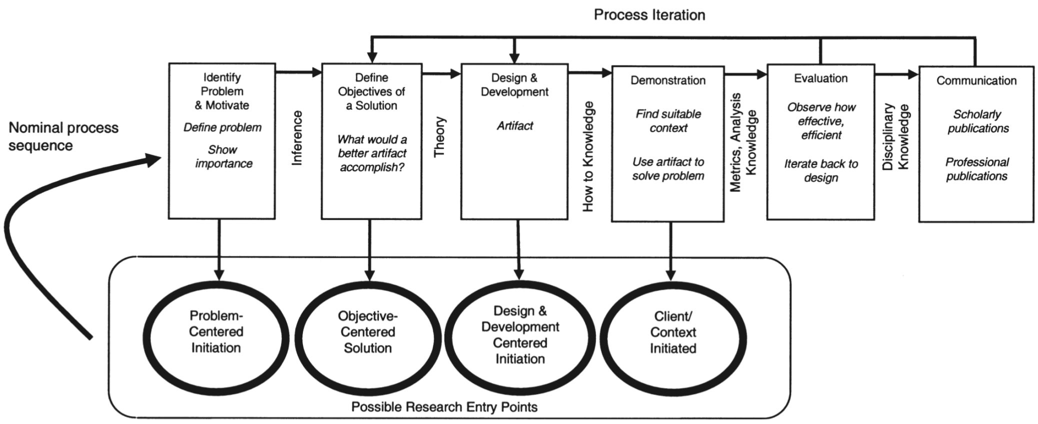

Figure 13. DSRM Process Model (Peffers et al., 2007).

4 Case: Tracey

Tracey is an information systems project aimed to incentivize artisanal fishers in rural areas in the Philippines to produce verified traceability and trade data to be leveraged by 3rd parties e.g. financial institutes, local government units and fish product supply chain enterprises. Tracey is developed by a Finnish IT consulting company TX [1] in collaboration with a Swiss based crypto project Streamr [2], a national organization to World Wildlife Foundation WWF-Philippines [3] and Union Bank of the Philippines [4]. The project has been ongoing since 2019 and it can be roughly divided in to three phases: design, develop and pilot. Tracey has finished the first phase and is currently in the development phase.

4.1 Background

Developing an information systems project for a developing nation in Southeast Asia sets unique requirements for the project. To understand these requirements better, some background needs to be established.

[1]https://tx.company/
[2]https://streamr.network/
[3]https://wwf.org.ph/
[4]https://www.unionbankph.com/

Philippines is a developing country that lives from the sea. According to Pearce, Mitchell, Duffy, Collins, and Wood (2015) in ".. 2012 the Philippines was the second highest ranked Southeast Asian nation in terms of total fish catches, behind only Indonesia". When it comes to tuna "...the Philippines is the world's third largest tuna producer" with almost half of the "...country's seafood exports coming from yellowfin, skipjack, and frigate tuna" (WWF-Philippines, 2019).

Fisherfolk are fishermen who live in coastal communities and practice artisanal handline tuna fishing as a livelihood. These people face multitude of challenges that endanger the continuity of their way of life such as sustainability of fisheries, the changing environment, access to fair finance and legal requirements to access foreign markets.

According to WWF-Philippines (2019) tuna stocks are threatened by climate change, overfishing and illegal fishing. Historically the fish stock levels have been on declining trend in the Philippines fisheries in the past 30 years (Anticamara & Go, 2016).

Also, the lack of access for fair financing is adversely affecting fishers. According to the Philippines Central Bank (BSP, 2019) in 2017 only 34.5 percent of Filipinos had a bank account, leaving almost two thirds of the whole nation unbanked. According to the World Banks report of financial inclusion, the access to useful and affordable financial products can help to drive development and "...help people escape poverty by facilitating investments in their health, education, and businesses" (Demirguc-Kunt, Klapper, Singer, Ansar, & Hess, 2018).

Export markets such as EU require stakeholders in the fish product supply chain to comply with set of requirements: traceability of fish product, catch certification, health and hygiene standards (CBI, 2019). Traceability of fish products require data from all stakeholders as the fish goes through the supply chain from bait to plate, yet paper based catch log documentations are still commonly used in the first step of the supply chain.

These challenges can be called as wicked problems. These problems are characterized by having ”...unstable requirements and constraints based upon ill-defined environmental contexts” and by ”...complex interactions among subcomponents of the problem and its solution” (Hevner et al., 2004).

4.2 Stakeholders, goals and challenges

Tracey project has multiple stakeholders: WWF-Philippines, TX, Streamr, Union Bank, fisherfolk and these stakeholders have different but overlapping goals. WWF-Philippines is operating Fisheries Improvement Project (FIP) sites on multiple locations in the Philippines. These FIPs aim to improve the livelihood of fisherfolk and sustainability of fisheries by educating fisherfolk about sustainable fishing practices and assisting them to move towards fisheries certification schemes such as MSC certification [5]. One of the challenges for becoming eligible for MSC certification is the requirement of catch log documentation system either paper-based or a digital one.

WWF-Philippines, BFAR - Philippines’ Bureau of Fisheries and Aquatic Resources and the local government units are concerned about the state of the fisheries. Accurate catch log data is needed to be able to estimate and predict the use of fisheries resources. Even though reporting the fish catches in the Philippines is a requirement for fisherfolk, not everyone is filling them.

Union Bank of the Philippines is interested in fisherfolk as potential future clients and as an untapped market. However at the moment, from institutional financing perspective fisherfolk are unbankable - too risky as a demographic to lend to. Fisherfolk are seen as micro entrepreneurs, they may not any have existing bank accounts, stable income or necessary personal identification or collateral to access financing services.

In general, fisherfolk are keen on trialing collecting and sharing catch log and trade data according to our studies. Especially if they are compensated to do so and the data is

[5] https://www.wwf.org.uk/what-we-do/projects/philippines-yellowfin-tuna-fishery-improvement-project

not shared between their immediate competitors or their peers (Marttila et al., 2019). However, some technical limitations exist for developing traceability solutions for them such as connectivity of mobile phones, availability of internet on rural areas, the types of mobile phones in use and the low educational background of users.

TX and Streamr as technology providers are keen on designing, developing and testing solutions leveraging blockchain technologies to solve the challenges set on the project. Challenges for the technology providers come from the physical distance to end-users, geographical and demographic differences on developing solutions from Europe to Southeast Asia.

To understand the end users needs and requirements, better survey studies have been designed and performed at FIP sites to scope out the current state of fisherfolks fishing activities (Marttila et al., 2019).

4.3 Small scale tuna fishing in Mindoro and Bicol

On design phase of Tracey project, two WWF-Philippines fisheries improvement project sites at Occidental Mindoro in west Philippines and at Lagonoy Gulf at Bicol in east Philippines were visited to gain better understanding of fisherfolk, fishing activities, supply chain of yellow fin tuna, and the prevalent boundary conditions set by the environment the fisherfolk are operating in. (Marttila et al., 2019)

Fisherfolk were surveyed, interviewed and studied by observing on how they work and operate. Survey studies and interviews were divided into questions in three different categories: traceability, technology and borrowing, to scope out e.g. what kind of data they collect, are they willing to share data if they were compensated for it, what kind of mobile devices they use, how much they earn, and how often they need to borrow money. (Marttila et al., 2019)

Survey results have indicated that the majority of interviewed fisherfolk collect data from the fishcatches with paper based forms; although the majority of fisherfolk have access to mobile phones, approximately only half of them have a smartphone. It has also been found that the majority of fisherfolk do not have a bank account but they do borrow money, usually from relatives or from a casa - a fish buyer and the fisherfolk are aware of different borrowing platforms operating in their local area. Typically loans are used to cover operational costs of fishing activities. Fisherfolk also fish other species than tuna as tuna fishing is seasonal activity due to migratory nature of tuna and fisherfolk often work other jobs during off-peak tuna fishing seasons. (Marttila et al., 2019)

But what does a typical fishing trip look like? A typical fishing trip starts with using savings or borrowing money to acquire supplies e.g. gasoline, food and ice for a 2-3 day fishing trip with a small one or two man banker boat up to 15 km away from Philippines coast. Fishermen spend several days on the ocean with hand line fishing equipment trying to catch tuna fish e.g. yellow fin tuna. For a fisherman, tuna is the single most profitable catch that they can get and a single catch may bring a week worth of income for a family.

Once fisherman has caught a tuna, he contacts a buyer and he proceeds to land the catch in a dedicated landing are. At the landing site, the quality of tuna is checked, catch log forms are filled and tuna fish is sold to a buyer. All this time, the fish is out from the ocean, the quality of the tuna fish is degrading until it is frozen and processed. As the quality of tuna is degrading, so is the value of it.

