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Sustainable supply chain management for blue economics in Northern Norway

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Master thesis in Industrial Engineering

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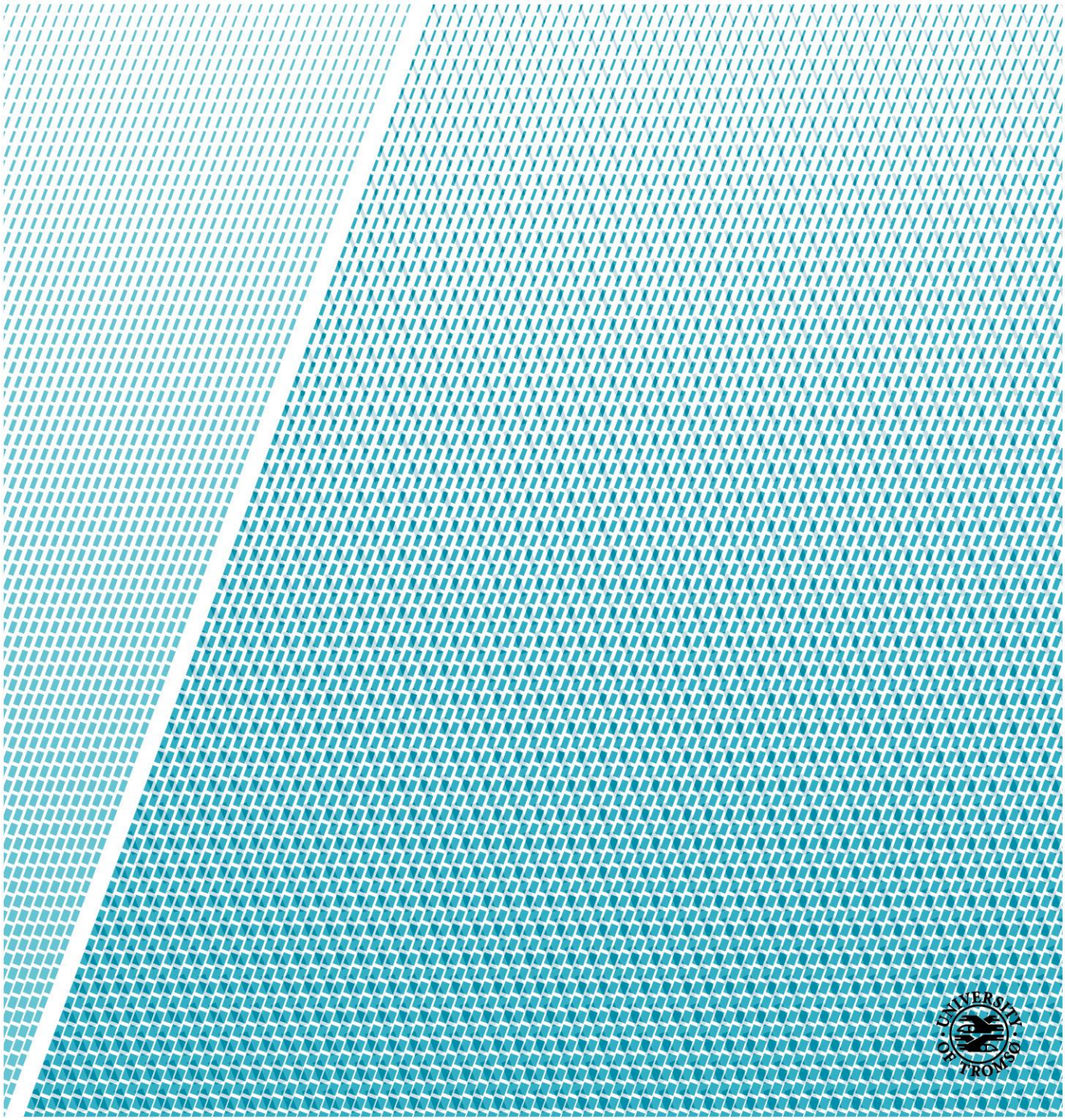

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In the first part of thesis, there was conducted a literature review of production and the supply chain with regards to fish farming, existing technologies, together with the potential of alternative digital technology.

In the second part, a case study of a relevant manufacturer who is involved in all the aspects of the value chain was carried out to gain insight into relevant supply chain management. There was also carried out research on consumer wishes, and consumer behaviour, to further understand the value-potential of fish products. Solution contains necessities and potential-assessment of a new product service system, and the accompanying benefits for both the consumer and manufacturer.

In memory of my beloved father, Arvid Magnar Sandåker

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Thank you

Anders Magnar Sandåker

Abstract

Scope for thesis was to investigate fish farming in Northern Norway, and the potential for improvements related to products from a consumer perspective, with the goal to develop a system that would result in increased control, communications, and provide value creation to the supply chain. The first part of thesis was an extensive literature review of fish farming in Norway, technology in use with the purpose of providing a customer-focused service, and technology with the potential to improve the supply chain.

In order to obtain necessary information about how the aquaculture industry operates and discover potential improvement around the supply chain, it was necessary examine the entire production, step by step, to acquire knowledge around all the joints in the chain. The Norwegian fishing industry is extensive both in size and concerning details, and there are several critical factors that must be considered during production.

Even with an industry in significant growth, there is available technology that can help elevate it even more. Identification technology with limited information regarding products, is all that is available to the end-customer in today's transactions. Development of production, services, and management methods will be vital to ensure a sustainable industry. There are considerable values that are being invested in research and development to help further develop the aquaculture and fish farming industry.

The second part of thesis included a case study of a relevant manufacturer in Northern Norway, and a study of consumer behaviour. Manufacturer in case study is an integrated aquaculture company with activities in all parts of the value chain, which is located in Northern Norway with a complete production.

Basis for the case study was to gain insight in to how an actual manufacturer handles various affairs related to supply chain management, technology utilization, and which services that are provided. Case study was conducted through repeated dialogue with the manufacturer, followed by a survey. At the request of the company, the name of the manufacturer was anonymized.

Awareness of consumer wishes, insight in which factors that determines whether a customer finds a product interesting or not, along with understanding a potential value increase of current products was very relevant when designing solution.

It was evaluated what information that was available, the potential and value around it, communication with end-customers, and how to disclose the desired information. Necessary technology together with other necessities are also considered in chosen solution. Size of the manufacturer and available resources of company is also taken into consideration. Solution expresses potential of value increase, and the necessities for implementing the system.

Sammendrag

Formål for masteroppgave var å se på oppdrettsproduksjon i Nord-Norge, og undersøke forbedringspotensialet knyttet til medfølgende fiskeprodukter fra et forbrukerperspektiv, med mål å utvikle et system som skal resultere i økt styring, kommunikasjon og verdiskapning i forsyningskjeden. Første del av oppgaven var en omfattende litteraturstudie av oppdrettsindustrien i Norge, eksiterende teknologi med formål å levere en kundefokusert tjeneste, og teknologi med potensial til å bedre forsyningskjeden.

For å innhente nødvendig informasjon av hvordan oppdrettsindustrien opererer og forbedringspotensial rundt næringen, var det nødvendig og ta for seg produksjonen, steg for steg, å tilegne seg kunnskap rundt alle ledd i forsyningskjeden. Fiskeindustrien i Norge er omfattende både i størrelse og detaljstyring, og det er mange kritiske faktorer som må tas hensyn til ved produksjon.

Selv med en omfattende industri er det tilgjengelig teknologi som kan være med å heve en næring i betydelig vekst. Identifikasjonsteknologi med begrenset informasjon rundt produkter er det som er tilgjengelig for sluttkunde ved dagens transaksjoner. Utvikling av produksjon, tjenester, og styringsmetoder vil være avgjørende å kunne sikre en bærekraftig industri. Det investeres betydelige beløp til forskning og utvikling av fiskeindustri og oppdrett.