A simplified Philippines' side of the supply chain of tuna fish is represented on the Figure 14. Fishermen sell the caught fish to buyers, after which buyers sell and transport the fish to processors who gut, skin, filet, bag and label the fish product for exporting. Some of these supply chain steps may happen together e.g. buyer, processor and exporter may be the same party.

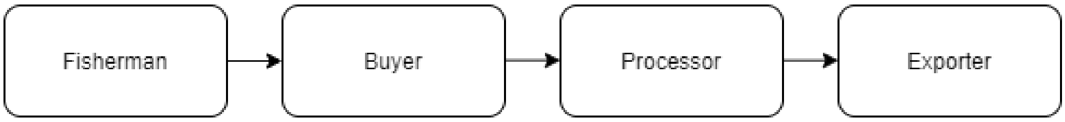

Figure 14. Simplified tuna fish supply chain on Mindoro and Bicol.

Tracey as an IT artifact focuses on the fishermen and the interface of first two actors of the presented supply chain; the act of catching fish from the sea, recording information related to the catch, trading the fish catch and recording the trade.

4.4 IT Artifact description

Tracey IT artifact consists of following components: mobile application for recording trade and traceability data, centralized backend system for user data storage and blockchain component for meta data storage.

4.4.1 Use cases

Several use cases exist for Tracey IT artifact. These include but are not limited to, recording of catch log and trade data, retrieval of trade data and retrieval of catch log data. The following use cases are considered as core functionalities of Tracey:

- Recording of catch log data. To have a provenance of tuna fish, the catch log data needs to be collected and verified.
- Recording of trade data. To have a history of financial performance, trade data needs to be collected to be able to perform credit scoring of a fisherman.
- Retrieval of catch data. To be considered as a traceability solution, the catch data must be retrievable and consumable by a 3rd party.
- Retrieval of trade data. To be able to establish credit worthiness, trade data related to an individual fisherfolk needs to be accessible.

- Payment for data. Fisherfolk need to be incentivized directly or indirectly to produce traceability and trade data.

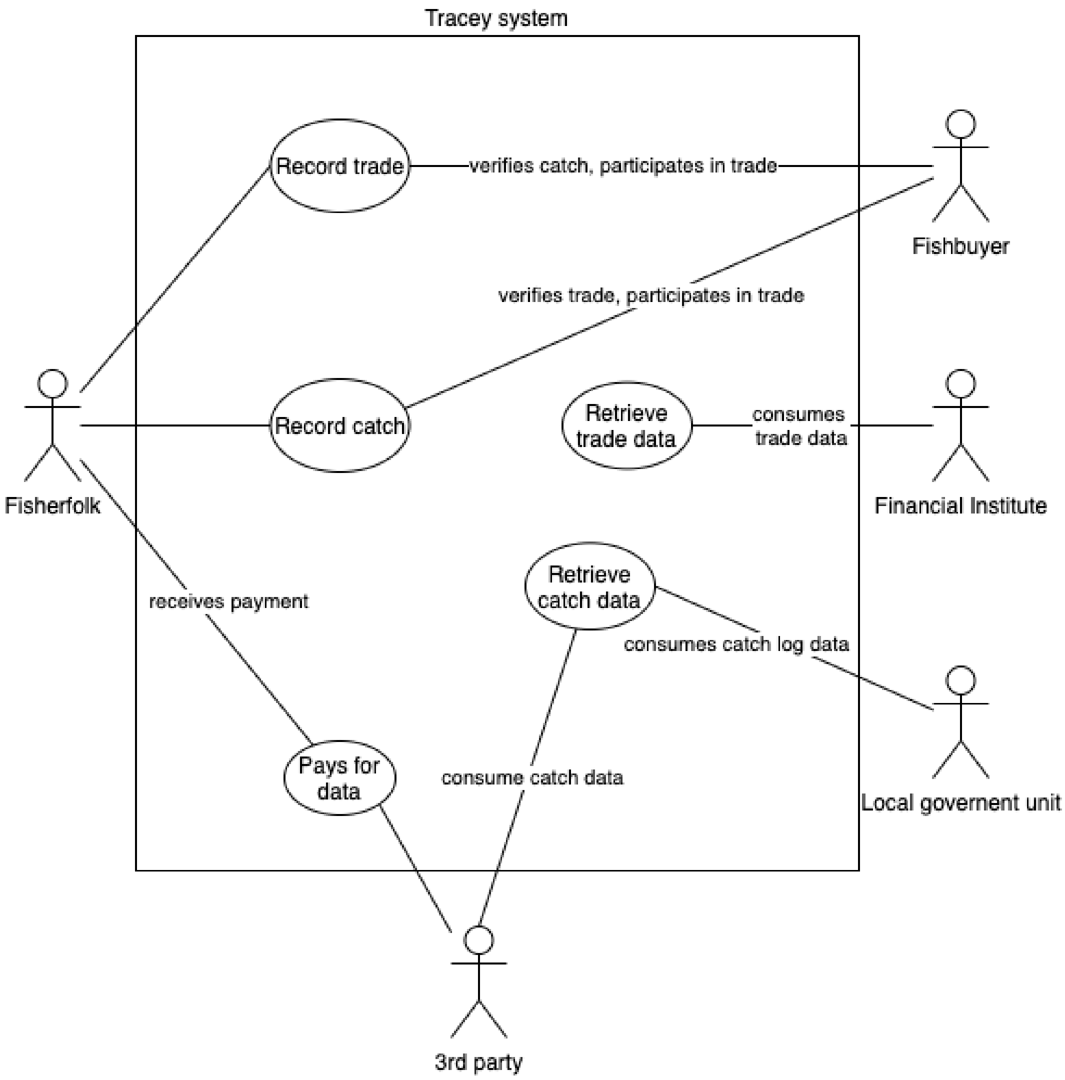

Figure 15. Tracey use cases.

4.4.2 Mobile application

Survey research results have indicated that the most used smart phone type in the rural Philippines is the Android phone. On basis of the findings an android mobile application has been designed and is under development for fisherfolk and fishbuyers. The mobile application, see figure 16, is the fisherfolk and buyers main interface to communicate with tracey backend. On the app, fisherfolk and fishbuyers are able to register either as fishermen or fish buyers as they will be given different functionalities depending on their role. Fishers will be able to record invididual catches. Upon creation of a new catch log, a set of GDST key data elements will be inquired from the fisher. Upon completion of catch log, it will be sent to tracey backend system where it will be stored in a centralized database and to a decentralized ledger.

Fisherfolk are able to view the history of their catches and trades. When the fish is being sold, the fisherman can initiate a trade on the Tracey application with a buyer. The buyer will be prompted about this trade and given the list of recorded GDST key data elements to verify that the product is the same as the recorded data. When the trade is negotiated and accepted, the trade and traceability data are considered as verified.

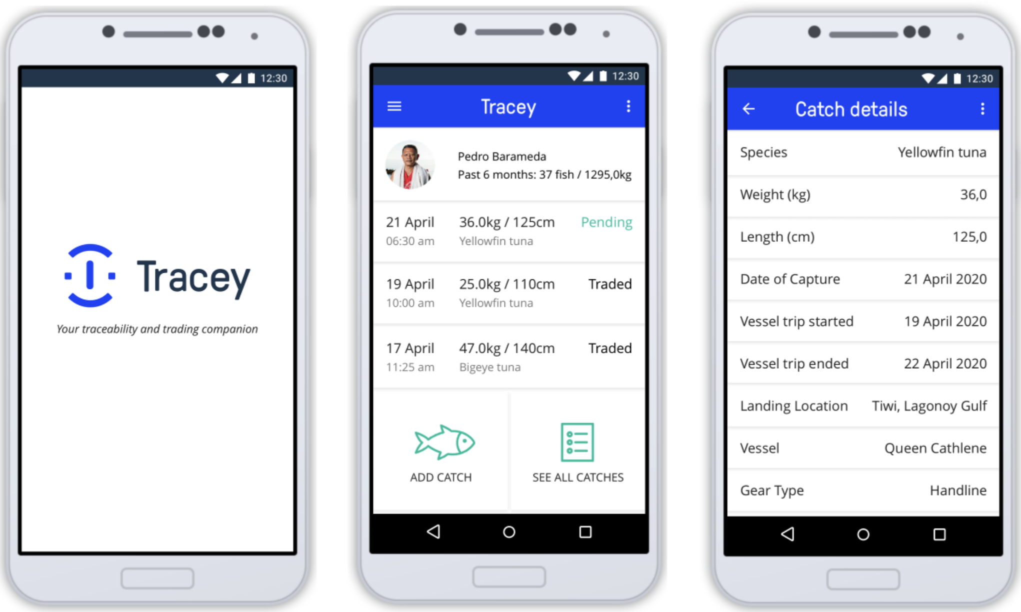

Figure 16. Tracey app for fishermen.

4.4.3 Centralized back-end

Tracey Android application communicates with a hosted back-end system. Back-end system consists of user management, user authorization and authentication, a relational database for traceability and trade data, data models and Application Programming Interfaces (APIs).

User management is available through command-line tools and APIs. Users are created and assigned with a specific role e.g. fisherman or buyer. When APIs are being used, the user is authenticated and authorized via Oauth 2.0 protocol. Internal data models and database structure are modeled after GDST wild catch KDE list. APIs provide access for authenticated users to record and retrieve trade and traceability data in JavaScript Object Notation (JSON) format.

4.4.4 Blockchain component

Public Ethereum blockchain is utilized in Tracey artifact as a storage for metadata generated from traceability KDEs. A smart contract is designed to function as a transparent and always available storage detailing a subset of recorded KDEs and a reference to the location of where the rest of the KDE data is stored or hosted. This contract is updated when new traceability data is stored to back-end system. Smartcontract provides Application Binary Interfaces (ABIs) to record and query traceability data.

5 Analysis

Peffers et al. (2007) have listed six activities that make up the Design Science Research Method. These activities are presented on the Table 1. First column lists each individual activity as nominal sequence, second column describes the activity, and third column links the activity to knowledge base (Geerts, 2011). The knowledge base is composed of tools ”...such as foundational theories, frameworks, instrumenst, constructs, models, methods and instantiations” and it provides ”...tools and materials through which design science research is accomplished” (Geerts, 2011; Hevner et al., 2004).

To be able to answer to research questions two and three set in chapter 1.2; how can Tracey artifact be tied to rigor and relevance of design science, and be able to provide recommendations on how to improve the Tracey IT artifact, we need first to establish the current state of the Tracey artifact by applying DSRM and reflecting the Table 1 activities against the artifact.

DSRM activities	Activity description	Knowledge base
Problem identification and motivation	What is the problem? Define the research problem and justify the value of a solution.	Understand the problem's relevance and its current solutions and their weaknesses.
Define the objectives of a solution	How should the problem be solved? In addition to general objectives such as feasibility and performance, what are the specific criteria that a solution for the problem defined in step one should meet ?	Knowledge of what is possible and what is feasible. Knowledge of methods, technologies, and theories that can help with defining the objectives.
Design and development	Create an artifact that solves the problen. Create constructs, models, methods or instantiaitons in which a research contribution is embedded.	Application of methods, technologies, and theories to create an artifact that solves the problem.
Demonstration	Demonstrate the use of artifact. Prove that the artifact works by solving one or more instances of the problem.	Knowledge of how to use the artifact to solve the problem.
Evaluation	How well does the artifact work? Observe and measure how well the artifact supports a solution to the problem by comparing the objectives with observed results.	Knowledge of relevant metrics and evaluation techniques.
Communication	Communicate the problem, its solution, and the utility, novelty, and effectiveness of the solution to researchers and other relevant audiences.	Knowledge of the disciplinary culture.

Table 1. Design science research methodology adapted from (Geerts, 2011; Hevner et al., 2004) .

5.1 Application of DSRM to Tracey IT artifact

As development of Tracey IT artifact is currently ongoing, the application of DSRM framework to Tracey IT artifact is performed by reflecting DSRM research entry points, activities, and knowledge base against the whitepaper description of Tracey.

There are four research entry points in the DSRM framework, but which one these match to Tracey? Tracey artifact could fit into any of the research entry points, however Tracey whitepaper portrays that Tracey IT artifact has been initiated by a client or context type of situation, a hackathon where "...an objective was to design an innovative solution that could incentivize fisherfolk to share data on traceability of fish catch and fish sales" (Marttila et al., 2019).

Taking the client or context as the research entry point, other DSRM activities are mapped and expanded from the demonstration step of DSRM process model. Results of mapping DSRM activities are on Table 2 representing the current state of the Tracey IT artifact as portrayed by the whitepaper.

DSRM activities	Activity description	Knowledge base
Problem identification and motivation	Need to address the issues of inequality of distribution of benefits on use of first mile traceability solutions. Lack of first mile traceability solutions for developing nations artisanal fishers. Traceability solutions need to enable collection of verified traceability data.	Real world problem. Understanding the problems of current solutions. Survey studies of fisherfolk.
Define the objectives of a solution	Design a first-mile traceability information systems that enable and support; fisherfolk to produce and monetise catch log and trade data from fish catch to landing, fish buyers to verify recorded information and data buyers to access data given that they compensate the fisherfolk.	Knowledge of information systems design, semantic modeling of centralized and decentralized databases.
Design and development	Conceptual design of Tracey IT artifact (e.g. how tracey should work and operate, where information capture by fisherfolk is stored in centralized and decentralized manner).	Information systems design, semantic modeling, seafood traceability systems studies.
Demonstration	Illustration of concept with technical architecture graph.	Semantic modeling, Information systems design.
Evaluation		
Communication	Published independently as a whitepaper	

Table 2. Design science research methodology applied to Tracey IT artifact.

Three different problems have been identified and derived from real world issues at the fisheries improvement project sites. These problems are tied to knowledge base by their nature, survey studies performed to fisherfolk and by understanding the general problems with the current traceability solutions.

Objectives have been defined to design a conceptual solution to assist fisherfolk to capture first-mile traceability data whilst incentivizing them directly and indirectly for producing it. These objectives are tied to knowledge base with knowledge of information systems design. Design and development consist of conceptual design of Tracey IT artifact and these activities are tied to knowledge base by information systems design. Concept has been demonstrated as an illustration of information systems level semantic graph and results of these activities have been communicated through a self-published whitepaper report (Marttila et al., 2019).

Evaluation of concept has neither been performed nor has it been tied to knowledge base, also communication has not been tied to a knowledge base.

5.2 Suggested improvements

Table 3 illustrates the suggested improvements that can increase the rigor and relevance of the Tracey IT artifact. On the following sub sections, these improvements are explored in more detail by each DSRM activity.

5.2.1 Problem identification and motivation

There are no recommended additions to problem identification and motivation. However, the identified problems are quite complex e.g. incentivization of people to produce results for tasks, traceability and verifiability of supply chain data and they could be ex-

DSRM activities	Activity description	Knowledge base
Problem identification and motivation	Need to address the issues of inequality of distribution of benefits on use of first mile traceability solutions. Lack of first mile traceability solutions for developing nations artisanal fishers. Traceability solutions need to enable collection of verified traceability data.	Literature review, understanding challenges and gaps of current traceability systems; need for accurate first mile traceability data, absence of low cost solutions for small scale fishers, lack of incentives for fishers to adopt new tools and technologies, unequal distribution of benefits of the use of traceability tools in supply chains understanding issues artisanal fisherwork face related to fishing and traceability understanding
Define the objectives of a solution	Design and implement a first-mile traceability information systems that enable and support; fisherfolk to produce and monetise catch log and trade data from fish catch to landing, fish buyers to verify recorded information and data buyers to access data given that they compensate the fisherfolk.	Literature review, Knowledge of information systems design, semantic modeling of centralized and decentralized databases, knowledge of emerging technologies, understanding requirements and challenges of fish product supply chains on developing nations
Design and development	Conceptual design of Tracey IT artifact (e.g. how tracey should work and operate, where information capture by fisherfolk is stored in centralized and decentralized manner). Implementation of a pilot version of Tracey IT artifact.	Knowledge of fish product traceability standards e.g. GS1 & GDST and emerging technologies e.g. blockchain.
Demonstration	Pilot and case study of the use of Tracey artifact on FIP sites	Application of novel information systems technologies e.g. blockchain to a real-world problem
Evaluation	Comparative analysis, qualitative analysis, survey studies	Understanding the proposed solution in practice and its weaknesses
Communication	Publish in peer reviewed academic journal	Journals that cover the context space of fisheries and use of novel information systems technologies to solve real-world problems

Table 3. Suggested improvements for Tracey IT artifact mapped by DSRM activities.

plored independently in a smaller scope and in more depth in the future phases of Tracey project.

The knowledge base is recommended to be expanded to increase the rigor by a literature review capturing concepts, gaps and challenges of implementing seafood traceability systems for small scale fishers. This thesis' literature review section is written as a basis for such a literature review.

5.2.2 Defining the objectives of a solution

Defining the objectives of the solution is recommended to be expanded to include both design and implementation of the IT artifact. This could be achieved by separating design and implementation as separate activities, which could be reflected and analyzed against the DSRM framework.

The knowledge base can be expanded to cover literature review including e.g. design concepts of traceability systems and use of emerging technologies such as blockchain in the context of traceability. Improvements related to literature review are captured in this thesis literature review section.

5.2.3 Design and development

There are a few suggestions on Table 3 on how the design and development of Tracey concept and implementation could be improved.

Tracey whitepaper outlines a high level concept and system design on how Tracey IT artifact could operate but it doesn't go into details, for example on how blockchain is utilized as a data storage in the concept.

There are several potential use cases related to using blockchain in Tracey concept: using blockchain as an 'always available' and transparent data storage for catch log and trade data, and using blockchain as a decentralized repository for unique IDs for traceable resources units.