Andre del av oppgave omfattet en casestudie av en relevant produsent i Nord-Norge, og en studie av forbrukeroppførsel. Produsent i casestudiet er et er integrert havbruksselskap med aktiviteter i alle deler av verdikjeden, og som er lokalisert i Nord-Norge, med en komplett produksjon.

Utgangspunktet for casestudiet var å få innsyn i hvordan en aktuell produsent håndterer ulike affærer relatert til styring av forsyningskjeden, teknologibruk, samt hvilke tjenester som leveres. Casestudie ble utført gjennom gjentatt dialog med produsent, etterfulgt av en undersøkelse. Etter ønske fra bedrift ble navn på produsent anonymisert.

Bevissthet rundt forbrukerønsker og hvilke faktorer som med å avgjøre om en kunde finner et produkt interessant, sammen med forståelse rundt en potensiell verdiøkning av aktuelle produkter var veldig aktuelt ved design på løsning.

Det ble evaluert hvilken informasjon som er tilgjengelig, potensialet og verdi rundt den, kommunikasjon med sluttkunde, og metode for videreformidling av ønsket informasjon. Nødvendig teknologi, og tilhørende nødvendigheter er også vurdert i valgt løsning. Størrelse på produsent og tilgjengelig ressurser er det også tatt høyde og tilrettelagt for. Løsning forteller om potensiell verdiøkning, og nødvendigheter for implementering av system.

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Glossary

SCM - Supply Chain Management

EU - European Union

NFSA - Norwegian Food Safety Authority

NCA - Norwegian Coastal Administration

NFSA - Norwegian Food Safety Authority

NOK – Norwegian Kroner

HACCP - Hazard Analysis and Critical Control Points

UIT – Universitet I Tromsø (University)

NTNU - Norges Teknisk Naturvitenskapelige Universitet *(*University*)*

QR code – Quick Response code

RFID - Radio Frequency Identification

GHz – Gigahertz

IoT- Internet of Things

CPS – Cyber Physical Systems

API - Application Programming Interface

UID - Unique Identifier

ICT - Information and Communications Technology

ROV - Remote Operated Vehicles

AUV - Autonomous Underwater Vehicles

B2B - business-to-business

1 Introduction

1.1 Background

Fishery and seafood production is Norway's second largest industry, only exceeded by the petroleum industry. In the EU, Norway is the largest supplier in fish and aquaculture products in terms of both volume and value, and fishery products from Norway enjoys good reputation both domestically and globally. Quality of products and services over many years has made several Norwegian fish products prominent on the market [16]. The ripple effects of the aquaculture and seafood industry in Norway are significant. A report that was carried out by SINTEF and funded by the Fisheries and Aquaculture Industry Research Fund presented that 9500 jobs are created by technology and service providers, while the ripple effect of the industry corresponds too approximately. 12,000 jobs. Suppliers to fish farming and seafood industry accounted for a value creation of NOK 24.5 billion in 2016 [51].

The increasing technological development and globalization has resulted in an increasingly demanding market around the world. For companies to survive and succeed in such a competitive market, it will be necessary for them to focus on increased efficiency within the chain and improve the product quality. At the same time, companies should also have a focus on expanding their product portfolio variability, increased response time, and more flexibility for the end-customer. In order to maintain and further develop important aspects such as increased interest and product quality, as well as reduced costs in terms of production, processing and labour, automated and semi-automated operations have been implemented in large parts of the industry. It will be very beneficial for Norwegian suppliers, who already have several geographical challenges, to possess modern and efficient solutions. Today's technology offers many solutions, and it can be of great advantage to be innovative and utilize available opportunities. Improved information flow between customer and supplier, and within the organization will be able to provide a more efficient supply chain and at the same time increase the customer experience. There are several alternatives to digital technology that can be used to solve several of these challenges within the companies.

Technological changes will also have a significantly impact on manufacturers and suppliers in northern Norway. Companies that are located in northern Norway are mainly small and medium-sized enterprises and geographically isolated from the outside world, as follows they have to calculate with longer transport routes and the accompanying challenges. New effective technological solutions and management methods could therefore be of great importance to such companies and their ability to improve competitiveness, increase value creation, and sustainability in both the domestic and global market. This thesis will mainly focus on fish and aquaculture products in northern Norway and what opportunities and challenges that exist there. The fishing industry in northern Norway plays an important role in the economic development of the region and has many positive ring effects.

The goal of this thesis is to improve the competitiveness and sustainability of seafood producers in northern Norway through a better customer-oriented product system. Food traceability is significant for any food supply chain and its logistics systems. Being able to ensure conditions for processing and transportation will be of great value to manufacturers. Such a system will improve the information flow through the supply chain, thereby improving tracking capabilities, and provide more detailed

information for the product through the chain, which will provide added value for both end customer and the supply chain.

In order to complete this thesis, an extensive review of the production and the supply chains for manufacturers, research of available and useful technological possibilities, and how they work together have been conducted. It is of importance that the communication between the various links in the chain, as well as the communication between manufacturers and customers must as efficient and functional as possible. Through the system, large amounts of data will be available, and analysis can provide valuable information, which will make it possible for producers to improve the quality of their products as well as their product portfolio.

1.1.1 Challenges in the industry

The fish farming industry in Norway has several challenges they meet on a daily basis, and they have the need to solve these in order to be able to ensure a sustainable production and retain its significant growth potential. Resolving these challenges will be of essential value for the industry to achieve its goals.

Escapes: Every year in Norway, hundreds of thousands of farmed fish escapes from fish farms. Some of the escaped fish are found again in spawning areas for the wild fish. This can adversely affect the wild stock's carrying capacity and lead to direct loss of genetic resources. In Norway it is mandatory to report all escapes, but it is estimated that there are a significant number of escapes that are never reported. In order to ensure a sustainable and environmentally friendly future for fishery industry, it is a prerequisite that the number of escapes is reduced. Greater knowledge about risk, side effects that comes with the escapees, and the severity of different scenarios will help the industry to take further steps to ensure such a future [3] [11].

The Institute of Marine Research is an organization that is conducting several projects to increase the understanding of challenges connected to escaped-fish, and to be able to close appurtenant knowledge gap. In a comprehensive field trial, about 90 family groups of farmed salmon and wild salmon were planted in a natural environment to observe factors such as increment, competition, and survival. The project was a five-year institute project and aimed at mapping the different genetic differences, as well as the underlying mechanisms. Biological trials supplemented with molecular methods would illuminate these problems, and in addition model the consequences of gene flow. DNA profiles from old shell material was compared to DNA profiles from 21 collected salmon stocks. The conclusion from this survey was that the entry of escaped farmed fish had caused significant changes in 4 of the 21 fish stocks examined, but despite this, much of the original geographical file structure was still intact [11].

Infections: Salmon lice (Lepeophtheirus Salmonis) is a natural ectoparasite found in saltwater on the northern hemisphere. The lice feed of the fish skin, blood, and mucus, and can cause wounds with varying degrees depending on the number of parasites and size of the host. The different stages of the infection are visually visible, and the wounds can be directly fatal to the host. The salmon lice are present in a large number of seawater facilities with salmon and rainbow trout in Norway, and as follows a big challenged for today’s production. The number of parasites depends largely on infection pressure and control measures. Regarding infection pressure, host density and temperatures are important aspects [12] [13].

The occurrence of lice is greater in areas with high production density, the development of infectious pressure also escalates with high temperatures in the water. The Food Safety Authority initiated a monitoring program for drug resistance of salmon lice in 2013, and the Veterinary Institute coordinate this program. The goal of the program was to describe the salmon lice's sensitivity to medicines and to advise the use of medication, as well as gaining a better control of salmon lice in fish farms. There are regulations that indicate how much lice / per fish that is allowed in a fish farm. Measures must always be taken to ensure that these limits are not exceeded [12] [13].

Medical treatment has originally been the main measure against salmon lice, but over several years it has been observed that the fish have had an increased resistance to such drugs. Today, it is becoming increasingly common to control the industry by other non-medication measures, such as tempered water, mechanical depletion (water pressure / brushes) or the use of cleansing fish. Cleansing fishes are put in fish farms together with the salmon and the cleansing fish eats the lice of the salmon fish. Examples of measures to prevent lice are shields against lice larvae in the form of specially laced lice tight skirts that are placed around the cages, and breeding of lice resistant fish. When using medicines, it is either added through the fish fodder or in the form of a bath. Treatment in form of bath usually occurs in a well boat or in a cage covered with tarpaulin. Some non-drug delousing methods can address various welfare issues with the fish such as injuries / wounds on the fish, or diseases developed as a result of the use of cleansing fish [12] [13].

1.2 Legal regulations

To be able to conduct fish farming, one must first have a public permit. In Norway, the county municipalities are responsible for deciding on aquaculture applications. Further on, the county municipality controls the applications, and further submits relevant applications to sector authorities and localization municipality. The Food Safety Authority, considering fish welfare and health, assesses the evaluation of facility and localization. The Norwegian Food Safety Authority (NFSA) supervises compliance with regulations under the Aquaculture Operation Regulations. The Aquaculture Operations Regulation deals with all operation of aquaculture facilities with fish, and all fish farms in Norway are obliged to comply with its regulations. According to the Aquaculture Act, permission cannot be granted if the Norwegian Coastal Administration, NFSA, or the county governor rejects the application. Permission cannot either be granted in violation of the protection measures, already sanctioned plans, the Cultural Heritage Act or the Planning and Building Act.

Norwegian food industry has clear regulations for production and handling of food. The regulations are there to hold unwanted events to a minimum level, and preferably prevent such events from occurring at all, such as disease or contamination. Producers of fishery products must have the necessary certificates to be able to manufacture and deliver products. This is to ensure that current products maintain satisfactory standard and quality, and that these products are processed in accordance with Norwegian laws and standards. Without necessary certificates, manufacturers cannot deliver their products [2] [20] [38].

Norwegian Coastal Administration

The Norwegian Coastal Administration (NCA) is an agency of the Norwegian Ministry of Transport and Communications with responsibility for maritime safety and infrastructure, coastal management, and contingency contamination. The agency works for safe and efficient sea- and port transport / traffic, preventive work to reduce damage in case of contamination / pollution, as well as working to ensure sustainable development of coastal areas in Norway.

KYSTVERKET

Figure 1:Logo of the Norwegian Coastal Authority [65].

The Coastal Administration's activities apply to the maritime sector in the National Transport Plan and execute authority and administrative tasks related to laws and regulations regarding fairways and compulsory pilotage.

NCA aims to develop the Norwegian coast to become the world's cleanest and safest, with overall goals as follows:

1. ***Navigability*.**

NCA will strengthen the competitiveness of the industry through better navigability, as well as reducing costs relating distances.

2. ***Traffic Safety*.**

The zero vision in Norway has as goal / vision that no accidents should result in any people killed or severely injured.

3. ***Environment.***

They will help Norway meet national goals and international obligations, reduce environment damages that results from transport, and limit climate gas emissions.

4. ***Preparedness against acute pollution*.**

Limit and prevent damage to the environment due to pollution.

Tasks of the Norwegian Coastal Administration:

- Maintenance / development of fishing Ports.
- Brand and lighthouse services.
- Traffic services.
- Piloting.
- Navigation alert.
- Messaging.
- Preparedness against pollution.
- Exercise of authority
- Transport Planning.
- Port Security. [41]

Norwegian Food Safety Authority

The Food Safety Authority (FSA) is an administrative body, which ensures that consumers have safe food and drinking water, as well as promote environmentally friendly production, secure health for people-, plants-, fish-, and animals, and ensures justifiable catch of fish and animals. The FSA responsibilities also include tasks for administration of medicine and cosmetics, and supervision of animal health personnel.

Figure 2: Logo for the Food Safety Authority in Norway [66].

The Norwegian Food Safety Authority provides advice to the Ministry of Fisheries, the Ministry of Agriculture and Food, and the Ministry of Health and Care. The FSA's roles are:

- Develop proposals.
- Manage regulations.
- Supervise.
- Conveying knowledge, preparedness, and information. [38]

1.3 Certificates on fish products in Norway:

Certificates is a necessary aspect of selling fish products today. Certificates on given products refer to which quality stamps the product holds. Examples of different quality stamps are:

MSC (Marine Stewardship Council): The label specifies that fish does not originate from overfished stocks and is not caught in ways that may be hazardously for the marine ecosystem. MSC has designed a standard called Chain and Custody, which guarantees that the branded product comes from MSC certified sustainable fishing.

DEBIO/KRAV: An organization in Norway that draws and approves rules for the production and marketing of organic products.

KOSHER: Certification indicating the standard (highest) of kosher. The certification of kosher shall ensure that labelled food is kosher, and therefore suitable for the current consumer.

HACCP: Hazard Analysis and Critical Control Point is a management system that helps ensure food safety through monitoring and control of raw material, processing, handling of finished product.

BRC (British Retail Consortium): Standard that sets requirements for product safety, hygiene, and quality among manufacturers. Applies for both food and packaging.

1.4 Problem formulation and objective

Scope for this thesis is divided into two parts. Part one is a theoretical review of supply chains of fish farming products in northern Norway, production methods, and current technologies applied for farmed fish with the purpose of customer-focused service. In the second part of thesis the focus will be on a case study to gain further insight into the production and interaction within manufacturers, develop an understanding around consumers' needs, and construction of a product service system.

The main objective of thesis is to improve the supply chain to manufacturers by raising the value of their products through the introduction of a new product system, which in turn will provide customers with supplementary services. The system will improve customer experience, streamline communication, and as follows increase the value to the entire supply chain.

1.4.1 Objectives

Task/Objectives for this thesis are:

1. Mapping current supply chains of fish farming products from Northern Norway – from producer to end-customer.
2. Conduct literature review on current technologies applied for farmed fish supply chains with the purpose of customer-focused service.
3. Conduct literature review on possible digital technologies (i.e., IoT, CPS, Big data analytics and Cloud computing) that enables and enhances traceability and improves customer experience on products and services.
4. Perform case study on relevant manufacturer.
5. Construct product service system.

2 Literature review

2.1 Blue economics

The "*blue economy*" term is widely used around the world and as follows the term has several interpretations. The term is often divided between (*a*) the use of the sea's activities for sustainable economic development, or (*b*) all economic activity within the maritime sector, regardless of whether it is sustainable or not.

The sea and coastal areas represent the largest ecosystems on the planet and is a valuable part of human and animals' natural heritage. These areas stand for great value creation globally and provide livelihood and food security for billions of people, as well as to contribute to economic growth for many nations.

A report from 2015 that was produced in association with The Global Change Institute at the University of Queensland and The Boston Consulting Group (BCG), contains a thorough review of the asset base of the ocean. In the report, key activities connected with the sea are conservatively estimated to be at least 24 trillion US dollars. Compared with the world's top 10 economies, the ocean would be ranked in seventh place with an annual value of two and a half billion US dollars.

The ocean is a perpetual resource if it is used correctly. To be able to fully benefit the values associated with the sea and coastal areas as well as make proper use of the accompanying opportunities will be of great importance for todays and future generations [10].