Blockchain as data storage

The conceptual design of using blockchain as a data storage should be improved on the basis of the requirements set by GS1 and GDST standards, and the designs should be reflected against a few different blockchain technologies. On Appendixes 2 and 3, example implementations of catch data and trade data storages for Ethereum blokchain are presented.

On appendix 2, an Ethereum smart contract created with solidity programming language implements a simple key data element storage for fish catch logging. Access control to the key data storage is based on OpenZeppelins smart contract libraries [6] for secure smart contract development which limits non-whitelisted Ethereum accounts from inserting or querying KDE data in the example implementation. Simple getters and setters are provided in the example to add new key data elements with a unique GTIN identifiers to an internal data structure which is subsequently stored to the Ethereum blockchain. On appendix 3, a similar Ethereum smart contract is presented which implements trade data storage with whitelisting and data manipulation functionalities.

These examples should be explored and expanded in the Tracey project depending on the use cases and user needs. For example, a whitelist may not provide adequate granularity for controlling users access and instead a tiered user access may be required e.g. fishermen should be allowed to create new key data element structures, but they should neither be able to delete inserted information nor modify other parties catch log information.

Blockchain as unique TRU id generator

One of the core challenges identified in the literature review related to traceability is the lack of unique identifiers for traceable resource units. Unique identifiers are typically only unique in their own context e.g. inside a processing facility, but nationally or globally they are no longer unique and may overlap with others.

One possible solution for this issue could be establishing a decentralized service that would function as a single transparent source of truth maintaining unique identifiers for traceable products. Some cloud based business solutions already exist in this problem space, such as fTrace (fTrace, 2020) which enable supply chain parties to register their respective enterprises to produce GS1 type of unique identifiers for products and goods, and to share the related supply chain information between parties. However, these types of solutions are typically priced out of the reach for artisanal fishermen in South-East Asia.

[6] https://github.com/OpenZeppelin/openzeppelin-contracts

An example implementation of a decentralized Traceable Resource Unit generator is demonstrated on appendix 4. The example code implements a GTIN-14 based unique id generator with a whitelist access control. GTIN-14[7] is a 14-digit long number sequence which is commonly used to uniquely identify trade items. This sequence consists of 4 parts: packaging level indicator digit, company or in the context of this thesis a fisherman specific prefix, an item reference digit and a check digit calculated form the three previous digits.

The implementation provides functionalities to register GTIN prefixes to an individual Ethereum account and generation of GTIN-14 codes. Implementation comes with certain limitations such as up to 9 million unique prefixes can be created and each unique prefix can have up to 90000 unique suffixes e.g. one fisherman can register up to 90000 catches with presented implementation.

This example implementation outlines a potential way to approach the concept of using blockchain as unique TRU id generator and as a TRU storage. This implementation should be explored and expanded to fit the exact requirements of Tracey design and implementation.

5.2.4 Demonstration

Implementation of Tracey IT artifact is expected to be piloted in two WWF fisheries improvement project sites in the Philippines. The exact pilot design and execution are still an open issue, but the recommendation for demonstration activity is to consider how demonstration or the use of Tracey by the fisherfolk can support for the evaluation activity and provide adequate feedback related to the core research questions set in the white paper e.g. how can TX and WWF support the fisherfolk on using the IT artifact in their daily fishing and trading activities to improve the chances of success of the pilot.

[7] https://www.gtin.info

5.2.5 Evaluation

Concept and implementation of Tracey IT artifact needs to be tested and evaluated in practice. As the IT artifact is planned to be piloted on FIP sites, it provides an unique opportunity to collect real-world data of its usage. There are many possible ways to evaluate Tracey artifact such as performing a comparative analysis against other solutions that are in use or performing a qualitative analysis about the use of Tracey in practice and survey studies related to effectiveness of incentivization for providing trade and traceability data.

The evaluation activity of Tracey should build towards understanding on how the proposed solution works in real world context and how it could be improved.

5.2.6 Communication

Currently the results of Tracey concept are communicated through a self-published white paper. For business communication, this method is adequate but to be able to improve the rigor and relevance of communication of the results, it is recommended to publishing them in a relevant peer reviewed academic journal.

By moving the dialogue of Tracey from business forum to a scientific forum, the concept is exposed to a new level of scrutiny and feedback which can improve the overall design and development of Tracey.

6 Discussion

Traceability and food traceability are complex topics involving multiple different scientific fields. Designing and implementing an information system to handle business critical traceability information is not trivial as can be perceived through the multitude of challenges related to traceability.

The **first research question** of this thesis sought to find out through a literature review on what kind of challenges are related to seafood traceability. By understanding the core challenges related to traceability in seafood context, it is possible to design better solution to answer to them.

On literature review, multiple types of challenges were identified. According to Borit and Olsen (2016) there are six general fields which contribute to challenges of traceability: awareness, knowledge/research, commitment, implementation, technology and standards. However, only five of these have been identified to have traceability related gaps. The findings indicate that there is a series of inconsistencies between standards and norms related to seafood traceability, a lack of understanding of what traceability is, and where the obstacles for adoption of traceability stem from. There is a lack of commitment by companies as they don't understand the financial benefits of traceability. There is a gap between regulatory requirements and feasibility of industry implementation. Though initiatives driven by the industry, such as GDST try to offer a standardised solution for this.

In regard to technology, there is a lack of integrable verification procedures which lead into storing information about traceable products without knowing it's authenticity and there is a lack of cheap, functional and robust technologies for data capture and tagging. These findings are portrayed on chapter 2.5.

Literature review indicated also that there are particular challenges related to developing solutions for small scale traceability in developing countries. Duggan and Kochen (2016) have identified that end-users for traceability solutions e.g. fishermen, in rural areas and in small communities typically suffer from poor infrastructure, accessibility, education levels and socioeconomic conditions. In addition, rural fishing communities fishers are being forced by the environment to focus on short-term e.g. where to get income to survive on day-by-day basis instead of long term which may pose a significant challenge towards developing long term solutions. These findings are portrayed on chapter 2.6.

But what if one wants to extend an existing traceability system or integrate with other traceability systems. There are also challenges related to them. One of the key challenges with traditional traceability systems has been interoperability (Olsen et al., 2019). This may be due to the myriad of custom solutions created with different supply chain parties but it could be tackled with a technology solution that standardizes the collected and stored data and the inside and outside the system. Moving from adoption of standards to support interoperability to adoption of blockchain-based traceability systems, could increase interoperability in itself (Olsen et al., 2019).

The literature review paints a holistic picture of challenges related to traceability and it should provide a wider understanding about what to consider when developing traceability solutions.

The **second research question** relates to the Case study presented in chapter 4 - How can Tracey be tied to rigor and relevance of design science and where does it fit in design science research methodology? On chapter 5 Tracey IT artifact was mapped against design science research methodology framework to identify the current state of the IT artifact. Results of this are presented in Table 2 on chapter 5.

Tracey can be tied to rigor and relevance by mapping Tracey IT artifact, presented in the whitepaper (Marttila et al., 2019), against the six different activities of DSRM framework. With this mapping process it is possible to extract and deduce the individual activities and their relevance to knowledge base.

Multiple research entry points exist for the Tracey IT artifact. In this case study, the entry point has been deduced to be client or context initiated. As DSRM is an iterative process, the research entry point could be refocused e.g. towards any of the three activities identified in the problem identification and motivation step, shifting the research entry point to problem-centered approach.

Due to the complexity of the designing and developing an IT artifact, it may be a reasonable in the future to have separate DSRM tracks for each of the identified problems.

Third research question continues on the path of the second one. How can the concept IT solution be improved by reflecting it to information systems research framework? Recommendations can be given on how to improve the IT artifact after the current status of it is known. Building on top of the outcomes of the second research question, suggestions have been provided on Chapter 5 Table 3.

In these suggestions implementation, specific details are being avoided e.g. giving advice on how some specific feature or traceability challenge should be exactly implemented or solved. Instead, the suggestions try to provide general understanding of what could be improved and why.

In comparison to the current state, knowledge base of each activity is expanded to reflect more accurately where the activities are expected to have a research contribution. The additions to knowledge base provides areas where Tracey IT artifact could be tied more strongly to rigor. These additions could also be interpreted as a map of where research contributions of Tracey IT artifact can be expected. For example, in relation to design and development activity, once Tracey artifact is implemented, the implementation process will provide insights of how to apply blockchain technologies to capture standard based traceability data.

Mapping of Tracey to DSRM framework has also revealed some gaps. For example, the evaluation of the IT artifact is currently undefined. The lack of apparent evaluation activities and their effect to knowledge base may be due to the fact that Tracey is still under development.