Changes in the world's population are of great relevance for the human impact on the planet's environment. Because of such a significant increase in population, it will be necessary to be able to produce protein-rich food faster and cheaper in the future. By 2030, the world must produce 70 percent more food, and it must be done with lower resource usage, and with the least possible environmental impact. The sea covers over two thirds of the earth's surface, but measured in energy, only 2 percent of consumed food originates from the sea. Producing animal protein through aquaculture requires fewer resources and is more climate friendly than animal husbandry on land. Since traditional fishing is almost fully utilized, the growth in aquaculture is crucial to provide food for future generations [54].

2.2 Supply chain management

Supply Chain Management (SCM) is a term that is widely used, and the definitions vary slightly depending on both industry and company. SCM defines management of activities associated with the supply chain, with the aim to fulfil maximized customer value while ensuring a sustainable competitive advantage.

Activities around SCM cover production, product and service development, procurement, sales, transportation, logistics and more, as well as all associated information-systems that are necessary to adequately coordinate and perform given activities. SCM involves the effort to constantly develop,

manage and execute activities, and operate the supply chain in an efficient, safe, and successful manner.

Supply Chain Management is based on the following two core ideas:

- Every product that ends up with an end-customer represents efforts from several different joints and organizations. The sum of these joints and organizations is collectively referred as the supply chain.
- The second part of the two core ideas is that most companies and organizations have reserved focus and view on what is happening within their company/organization, and little insight and influence with the rest of the supply chain, which also has a major impact on the final product. This often results in inefficient supply chains with high potential for improvement.

The joints in a supply chain are tied together both physically and through information flow. Storage, material usage, and movements are physical flows and the part of the supply chain that can be easily observed since they are usually tied together physically in various industries. The information section makes it possible to coordinate, plan and implement necessary plans to achieve long-term and short-term goals. It is important to be able to coordinate and control the daily flow of goods and services adequately both ways in the supply chain.

Significance of SCM

Strategies around the supply chain are critical for organizations in today's market, because the strategies are the main part in defining how companies make money and keep their value as well as making sure they can deliver satisfactory products. Availability of products and adequate market coverage are essential for securing revenue and depends directly on the efficiency of the supply chain. When a product is advertised and introduced to the market, it is necessary to ensure that it is available where the customer base is located, and the interest rate is high. An item that is unavailable can lead to reduced interest / demand, and as follows result in adverse consequences for a company or organization. Transport choices and management, as well as sales and marketing strategies must therefore be coordinated satisfactorily.

Storage visibility and inventory management are cost drivers with a direct impact on the bottom lines of the balance, which make them critical elements for any operation. "*Every business has a standard for inventory turnaround that is optimum for the business. Inventory turnaround refers to the number of times the inventory is sold and replaced over a period of twelve months. The health of the inventory turn relates to the health of business* [15]. In global scenarios, finished products are often stored in multiple distribution locations, and may be managed by third parties. Values in form of inventory will be found in stock, as well as during transport. Any loss in inventory will result in diminished value for the supply chain, therefore it is critical to obtain an effective stock- and inventory management.

It is of great importance that companies, and industries has defined strategies for how they can manage their supply chain in the best possible way. The fishery industry is in general one industry that understands the importance of such adequate strategies since they handle a lot of fresh raw materials and products [14] [15].

2.3 Fish farming

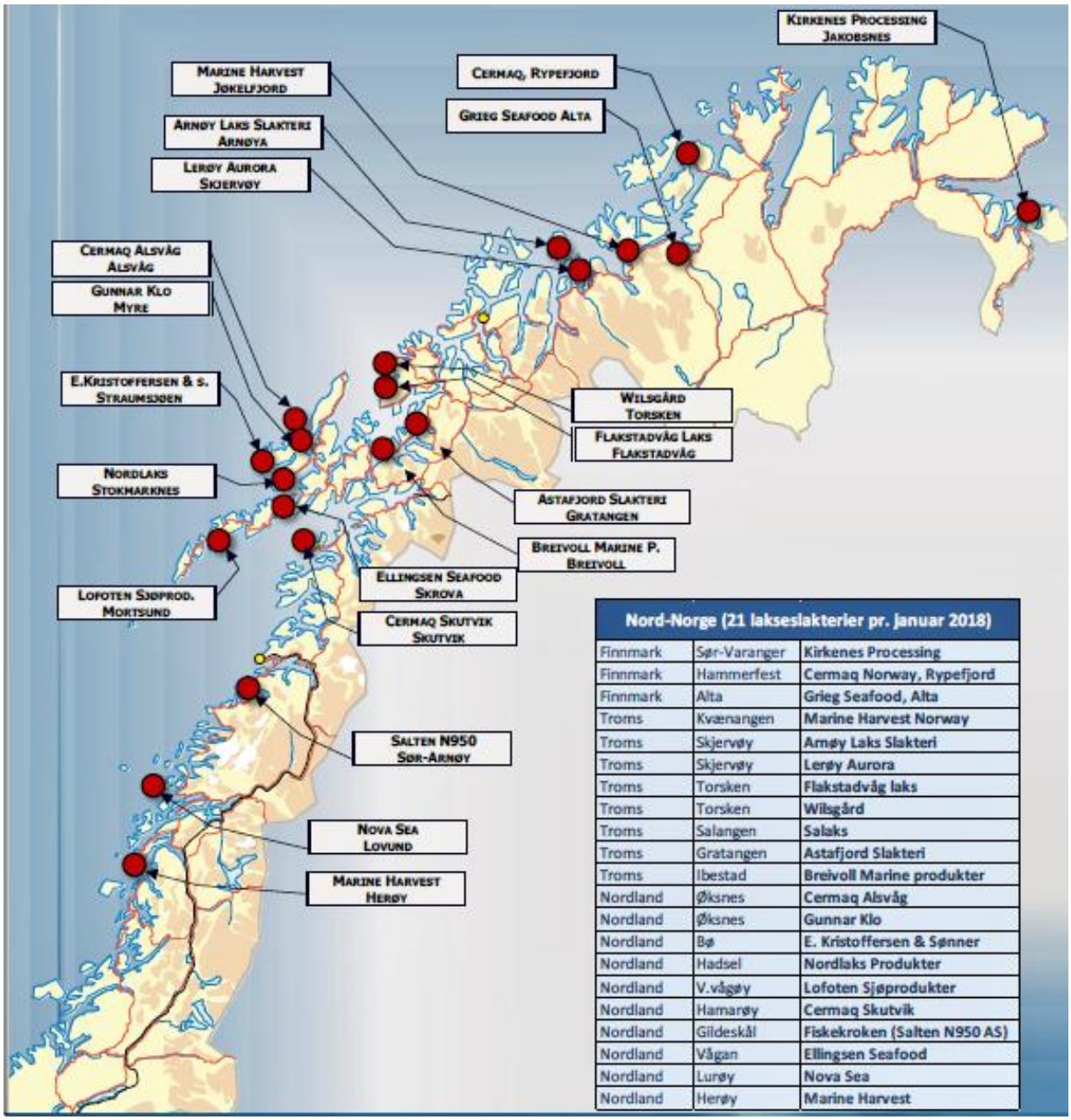
Fish farming is a part of aquaculture and deals with artificial fertilization and farming of fish in captivity. The cultivation itself may apply to the entire life cycle of the fish or only specific parts. Through farming, fish protein is processed into a high-value food source. Fish farming has high value creation both through economic gain, but also as a cheap source of protein for an ever-increasing population. In Norway, the largest share of fish farming is in salmon and trout and is the primary focus of the task.

Figure 3:Closed-containment salmon farming in Norway [67].

Anadrome salmon fish (salmon, rainbow trout) means that spawning, hatching and further growth until emigration stage takes place in freshwater (smoltification). After smoltification, the fish will migrate into the sea (salt water), and then at a later stage return to fresh water to spawn. Smoltification means that the fish adapts to a life in saline and develops the function to separate salts. A fish that does not complete this stage will not be able to survive in saline. The time usage of the stage depends on several factors. Fish species, food supply, temperatures for surroundings, lighting conditions, growth rates are all critical for the length of smoltification. In nature under normal conditions, this stage can take from 1 to 4 years, while during farming the process can be manipulated by regulating the factors to optimal conditions [2].

2.3.1 Locations of salmon slaughter in Northern Norway

In northern Norway per. February 2018, there are 21 salmon slaughterhouses. The location and the name of companies are illustrated in figure 4 [39]. By the figure one can observe that the slaughterhouses are located widely apart from each other because of the geographical area and production criteria's. As follows the materials and products in most cases must be transported over large distances.



Nord-Norge (21 lakseslakterier pr. januar 2018)		
Finnmark	Sør-Varanger	Kirkenes Processing
Finnmark	Hammerfest	Cermaq Norway, Rypefjord
Finnmark	Alta	Grieg Seafood, Alta
Troms	Kvænangen	Marine Harvest Norway
Troms	Skjervøy	Arnøy Laks Slakteri
Troms	Skjervøy	Lerøy Aurora
Troms	Torsken	Flakstadvåg laks
Troms	Torsken	Wilsgård
Troms	Salangen	Salaks
Troms	Gratangen	Astafjord Slakteri
Troms	Ibestad	Breivoll Marine produkter
Nordland	Øksnes	Cermaq Alsvåg
Nordland	Øksnes	Gunnar Klo
Nordland	Bø	E. Kristoffersen & Sønner
Nordland	Hadsel	Nordlaks Produkter
Nordland	V.vågøy	Lofoten Sjøprodukter
Nordland	Hamarøy	Cermaq Skutvik
Nordland	Gildeskål	Fiskekroken (Salten N950 AS)
Nordland	Vågan	Ellingsen Seafood
Nordland	Lurøy	Nova Sea
Nordland	Herøy	Marine Harvest

Figure 4:Overview of the slaughterhouses in northern Norway [39].

2.3.2 Prognoses

Based on historical statistics from the Directorate of Fisheries, it is possible to get an indication of how the aquaculture production will evolve in the future, both nationally and in northern Norway. It is not considered unrealistic that aquaculture production in Norway will be fivefold within a 20-30-year span. Figure 5 shows the increase in aquaculture production national and in northern Norway. The Blue Line represents Norway nationally, while the red illustrates the northern part of Norway. If the increase continues as illustrated, aquaculture as industry in northern Norway will expand significantly and production and sales volumes also.

Table of production development:

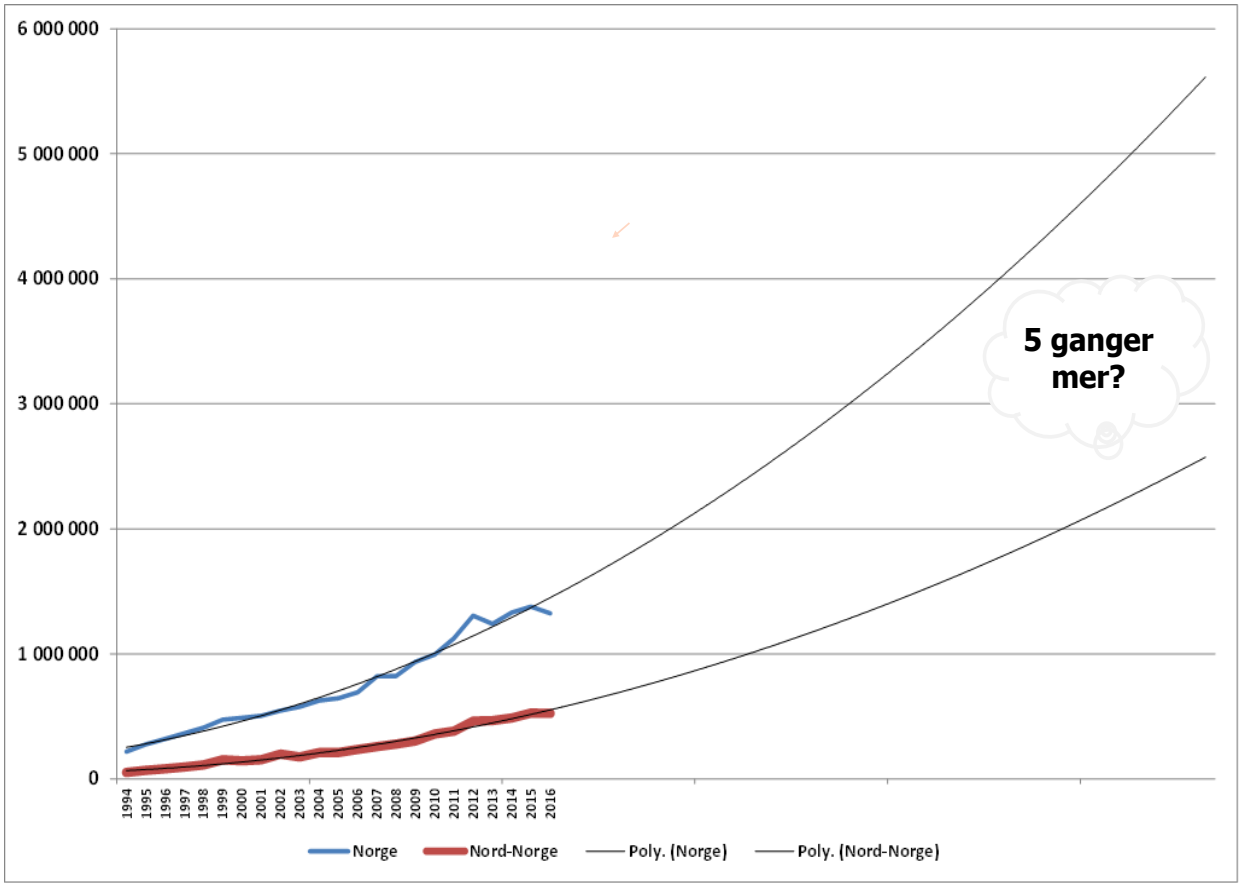


Figure 5:Prognosis for the industry's growth, both national, and for Northern Norway [39].

A significant increase in production volume will add positive effects to the region, along with some challenges. Increased growth can lead to more jobs both through aquaculture, but also for suppliers, maintenance, and construction companies.

In Norway there is an expansion in centralization of the population and increasing increment into larger districts and cities, meaning that northern Norway have various challenges with labour, growth, and development. Despite various political measurements such as reduced income tax, write-downs on student loans, and lower electricity fees, this is still a challenge. Increased value creation in the region will therefor make it more attractive to both work and live in it. By directing focus on challenges that the fishery industry in northern Norway faces, one will be able to increase the production volume that

will result in an increase in transportation of both products and raw materials. The infrastructure related to this may be a challenge and may require improvements and / or expansion [39] [40].