On suggestions, a few different approaches are given on how to improve the evaluation of the IT artifact. However, these are at general level. Different analysis and data collection methods could be applied to gain feedback and understanding of the performance of the Tracey IT artifact. Comparative or qualitative analysis could be implemented to find out how Tracey differs from other available tools and technologies currently in use and what are the pros and cons of Tracey. Survey studies should be taken to scope out e.g. how do the fishermen in the pilot phase utilize Tracey in their daily use, what kind of data do users produce and to understand how do users act on the basis of different incentivization schemes.

As a design and implementation improvement suggestion, examples are provided on how Ethereum blockchain smart contracts could be utilized to serve as a trade data storage, fish catch related key data element storage, and as a global trade identity number generator and storage. These examples provide a general idea on how smart contracts on Ethereum blockchain could be used, for example on solving the challenges of interoperability of traceability information systems.

The carrying idea of utilizing blockchains for traceability comes from the technical features e.g. immutability of information providing provenance of who has stored or modified the information, as well as the general documentation and standardisation of how the blockchains work which provides a clear way of how to integrate with blockchain systems.

What this thesis doesn’t answer is that whether the use of blockchain is a cost effective solution, or what type of blockchain would fit the problem best from costs vs value perspective or if all information related to traceability should be stored in decentralized fashion.

For example, in case of using public Ethereum blockchain, storing one kilobyte of information requires approximately 0.03 Eth - currency that is used to transact with the blockchain. On today's price [8], this would cost approximately 16 USD, bringing the cost of storing only 1024 characters worth of data to a decentralized ledger fairly high in comparison to costs of storing data to a traditional database. To make matters worse from the point of view of estimating the costs of using public blockchains the cryptocurrencies are volatile.

From business perspective these unanswered questions are important, and they should be investigated in the future studies among the suggested improvements offered in this thesis.

[8] 21.11.2020 Binance.com 1 Eth = 540 USD

7 Conclusions

Literature review has shown that multiple challenges exist for traceability from standards to regulations, to different attitudes and implementations of traceability systems. Use of distributed ledgers or blockchains for food treaceability and especially for seafood traceability is still a relatively young area where further research is required to establish information systems design suggestions, and deeper understanding of benefits of using blockchain solutions to be able to answer to myriad of challenges related to traceability.

In this thesis, a novel IT artifact called Tracey has been analysed with DSRM framework. The analysis has identified gaps related to the whitepaper version of Tracey artifact such as lack of evaluation methods. Recommendations have been given on the basis of the findings of the analysis on how to improve Tracey in form of DSRM activities and example Ethereum smart contract code.

This thesis contributes towards using design science research methods in the context of traceability and towards building the theoretical background for the future pilot studies related to use of Tracey and similar applications in the fisheries improvement projects.

7.1 Recommendations

The analysis and discussion chapters provide recommendations on how to improve Tracey IT artifact. For future research, it would be beneficial to investigate the cost of using blockchains e.g. when storing traceability data, use of different blockchains and different use cases of blockchains e.g. consortia, public and private, in the context of Tracey and the use of different incentivization methods for collecting the traceability data from fishermen.

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Appendices

Appendix 1. GDST Wildcatch KDE list

GLOBAL DIALOGUE on Seafood Traceability

GDST Basic Universal List-KDES-Wild

KDE No.	KDE Name	KDE Definition	Standard Data Options	Standards Org.	List Link	Authoritative Data Source	Authoritative Data Document	Data Semantics & Syntax	Data Hierarchy	EPCIS Attribute	EPCIS CBV Type	EPCIS CBV Description
W01	Item / SKU / UPC / GTIN	identifier of seafood material to distinguish it within a particular facility, company, or globally.	Free-entry Field	N / A (No single source exists)	N / A	Person at a scale, on a production line or other place with the responsibility of recording an accurate weight of the product	Weight ticket, production records, packing lists etc.	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance) Listed with every CTE	EPCClass	EPCClass	A class-level identifier for the class to which the specified quantity of objects belongs.
W02	Linking KDE	identifier associated with physical product marking a particular instance of seafood material such as a batch/lot number, serial number, or container number.	Free-entry Field	N / A (Individual facility / supply chain actor in most cases)	N / A	Person at a scale, on a production line or other place with the responsibility of recording an accurate weight of the product	Weight ticket, production records, packing lists etc.	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance) Listed with every CTE	EPC Batch/Lot or Instance	lgtin	The GTIN+ Batch/Lot scheme is used to denote a class of objects belonging to a given batch or lot of a given GTIN.
W03	Weight / Quantity	numerically quantifiable amount of seafood with a standard Unit of Measure.	Recommendation No. 20, Codes for Units of Measure Used in International Trade	UN Centre for Trade Facilitation and E-business (UN/CEFACT)	http://tfig.unece.org/contents/recommendation-20.htm http://www.unece.org/cefact/codesfortrade/codes_index.html	Person at a scale, on a production line or other place with the responsibility of recording an accurate weight of the product	Weight ticket, production records, packing lists etc.	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance) Listed with every CTE	quantity + uom	decimal + UOM	A number that specifies how many or how much of the specified EPCClass is denoted by this QuantityElement. + specifies a unit of measure by which the specified quantity is to be interpreted as a physical measure, specifying how much of the specified EPCClass is denoted by this QuantityElement.
W04	Vessel Name	verbal moniker of a fishing vessel for identifying it visually and on vessel registries.	Latin Alphabet, numbers and punctuation - ISO 7-bit coded character set for information interchange (ISO/IEC 646:1991)	International Organization for Standardization (ISO)	https://www.iso.org/standard/4777.html?browse=tc https://en.wikipedia.org/wiki/ISO/IEC_646	Flag state regulatory body with oversight of the nation's fishing fleet or Regional Fishery Management Organization with jurisdiction	Respective Flag state or RFMO fishing vessel registry	[See GS1 CBV Descriptions]	Master data - Fishing Vessel "GLN"	vesselName	String	Name of the vessel Example: HMS Gena
W05	Vessel Registration	standardized number or identifier for distinguishing vessels registered under the same flag nation.	Free-entry Field	N / A	N / A	Flag state regulatory body with oversight of the nation's fishing fleet or Regional Fishery Management Organization with jurisdiction	Respective Flag state or RFMO fishing vessel registry	[See GS1 CBV Descriptions]	Master data - Fishing Vessel "GLN"	vesselID	String	Identifier for the vessel Example: DE-X-1234
W06	Unique Vessel Identification	identifier associated with a vessel for the duration of its existence that cannot be re-used by any other vessel with a permanent physical marking on the craft.	IMO Number registry managed by IHS Maritime (For eligible vessels)	International Maritime Organization (IMO) - http://www.imo.org/en/ourwork/msas/pages/imo-identification-number-scheme.aspx http://www.fao.org/fishery/docs/DOCU	https://gisis.imo.org/Public/SHIPS/Default.aspx	IHS Maritime on behalf of the International Maritime Organization	The IHS Maritime registry of valid IMO numbers	########	Master data - Fishing Vessel "GLN"	Does not exist currently	Does not exist currently	Does not exist currently
W07	Vessel Flag	nation with supervision over safety, fishing operations, and catch reporting.	ISO 2-letter country code list - ISO 3166	International Organization for Standardization (ISO)	https://www.iso.org/iso-3166-country-codes.html https://www.iso.org/obp/ui/#search	Flag state regulatory body with oversight of the nation's fishing fleet or Regional Fishery Management Organization with jurisdiction	Respective Flag state or RFMO fishing vessel registry	[See GS1 CBV Descriptions]	Master data - Fishing Vessel "GLN"	vesselFlagState	String	The ISO 3166-1 alpha-2 code specifying the state under whose laws the vessel is registered or licensed.Example: UK
W08	Vessel Trip Dates	calendar start and end dates of a fishing vessel's voyage between the last point the fishing hold was empty and seafood is discharged. (Continued in Definitions Appendix sheet)	ISO Date and time format (ISO 8601)	International Organization for Standardization (ISO)	https://www.iso.org/iso-8601-date-and-time-format.html https://en.wikipedia.org/wiki/ISO_8601	Fishing vessel captain	Captain's logbook / harvest records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	harvestStartDate + harvestEndDate	Date	The dates when harvesting started and ended. Example: 2016-03-15
W09	Date(s) of Capture	calendar date(s) when seafood was extracted for capture, irrespective of the fishing vessel's voyage at sea.	ISO Date and time format (ISO 8601)	International Organization for Standardization (ISO)	https://www.iso.org/iso-8601-date-and-time-format.html https://en.wikipedia.org/wiki/	Fishing vessel captain	Captain's logbook / harvest records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	harvestStartDate + harvestEndDate	Date	The dates when harvesting started and ended. Example: 2016-03-15