2.3.3 Fish life cycle

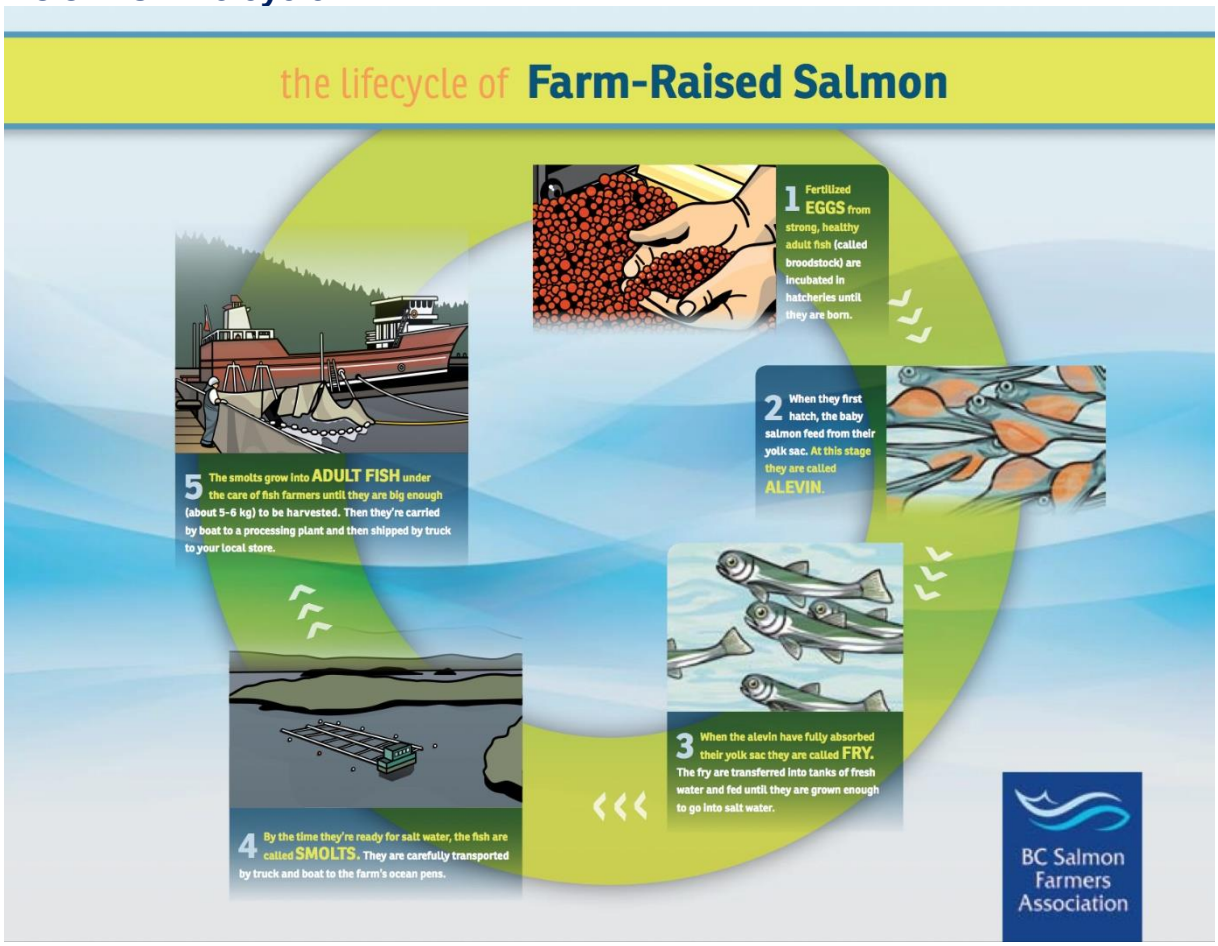


Figure 6:Lifecycle for farmed fish [8].

Eggs: Farm-raised salmon begins with insemination and hatching of eggs.

Alevin: Hatched baby salmon are referred to as *alevin*. During this stage the fish feed from their yolk sac.

Fry: When the alevin have consumed their yolk sac they evolved into *fry* and are transferred into water tanks (fresh water) until they are sufficiently developed and large enough to be transferred further to the sea (saline).

Smolt: When the fish is ready to be transported to salt water the fish is termed *smolt* and is transferred to farm site with the help of well boats.

Adults: On the farm site the smolt grows (18-22 months) to adult fish (5-6kg). When the fish has reached desired slaughter size, the fish is again transported with the help of well boats to slaughter and processing [8].

Breeding: The foundation for farmed fish starts at hatcheries and fingerlings facilities. Here all life stages of the fish take place, from fertilization until the fish is ready for transport to the sea. Development in roe is measured in day degrees (number of days multiplied with the mean water temperature).

Farmed salmon starts with eggs that are fertilized and incubated in hatchery until birth. The roe is developed in incubation tanks with freshwater and the ratio is about 5000 roe corns per litre fresh water. The eggs are then hatched (hatching takes about 60 days) into fish with a yolk sac, which ensures the fish's nutrition at this stage (four to six weeks). The fish then lives in fresh water until they are about 60 to 100 grams. During this time the fish are sorted and vaccinated. To ensure optimal living conditions and provide desired fish welfare, water quality is of critical importance throughout the entire process. In the last stage, the fish is adapted to life in ocean (saltwater), also known as smoltification.

Figure 7:Processing of roe [68].

Figure 8:Picture of salmon at alevin stage, and incubation tanks [68].

Transport: When the fish reaches the stage called smolt, it is transported to farming sites. The smolt is transported by means of well boats. The well boat has rooms (wells) where the fish is stored, and fresh seawater is constantly circulating in these wells. Counters on the boats make it possible to register the number of smolts, which again is needed to utilize the full capacity of the boats, calculate food ratio, and help distribution of smolt to cages. The technology around well boats is under constant progression, and greater and better utilization of capacity, more accurate counting systems and more applications for the boats are still evolving. In Norway, well boats are also used for treatment of parasites such as salmon lice.

Tank trucks are also used to transport live fish, but with rather less biomass, for example, transportation of fry between fingerlings facilities.

All operation of live fish to / from aquaculture facilities is regulated in "*Regulations on transport of aquaculture* ". Fish transport is further regulated in "*Regulations on further requirements for transportation, sales and import of aquaculture and products* ", as well as in" *Regulations on the protection of animals during transport and associated activities*".

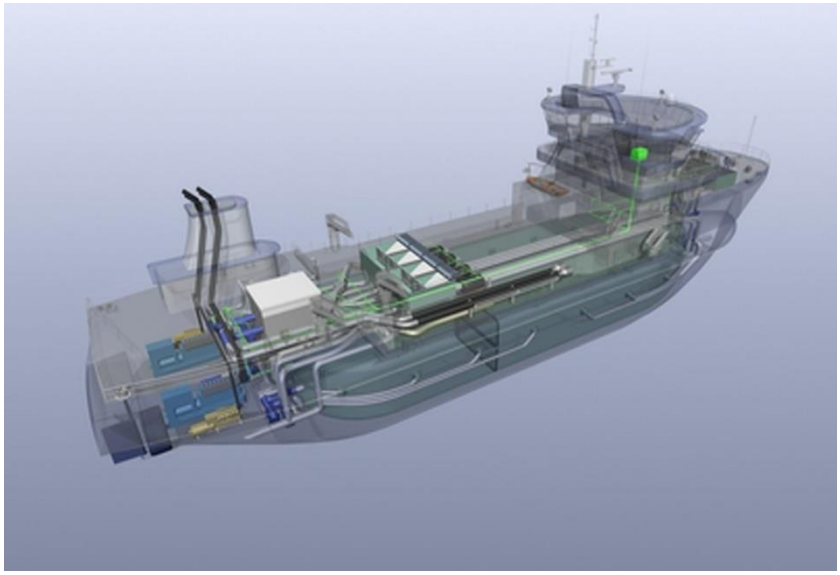


Figure 9:Illustration of a well boat [69].

The Norwegian Food Safety Authority must approve all transport of live aquaculture animals at least every five years. Requirements for approval are described in the «Transport Regulations (*Regulations on the transport of aquaculture animals*)". Examples of requirements are design with possibility of necessary washing, disinfection, inspection, installations, and all equipment must be tested and documents as safe, as well as meets the requirements for fish welfare. Internal control systems must be available to ensure compliance with the requirements for hygiene and general welfare. To obtain necessary approval for a well boat, one must apply to the FSA.

On-growing farm: The smolt is further transported to fish farms. In Norway, floating cages are the most common type of facility. The cage consists of three main elements, floating element on surface, net bag as the fish swims in, and a jumping fence, together with plumbs and moorings. Localization of cages is important to fulfil optimal living conditions for the fish, and there are high demands for location and operation of fish farming in the sea. Good water flow, proper depth, water quality, light and salt content and water temperature are all important factors. These factors, along with feeding, help determine the time (12 to 22 months) the fish uses to reach slaughter weight (4 to 6 kg). Being able to create optimal conditions for the fish throughout the life cycle is critical to achieving optimal quality of end-product [5][6][8].

Figure 10:Picture of a on-growing farm at sea in Norway[70].

Welfare: Proper and satisfactory fish welfare is important for the overall health of the fish, quality of product, and reputation and profitability for the company, as well as keeping mortality and thus waste as low as possible. Requirements regarding the welfare of captured fish are specified in the *Animal Welfare Act*. Regulations provide clear provisions on how processes and slaughter are to take place. The main responsibility for ensuring welfare of farmed fish and other aquatic animals lies with the Norwegian Food Safety Authority.

Figure 11:Aspects regarding fish welfare [71].

During farming, there are a large number of individuals, which in turn make it challenging to monitor the environment and the welfare of each individual. The aquaculture industry in Norway takes this challenge seriously and is working actively to improve knowledge of environmental regulations, procedures, various life stages of the fish, and overall tolerance limits. Being able to acquire new knowledge and develop technology to meet these challenges will give the industry a new boost and opportunities to improve operations and achieve higher results.

Bacterial and viral diseases, together with parasite infections are a big challenge, with so many individuals gathered in a limited area. Vaccination of all individuals is therefore necessary to prevent spread of infection and prevent other unwanted situations. This is an area that is being worked comprehensive with to improve today's solutions, and how to avoid side effects that adversely affect the welfare of the fish. New and improved knowledge of infections, spread, defence mechanisms and infectious agents are all factors to succeed. Localization of cages is particularly important for the welfare of the fish, and thorough analyses must be carried out before deciding location.

Waste management must also be considered when placing cages / farms. Large biomass can affect the locally carrying capacity negatively in terms of regional environmental effects relating to emissions of infectious agents, and through genetic side effects that follows escaped fish, or eutrophication. When placing cages, these elements must be thoroughly evaluated, as well as the distances between individual cages. Interdisciplinary knowledge of fish biology and environmental requirements together with technology development is necessary to ensure fish welfare, operation of facilities and full utilization of coastline and sea area, while avoiding the undesirable environmental effects.

Preventing that the fish escapes from facilities is another challenge for the industry. Procreation between species can lead to genetic alteration of wild populations and can also be a threat to the populations in the form of infection carrying to rivers and fjord systems. Alternatives here are production of sterile fish by means of pressure shock on eggs after fertilization, but here development is still needed to ensure the welfare and production aspects of commercial farming [4] [7] [17].

Slaughter and processing:

Figure 12: Picture of production facility [72].

The Aquaculture Regulations regulate the slaughter of fish in Norway, while NFSA is responsible for the supervision of the slaughterhouses, farms, animal health personnel, and electronic slaughter reports and drug delivery at farms. The Norwegian Food Safety Authority has a separate program (OK program) for mapping and monitoring residues of medicinal products and various foreign substances in fish from aquaculture facilities. The program aims and provides an overview of the health status of the fish. The slaughterhouses are required to comply with given regulations, which states that all slaughtering must take place following ethical and proper anaesthetic and killing methods. This means immediate death or loss of consciousness with the fish. The fish should not feel pain or other discomfort, even with long-acting anaesthetics. The slaughtering process also has very precise hygiene requirements.

In addition to hygiene regulations, fishery products have a separate regulatory framework that help ensure quality. Quality of fish and fishery regulations (*the fish quality regulations*) apply to the entire production chain (from catch to turnover) and helps ensure quality and market access abroad. Quality requirements apply to slaughter, handling, and storage of fish, as well as the use of raw materials used in production of various products such as salted fish, klippfish, and stockfish. Previous provisions of the *Fishery Regulations* are also included in the *Fish Quality Regulations*.

All fish that originates from fish farm facilities should be safe for the consumer. The fish should not contain substances that in quantities may be harmful to the end-customer. To prevent the fish from containing unwanted substances, preventive work is the most important measure. In some cases, however, situations arise where medication of fish is necessary. Regarding medication, several measures and processes are carried out to ensure that the fish do not possess any amounts of pharmaceuticals that exceed the limit value when reaching slaughter stage. This responsibility lies with the breeders, slaughterhouses and fish health personnel who are operational during processing / handling. No quality differences have been found whether the fish were slaughtered on land or in a vessel at sea. NFSA also focuses on the consumer having the necessary information regarding the product as well as being properly marketed within the industry.

In all food production, hazards and undesired incidents must be assessed adequately. In seafood production, it is extremely important to consider both contaminants and substances that are undesirable in the food. Companies are required to operate and possess an internal control system, as well as use HACCP (hazard analysis and critical control points) as a tool for assessing different scenarios and hazards. HACCP's purpose is to prevent, secure and eliminate risks associated with food safety and ensure that all risks are within an acceptable level.

HACCP's seven main principles are:

1. Identification of hazards.
2. Determine where necessary control is required.
3. Determining acceptable limits.
4. Conduct monitoring.
5. Carry out corrective measures at unacceptable limits.
6. Regular check that Points 1-5 work adequately.
7. Registration showing that points 1-6 are met.

All companies that receive or manufacture fish and seafood must apply, and then be approved by the Norwegian Food Safety Authority before they can start their activity or production. Fresh fish sold to consumers have all requirements for marking, including catch date, date of slaughter, fish species, and whether fish are farmed or caught in the wild.

Before slaughter, the fish is starved for a given time to achieve a slimmer fish, which in turn gives better quality to the final product. Before slaughter, the fish is anesthetized, this process is performed to avoid that the fish feels unnecessary pain or suffering, as well as avoiding unnecessary stress that may adversely affect the finished product. The anaesthetics are carried out through electrical power (current exposure leads to unconsciousness occurring, can be performed either in water or in dry surroundings), or a blow to the head (unconsciousness occurs through concussion and / or bleeding in the brain. The operation is executed with the use stroke machine in modern production). Previously, CO2 was also used for this purpose, but this method is no longer permitted. According to the Norwegian Food Safety Authority, electrical exposure or stroke to the head are the methods that best favours the fish. To achieve optimal welfare of the fish, one must have knowledge and insight on how methods and equipment are operated and the consequences that comes with. Methods and equipment must therefore be tested and documented before being used in any operations.

Figure 13: Picture of an electric stunner [74].

Development of methods and equipment must be carried out through the requirements of the *Animal Welfare Act*. The result of this is that all testing and / or use of new methods or equipment is prohibited unless one can document the necessary knowledge and the accompanying consequences of given method / equipment. NFSA is the organization that can give the necessary permission. The responsibility is awarded to both the seller and the user. Any sale of equipment that is not welfare-safe is forbidden.

- **Responsibility Supplier:** Method and equipment must be tested and documents prior to commercial use. Testing will ensure that method / equipment is of a professional standard, that undesirable consequences are revealed, ensure that the welfare of the fish is adequately met, and dissemination of user guide to ensure legal use.
- **Responsibility breeder / operator:** Responsible for the fish's health and general welfare, and that accompanying documentation covers the use of equipment and method. Use of equipment and method must be terminated and adjusted if there is any uncertainty about welfare conditions. The operator is therefore responsible that any operations connected the facility are carried out in accordance with the given legislation. Transport and slaughter has the same responsibility as a breeder when the fish under their custody.