W10	Gear Type	equipment used to extract seafood from water for capture.	The International Standard Statistical Classification of Fishing Gear (ISSCFG) Revision 1	UN-FAO's Coordinated Working Party on Fishery Statistics (CWP)	http://www.fao.org/3/a-bt987e.pdf	Fishing vessel captain	Vessel's logbook / harvest records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	fishingGearTypeCode	Code	A code specifying the type of gear used in capture of fisheries.The code list for this attribute is defined by the Food and Agriculture Organization of the United Nations (FAO);
W11	Fishing Authorization	unique number associated with a regulatory document, from the relevant authority, granting permission for wild-capture of seafood by a fisher or fishing vessel.	Free-entry Field	N / A	N / A	Regulatory body of a coastal state, RFMO or orhter relevant international authority with supervision over the capture of the underlying seafood species	Coastal state authority or RFMO or other relevant international authority registry of permits, licenses or quotas.	String (1-500 characters) - Example: ABCDEFG-########	ILMD (Event to Event variance)	Does not exist currently	String	Does not exist currently
W12	Availability of Catch Coordinates	Indicator whether GPS coordinates were collected and are available	Free-entry Field	N / A	N / A	Fishing vessel captain	Vessel's logbook / harvest records	String (1-500 characters) - Example: ABCDEFG-########	Master data - Fishing Vessel "GLN"	Does not exist currently	String	Does not exist currently
W13	Satellite Vessel Tracking Authority	Indicator of Satellite Vessel Tracking. Authority responsible for the satellite tracking or verification.	Free-entry Field If satellite tracking not available, "N / A"	N / A	N / A	Fishing vessel captain	Vessel's logbook / harvest records	String (1-500 characters) - Example: ABCDEFG-########	Master data - Fishing Vessel "GLN"	Does not exist currently	String	Does not exist currently
W14.1	Catch Area	location(s) where capture of seafood occurred.	FAO Major Fishing Areas	FAO Major Fishing Areas - UN-FAO's Coordinated Working Party on Fishery Statistics (CWP)	FAO Areas - http://www.fao.org/cwp-on-fishery-statistics/handbook/general-concepts/fishing-areas-for-statistical-purposes/en/			[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	catchArea (Repeating)	Code	A code specifying the area(s) where the product was caught. The code list for this attribute is defined by the Food and Agriculture Organization of the United Nations (FAO);
W14.2	(Compliacne with this KDE requires completing all applicable Catch Area data fields)		Exclusive Economic Zones (EEZ)	Exclusive Economic Zones - International Organization for Standardization (ISO)	Exclusive Economic Zones - https://en.wikipedia.org/wiki/ISO_3166-	Fishing vessel captain	Vessel's logbook / harvest records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	economicZone (repeating)	Code	Economic zone in which fishery or aquaculture products were caught or cultivated.
W14.3			Regional Fishery Managmenet Organizations (RFMO)	Regional Fishery Management Organizations - FAO List of Regional Fishery Bodies	Regional Fishery Management Organizations - http://www.fao.org/fishery/rfb			ABCDEFG	ILMD (Event to Event variance)	Does not exist currently	String (1-500 characters)	Does not exist currently
W14.4			Sub-national permit areas - Free-entry Field	[N / A (No single source exists)]	[N / A]			String (1-500 characters)	ILMD (Event to Event variance)	Does not exist currently	String (1-500 characters)	Does not exist currently
W15	Species	scientific (latin) name of the seafood.	ASFIS List of Species for Fishery Statistics Purposes	FAO Fisheries and Aquaculture Statistics and Information Branch (FIAS)	http://www.fao.org/cwp-on-fishery-statistics/handbook/general-concepts/identi	Fishing vessel captain	Vessel's logbook / harvest records	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance)	speciesForFisheryStatisticsPurposesCode + speciesForFisheryStatisticsPurposesNa	Code + String (1-500 characters)	The FAO 3 Alpha code of the species of fish for fish and seafood. Example: COD + The scientific name
W16	Product Form	commercial short-hand reference of the degree of transformation of seafood from its original living form.	Free-entry Field	N / A (GDST could author a list)	N / A	Fishing vessel captain, person at a scale, on a production line or other place with the responsibility of	Vessel's logbook / harvest records, weight ticket, production records, packing lists etc.	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance)	tradeItemConditionCode	Code	A code depicting the type of preparation that a trade item will have before being sold to the end consumer (e.g. cut for sale, portioned/pieced)

W17	Transshipment Location	geographic rendezvous where seafood is discharged from a fishing vessel to a transshipment vessel.	**In-Port Transshipment:** Port Name - United Nations Code for Trade and Transport Locations (UN/LOCODE)	UN Centre for Trade Facilitation and E-business (UN/CEFACT)	https://www.unece.org/cefact/locode/service/location	Fishing vessel & Transshipment vessel captain	Fishing vessel captain / master's records & Transshipment vessel captain / master's records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	unloadingPort	UN LOCODE	Port where the goods were unloaded from a seagoing vessel after having been transported by it. The value of this attribute is a user vocabulary maintained by UN/ECE; see http://www.unece.org/cefact/locode/welcome.htmlExample: DE BRV
			At-Sea Transshipment: GPS Coordinates	International Organization for Standardization (ISO)	https://www.iso.org/standard/39242.html https://en.wikipedia.org/wiki/ISO_6709			(/-)###.###### + (/-)###.###### [37.42242 + -122.08585]	ILMD (Event to Event variance)	latitude + longitude	xsd:string	Angular distance North or South from the earth's equator measured through 90 degrees. + The arc or portion of the earth's equator intersected between the meridian of a given place and the prime meridian and expressed in degrees
W18	Dates of Transshipsment	calendar start and end dates of a rendezvous to discharge seafood from a fishing vessel to transshipment vessel.	ISO Date and time format (ISO 8601)	International Organization for Standardization (ISO)	https://www.iso.org/iso-8601-date-and-time-format.html https://en.wikipedia.org/wiki/ISO_8601	Fishing vessel & Transshipment vessel captain	Fishing vessel captain / master's records & Transshipment vessel captain / master's records	####-##-## + ####-##-## [YYYY-MM-DD]	ILMD (Event to Event variance)	Does not exist currently	Date	Does not exist currently
W19	Transshipment Vessel Name	verbal moniker of a transshipment vessel for identifying it visually and on vessel registries.	Latin Alphabet, numbers and punctuation - ISO 7-bit coded character set for information interchange (ISO/IEC 646:1991)	International Organization for Standardization (ISO)	https://www.iso.org/standard/4777.html?browse=tc https://en.wikipedia.org/wiki/ISO/IEC_646	Flag state regulatory body with oversight of the nation's fishing fleet of shipping vessel fleet	Respective Flag state fishing or shipping vessel registry	[See GS1 CBV Descriptions]	Master data - Transshipment Vessel "GLN"	vesselName	String	Name of the vessel Example: HMS Gena
W20	Transshipment Vessel Unique Vessel Identifcation	identifier associated with a vessel for the duration of its existence that cannot be re-used by any other vessel with a permanent physical marking on the craft.	IMO Number registry managed by IHS Maritime (For eligible vessels)	International Maritime Organization (IMO) - http://www.imo.org/en/ourwork/msas/pages/imo-identification-number-	https://gisis.imo.org/Public/SHIPS/Default.aspx	IHS Maritime on behalf of the International Maritime Organization	The IHS Maritime registry of valid IMO numbers	#######	Master data - Transshipment Vessel "GLN"	Does not exist currently	Does not exist currently	Does not exist currently
W21	Landing Location	where seafood was first discharged to land.	**In-Port Landings:** Port Name - United Nations Code for Trade and Transport Locations (UN/LOCODE)	UN Centre for Trade Facilitation and E-business (UN/CEFACT)	https://www.unece.org/cefact/locode/service/location	Unloading vessel (fishing or transshipment) captain	Unloading vessel (fishing or transshipment) captain's records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance); Could be 'Read Point' of Landing if actually recorded at site	unloadingPort	UN LOCODE	Port where the goods were unloaded from a seagoing vessel after having been transported by it. The value of this attribute is a user vocabulary maintained by UN/ECE; see
			Non-Port Landings: GPS Coordinates	International Organization for Standardization (ISO)	https://www.iso.org/standard/39242.html https://en.wikipedia.org/wiki/ISO_6709			(/-)###.###### + (/-)###.###### [37.42242 + -122.08585]	ILMD (Event to Event variance); Could be 'Read Point' of Landing if actually recorded at site	latitude + longitude	xsd:string	Angular distance North or South from the earth's equator measured through 90 degrees. + The arc or portion of the earth's equator intersected between the meridian of a given place and the prime meridian and expressed in degrees
W22	Dates of Landing	calendar start and end dates when seafood is discharged to a landing location.	ISO Date and time format (ISO 8601)	International Organization for Standardization (ISO)	https://www.iso.org/iso-8601-date-and-time-format.html https://en.wikipedia.org/wiki/ISO_8601	Unloading vessel (fishing or transshipment) captain	Unloading vessel (fishing or transshipment) captain's records	####-##-## + ####-##-## [YYYY-MM-DD]	ILMD (Event to Event variance)	Does not exist currently	Date	Does not exist currently
W23	Expiry / Production date	calendar date associated with a particular instance of a product seafood indicating the key date in its life cycle.	ISO Date and time format (ISO 8601)	International Organization for Standardization (ISO)	https://www.iso.org/iso-8601-date-and-time-format.html https://en.wikipedia.org/wiki/ISO_8601	Person within a production or processing facility with the responsibility of accurately recording the date(s) of production	Production / processing records	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance)	itemExpirationDate	Date	The date after which the product should not be used or consumed.
W24	Production Method	categorization, on the spectrum of wild-capture to captive-culture, of the general seafood harvest method.	GDST defined Standard Data Options: 'Farmed' or 'Wild'	Global Dialogue on Seafood Traceability (GDST)	N/A	Fishing vessel captain	Vessel's logbook / harvest records	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	productionMethodForFishAndSeafoodCode	Code	A code specifying how the fish had been grown / cultivated. The code list for this attribute is defined in GS1 EDI;
W25	Product Origin	country where seafood underwent the last substantial transformation.	ISO 2-letter country code list - ISO 3166	International Organization for Standardization (ISO)	https://www.iso.org/iso-3166-country-codes.html https://www.iso.org/obp/ui/#search	Customs authority of the relevant exporting or production country	Certificate(s) of origin from relevant customs authority	[See GS1 CBV Descriptions]	ILMD (Instance to Instance variance)	countryOfOrigin	Code	Country from which the goods are supplied.The code list for this attribute is the ISO 3166-1 Alpha-2 list of 2-letter country codes; see http://www.iso.org/iso/country_codes Example: UK

W26	Harvest Certification	name of harvest standards body which a particular harvest seafood is subject to and the unique identifier associated with the certified entity.	Free-entry Field	N / A	N / A	Standards body which holds the intellectual property of the standard and is responsible for its revision	Respective registry of the standards body	[See GS1 CBV Descriptions]	ILMD (Event to Event variance)	certificationStandard + certificationIdentification	String	Name of the certification standard. Example: MSC + A reference issued to confirm that something has passed certification. Example: MFCS-F-0123
W27	Harvest Certification Chain of Custody	name of chain of custody standards body which particular harvest seafood is subject to and the unique identifier associated with the certified entity.	Free-entry Field	N / A	N / A	Standards body which holds the intellectual property of the standard and is responsible for its revision	Respective registry of the standards body	[See GS1 CBV Descriptions]	Master Data - Processor "GLN";	certificationStandard + certificationIdentification	String	Name of the certification standard. Example: MSC + A reference issued to confirm that something has passed certification. Example: MFCS-F-0123
W28	Fishery Improvement Project	publicly-listed name of fishery improvement project which the harvest event is subject to.	Free-entry Field	N / A	N / A	Independent body with responsibility of publicly listing Fishery Improvement Projects	FisheryProgress.org	String (1-500 characters)	ILMD (Event to Event variance)	Does not exist currently	String	Does not exist currently
W29	Transshipment Vessel Flag	nation with supervision over safety, transshipment operations, and catch transfer reporting.	ISO 2-letter country code list - ISO 3166	International Organization for Standardization (ISO)	https://www.iso.org/iso-3166-country-codes.html https://www.iso.org/obp/ui/#search	Flag state regulatory body with oversight of the nation's fishing fleet of shipping vessel fleet	Respective Flag state fishing or shipping vessel registry	[See GS1 CBV Descriptions]	Master data - Transshipment Vessel "GLN"	vesselFlagState	String	The ISO 3166-1 alpha-2 code specifying the state under whose laws the vessel is registered or licensed. Example: UK
W30	Transshipment Vessel Registration	standardized number or identifier for distinguishing vessels registered under the same flag nation.	Free-entry Field	N / A	N / A	Flag state regulatory body with oversight of the nation's fishing fleet of shipping vessel fleet	Respective Flag state fishing or shipping vessel registry	[See GS1 CBV Descriptions]	Master data - Transshipment Vessel "GLN"	vesselID	String	Identifier for the vessel Example: DE-X-1234
W31	Landing Authorization	unique number associated with a regulatory document, from the relevant authority, granting permission for discharge of wild-capture of seafood to land by a fisher, fishing vessel or transshipment vessel.	Free-entry Field	N / A	N / A	Regulatory body with oversight of the landing of seafood for a particular location	Respective Landing Authority listing of authorizations	String (1-500 characters)	Biz Step' "Certification"	Does not exist currently	String	Does not exist currently
W32	Public Vessel Registry Hyperlink	website address where the public registry containing the listing of the fishing vessel.	Free-entry Field for hyperlinks;	N / A	N / A	Flag state regulatory body with oversight of the nation's fishing fleet	Respective Flag state fishing vessel registry	String (1-500 characters)	Master data - Fishing Vessel "GLN"	Does not exist currently	String	Does not exist currently
W33	Transshipment Authorization	unique number associated with a regulatory document, from the relevant authority, granting permission for discharge of wild-capture of seafood from a fishing vessel to a transshipment vessel.	Free-entry Field	N / A (No single source exists)	N / A	Regulatory body with oversight of the transshipments of seafood for a particular location	Respective Transshipment Authority listing of authorizations	String (1-500 characters)	Biz Step' "Certification"	Does not exist currently	String	Does not exist currently
W34	Existance of Human Welfare Policy	Indicator of human welfare policies in place on a vessel/trip, answering the question "What kind of human welfare, labor, or anti-slavery policy was in place on this vessel/trip?" (If internal policy subject to 3rd party audit, select '3P Audit'.)	GDST defined Standard Data Options: 'None' 'Internal policy' '3P Audit'	N / A (No single source exists)	N / A	Fishing or Primary Processing Company	Fishing or Primary Processing Company Policy	String (1-500 characters)	ILMD (Event to Event variance)	Does not exist currently	String	Does not exist currently
W35	Human Welfare Policy Standards	Name of internationally recognized standards to which policy on a vessel/trip claims conformity	Free-entry Field or "not applicable" (example: "ILO C188")	N / A (No single source exists)	N/A	Fishing or Primary Processing Company	Fishing or Primary Processing Company Policy	String (1-500 characters)	ILMD (Event to Event variance)	Does not exist currently	String	Does not exist currently

Appendix 2. Ethereum template contract for catch data storage

```
pragma solidity ^0.5.10;
//uses https://github.com/OpenZeppelin/openzeppelin-contracts
// /blob/release-v2.5.0/contracts/ownership/Ownable.sol
import "./Ownable.sol";

contract KDEStorage is Ownable {

    event MemberAdded(address member);
    event MemberRemoved(address member);
    event KDELog(string updateType, string GTIN, uint KDEcount);

    struct KDEStruct {
        address updater;
        string json;
        bool isKDE;
    }

    //whitelist
    mapping (address => bool) members;

    //kde mapping
    mapping(string => KDEStruct) public kdeStructs;

    // key-value map of gtins to kde lists
    string[] public kdeList;
```

```
constructor() public Ownable() {
    members[msg.sender] = true;
}

function isMember(address _member)
public
view
returns(bool)
{
    return members[_member];
}

function addMember(address _member)
public
onlyOwner
{
    require(
        !isMember(_member),
        "Address is member already."
    );

    members[_member] = true;
    emit MemberAdded(_member);
}

function removeMember(address _member)
public
onlyOwner
{
    require(
```

```
            isMember(_member),
            "Not member of whitelist."
        );

        delete members[_member];
        emit MemberRemoved(_member);
    }

    function isKDE(string memory kdeKey) public view
    returns(bool isIndeed) {
        return kdeStructs[kdeKey].isKDE;
    }

    function getKDECount() public view returns(uint kdeCount) {
        return kdeList.length;
    }

    function newKDE(string memory gtin, string memory json)
    public returns(uint rowNumber) {
        require(isMember(msg.sender), "Account not whitelisted.");

        if(isKDE(gtin)) revert();
        kdeStructs[gtin].json = json;
        kdeStructs[gtin].updater = msg.sender;
        kdeStructs[gtin].isKDE = true;
        kdeList.push(gtin);

        emit KDELog('KDE created', gtin, kdeList.length);
        return kdeList.length;
    }
```

```
    function updateKDE(string memory gtin, string memory json)
    public returns(bool success) {
        require(isMember(msg.sender), "Account not whitelisted.");
        if(!isKDE(gtin)) revert();
        kdeStructs[gtin].json = json;
        emit KDELog('KDE updated', gtin, kdeList.length);
        return true;
    }

    function getKDE(string memory gtin) public
    view returns (address _updater, string memory _json, bool _iskde) {
        require(isMember(msg.sender), "Account not whitelisted.");
        return (kdeStructs[gtin].updater,
        kdeStructs[gtin].json, kdeStructs[gtin].isKDE);
    }

}
```

Appendix 3. Ethereum template contract for trade data storage

```
pragma solidity ^0.5.10;
//uses "https://github.com/OpenZeppelin/openzeppelin-contracts/
//blob/release-v2.5.0/contracts/ownership/Ownable.sol";
import "./Ownable.sol";

contract TradeDataStorage is Ownable{

    event MemberAdded(address member);
    event MemberRemoved(address member);
    event TradeLog(string updateType, string GTIN, uint TradeCount);

    struct TradeStruct {
        address updater;
        string information;
        string currency;
        uint price;
        bool verified;
        bool isTrade;
    }

    //whitelist
    mapping (address => bool) members;

    //kde mapping
    mapping(string => TradeStruct) public tradeStructs;
```

```
// key—value map of gtins to kde lists
string[] public tradeList;

constructor() public Ownable() {
    members[msg.sender] = true;
}

function isMember(address _member)
public
view
returns(bool)
{
    return members[_member];
}

function addMember(address _member)
public
onlyOwner
{
    require(
        !isMember(_member),
        "Address is member already."
    );

    members[_member] = true;
    emit MemberAdded(_member);
}

function removeMember(address _member)
public
```

```
onlyOwner
{
    require(
        isMember(_member),
        "Not member of whitelist."
    );

    delete members[_member];
    emit MemberRemoved(_member);
}

function isTrade(string memory kdeKey) public view
returns(bool isIndeed) {
    return tradeStructs[kdeKey].isTrade;
}

function getTradeCount() public view returns(uint kdeCount) {
    return tradeList.length;
}

function newTrade(string memory gtin, string memory information,
uint price, string memory currency,
    bool verified) public returns(uint rowNumber) {
    require(isMember(msg.sender), "Account not whitelisted.");

    if(isTrade(gtin)) revert();
    tradeStructs[gtin].information = information;
    tradeStructs[gtin].currency = currency;
    tradeStructs[gtin].price = price;
    tradeStructs[gtin].updater = msg.sender;
```

```
    tradeStructs[gtin].verified = verified;
    tradeStructs[gtin].isTrade = true;
    tradeList.push(gtin);

    emit TradeLog('Trade created', gtin, tradeList.length);
    return tradeList.length;
}

function updateKDE(string memory gtin, string memory information,
bool verified, uint price, string memory currency
) public returns(bool success) {
    require(isMember(msg.sender), "Account not whitelisted.");
    if(!isTrade(gtin)) revert();
    tradeStructs[gtin].price = price;
    tradeStructs[gtin].verified = verified;
    tradeStructs[gtin].currency = currency;
    tradeStructs[gtin].information = information;
    emit TradeLog('Trade updated', gtin, tradeList.length);
    return true;
}

function getKDE(string memory gtin) public view
returns (address _updater, string memory _information, bool _iskde,
    uint _price, string memory _currency, bool _verified) {
    require(isMember(msg.sender), "Account not whitelisted.");
    return (tradeStructs[gtin].updater,
    tradeStructs[gtin].information, tradeStructs[gtin].isTrade,
    tradeStructs[gtin].price, tradeStructs[gtin].currency,
    tradeStructs[gtin].verified);
}
```

}

Appendix 4. Ethereum template contract for GTIN-14 generation

```
pragma solidity ^0.5.10;
//uses https://github.com/OpenZeppelin/openzeppelin-contracts/blob/
//release-v2.5.0/contracts/ownership/Ownable.sol
import "./Ownable.sol";

contract GTINgenerator is Ownable {

    // Events
    event MemberAdded(address member);
    event MemberRemoved(address member);
    event GTINCreated(uint indicator, uint prefix,
    uint itemReference, uint checkdigit);
    event GTINPrefixCreated(address creator, uint prefix);
    // Data types
    mapping (address => bool) members;

    struct GTINprefix {
        uint prefix;
        bool isGTIN;
        string ownerInformation;
    }
    // GTIN-14 in its components
    struct GTIN {
        uint indicatorDigit;
        uint prefix;
        uint itemRefence;     //item reference
```

```
    bool isGTIN;
    uint checkDigit;
}

// wallet address -> GTIN-14 prefix map
// max 9999999 registered fishermen when
// company prefix is 7 digits long
mapping(address => GTINprefix) public GTINprefixes;

// wallet address ->
// number of GTIN-14 (itemRefenceCounter) -> GTIN struct
mapping(address => mapping( uint => GTIN)) public GTINs;

// wallet address -> used suffixes
// wallet address -> itemRefence counter
// 5 digits (max 89999 registered catches per fisherman)
// e.g. 0x570d922397b398BC74AaE3A7594AD76e4F221C45 -> 12345
mapping(address => uint) public itemRefenceCounter;

uint public prefixCounter;

constructor() public Ownable() {
    members[msg.sender] = true;
    prefixCounter = 1000000;
}

// Whitelist handling logic
function isMember(address _member)
public
view
```

```
returns(bool)
{
    return members[_member];
}

function addMember(address _member)
public
onlyOwner
{
    require(
        !isMember(_member),
        "Address is member already."
    );

    members[_member] = true;
    emit MemberAdded(_member);
}

function removeMember(address _member)
public
onlyOwner
{
    require(
        isMember(_member),
        "Not member of whitelist."
    );

    delete members[_member];
    emit MemberRemoved(_member);
}
```

```
// GTIN registration and generation logic
// array size prefixed to number digits
function generateDigits(uint number,
uint8[] memory arr) public returns(uint8[] memory){
    require(isMember(msg.sender), "Account not whitelisted.");
    for (uint i = 0; i < arr.length; i++) {
        uint8 digit = uint8(number % 10);
        number = number / 10;
        arr[i] = digit;
    }
    return arr;
}

//check if wallet address has a registered GTINprefix
function isGTINprefix(address GTINowner)
public view returns(bool) {
    return GTINprefixes[GTINowner].isGTIN;
}


function getItemReferenceState() public view returns(uint) {
    return itemRefenceCounter[msg.sender];
}

function registerGTINprefix(string memory _ownerInformation)
public returns (bool) {
    require(isMember(msg.sender), "Account not whitelisted.");
    //Todo: allow only whitelisted user to call function
    //Todo: check if wallet is already in GTINprefixes map
```

```
        if(isGTINprefix(msg.sender)) revert();
        GTINprefixes[msg.sender].ownerInformation = _ownerInformation;
        GTINprefixes[msg.sender].isGTIN = true;
        GTINprefixes[msg.sender].prefix = prefixCounter;
        itemRefenceCounter[msg.sender] = 10000;
        emit GTINPrefixCreated(msg.sender,
        GTINprefixes[msg.sender].prefix);
        prefixCounter+=1;
        return true;
    }

    function generateGTIN(uint _indicatorDigit)
    public returns (uint, uint, uint, uint) {
        require(isMember(msg.sender), "Account not whitelisted.");
        //Enables generation of GTIN-14 codes
        // in the range of 1 1000000 10000 X to 1 999999 99999 Y
        uint _index = itemRefenceCounter[msg.sender];

        GTIN memory _gtin;
        _gtin.indicatorDigit = _indicatorDigit;
        _gtin.prefix = GTINprefixes[msg.sender].prefix;
        _gtin.itemRefence = _index;
        _gtin.isGTIN = true;

        uint8[] memory _prefixDigitArray = new uint8[](7);
        uint8[] memory _referenceDigitArray = new uint8[](5);
        _prefixDigitArray =
        generateDigits(_gtin.prefix, _prefixDigitArray);
        _referenceDigitArray =
        generateDigits(_gtin.itemRefence, _referenceDigitArray);
```

```
        uint firstSum = _gtin.indicatorDigit *3 +
        _prefixDigitArray[0]*1 + _prefixDigitArray[1]*3
        + _prefixDigitArray[2]*1 + _prefixDigitArray[3]*3
        + _prefixDigitArray[4]*1 +
        _prefixDigitArray[5]*3 + _prefixDigitArray[6]*1 +
        _referenceDigitArray[0]*3 + _referenceDigitArray[1]*1
        + _referenceDigitArray[2]*3 * _referenceDigitArray[3]*1 +
        _referenceDigitArray[4]*3;
        _gtin.checkDigit = 10 - firstSum % 10;
        if (_gtin.checkDigit == 10) _gtin.checkDigit = 0;

        GTINs[msg.sender][_index] = _gtin;
        itemRefenceCounter[msg.sender]+=1;

        emit GTINCreated(GTINs[msg.sender][_index].indicatorDigit,
            GTINs[msg.sender][_index].prefix,
            GTINs[msg.sender][_index].itemRefence,
            GTINs[msg.sender][_index].checkDigit);
        return (GTINs[msg.sender][_index].indicatorDigit,
        GTINs[msg.sender][_index].prefix,
        GTINs[msg.sender][_index].itemRefence,
        GTINs[msg.sender][_index].checkDigit);
    }

}
```