Previously, the fish were slaughtered before it was transported to shore, but as the volumes increased and the industry expanded, new methods were introduced. Examples of routines in today's slaughter process are:

- Starving (to avoid too fat fish).
- Relocation to well boat.
- Relocation to waiting cage / or directly to slaughter.
- Anaesthetisation.
- Gutting / slaughter.
- Packing.

Some companies that operate the filleting process must mature the fish, as a result of the fish entering a specific stage (rigor mortis) that causes the fish to become death stiff. The maturation time means that it takes about 3 days before processing of the fish can take place. Recent time has found that processing of fish before entering this stage is positive, inter alia, to avoid unnecessary stress on the fish, stress that has been shown to have negative consequences for product quality.

Pre-rigor filleting (slaughter and filleting before rigor mortis occurs):

By avoiding the maturity time fish can reach the market 3 to 5 days earlier, which can give the following benefits:

- The customer can receive fresher fish.
- Consistency on fish / muscle is firmer.
- Product may be longer on the market before retraction.
- Best quality when freezing product is achieved by pre-rigor.
- Expense reduction in the form of smaller stockholdings / time usage.

Filleting with the use of this method is harder and more difficult to perform, as well as bone removal is more challenging. The fillet becomes thicker and has a darker colour. To succeed satisfactorily with the method, it is important to be able to obtain fish with lowest possible stress level. A parameter of stress level is the pH of the muscle in the fish, and this parameter lies around 7,5 on an unstressed individual. Fish with low stress levels can be stored on ice up to 24 hours before rigor mortis stage occurs.

Slaughter in modern times:

Slaughter in modern times has produced new and alternative methods, both through requests from customers, but also the industry's desire to practice good welfare and cater statutory requirements (Regulations on slaughterhouses and aquaculture production facilities). As mentioned earlier, there is a requirement for fish to be anesthetized before slaughter can occur. The fish are slaughtered by cutting the arteries, and as a result the fish dies from blood loss. Fish handled while alive can cause increased stress, so for productions reasons, in addition to welfare reasons, it is important to carry out all processes gently and efficiently.

Through observations one can determine whether the fish is unconscious or not. Examples of awareness are as follows:

- Spontaneous movements.
- Response through touches or stimulation.
- Presence through reflexes (gill movement, eye scrolling).
- Displays swimming movements (coordinated).
- Turns when placed on back in water.

Adequate competence regarding fish welfare in day-to-day operations is a requirement.

Slaughter at sea:

Figure 14: Slaughter at sea [74].

As mentioned earlier, the fish were initially killed at sea then transported to land. This method has several positive benefits and is also used in recent times.

Advantages of slaughter directly at fish farms facility are:

- Closed transport provides better contamination hygiene.
- Transport mortality is eliminated.
- Fish welfare is increased (no stress influences during transport).
- Transport volume to slaughter / processing facility can be increased.
- Cost reduction regarding fish fodder (no food under transport).
- Fish is delivered refrigerated.
- Capacity for slaughterhouses can be increased by eliminating cooling for live fish and bleeding tanks.

Checklist for welfare of slaughterhouses:

Examples of checkpoints that can be used as part of an internal control at the slaughterhouse, thus ensuring the necessary fish welfare, are as follows:

- **Waiting cage:** Conditions should not be of lower quality than under normal farming operation. Apart of absence of lining, both water quality and density with individuals must be of the same quality / standard.
    - ✓ Do the fish swim normal / calm?
    - ✓ Do all requirements comply with legislation within practicing fish farming?

- **Slaughter cage:** When slaughter is prepared, the waiting cage converts over to so-called slaughter cage. At high water temperatures, oxygen saturation should be checked and documented. Limit for required oxygen saturation is at least 70-80%.
    - ✓ Is oxygen saturation equipment easily accessible?
    - ✓ Is equipment for oxygen supply operatively?
    - ✓ Are criteria for implementing oxygen supply done / ready?

After slaughter, the fish is packed (usually in Styrofoam boxes with ice) for further transport. Companies have different methods depending on product and delivery method. The fish are then transported to intermediate storage and / or directly for resale before end-product eventually ends with the consumer. The supply chain can therefore have some differences depending on applicable product [18] [19] [20] [21] [22] [23] [24] [25] [26].

2.4 Technology

Working life, production and general everyday life are becoming increasingly automated. The fishing industry and fish farming is no different. Automation of various processes can help to ensure a safer and efficient industry, including the safety of personnel, emissions, and problems regarding salmon lice. Problems with salmon lice are many and are accompanied with high costs for breeders. Current methods are not optimal, and with the use of alternative methods, one must always consider factors such as efficiency, welfare of the fish, and not at least the environment [44].

Seafood Norway is an example of an organization that covers all aspects of the value chain in the Norwegian seafood industry, with 12,500 members spread over 550 companies in the fishing industry, aquaculture, pre-production, forage production, technology, and service. The Director of Aquaculture in Seafood Norway has stated: "*There are already a number of automated solutions, but I am convinced that we can improve in all stages of production. We want to fivefold salmon production towards 2050, which means we must automate and streamline all aspects of production*. «With an industry in such a big growth, efficient and technological solutions in the form of automation of processes will be of great importance [45] [46].

Automation of various processes may help secure workers on fish farms. Work in aquaculture involves different risks that follows distinctive tasks and processes. Various risks may be falling, risks accompanying with chemical treatment, and drowning. Norwegian climate together with the environment around various work tasks make certain risks difficult to avoid with today's production.

Future increase in production will lead to location of fish farms further and further out at sea. Scientist Ingunn Marie Holmen at SINTEF (Norwegian research group) has stated that such relocation will lead to more dangers accompanying with the work. More powerful wind forces combined with bigger waves will expose facilities to even more stresses, that again can lead to escape of fish or unwanted events that may expose workers to risk, especially during winter conditions. Inspections at facilities are required daily, and in case of bad weather, hard climate or with long distances out at sea, manual inspection can be both demanding and challenging.

Inspection and repairs under water are mostly performed by divers or Remote Operated Vehicles (ROV). ROV is a designation of a submarine that is unmanned and manually remote controlled. If facilities are moved far out at sea, this will lead to more challenging surface conditions that will make operator jobs more difficult. An exchange of ROV with Autonomous Underwater Vehicles (AUV) will be a major improvement for both operational efficiency and safety. AUV will be able to secure, streamline and reduce the manual workload of facilities. Manual operations are still a big part of aquaculture in Norway and automation can help to supply the industry with safer and more efficient working methods [47].

Figure 15: Image of a cage at a fish farm facility that is covered with ice during winter [75].

Salmon lice is as mentioned, a major challenge for the industry. With so many individuals gathered in one area it may be difficult to observe and record fish that are exposed to the parasite. Clarity and various particles in the water make observations demanding. Constant motion, reflections, along with the salmon's bright surface, contributes to make such observations even more difficult. Cameras and supporting programs that is used for this purpose must have the capacity to handle fish that change position between themselves and at high speed.

Robots (drones) can make this process significantly more efficient and reduce manual labour. Robotic vision revolves around robots understanding situations and interact with the environment with the help of vision. Mechanical robots must be integrated with computers in order to process, analyse and retrieve images and data. Such a system will be able to see changes in the fish's behaviour through movement and breathing patterns. Changes in breathing and movement patterns may be indications of stressed fish. Stressed fish has as mentioned a greater chance to die during treatment, for example, under medication.

Robotic vision can also contribute to other important observations at breeders. Measurement of quantities of salmons in cages can help with optimization of feeding, while registration of any holes in at facilities can prevent unwanted escapes. The use of robotics and accompanying vision technology can supply the industry with autonomous drones that can make such observations, and with significantly greater accuracy than a human. This will lead to a more efficient and profitable industry, while the welfare of the fish also will be improved [48].

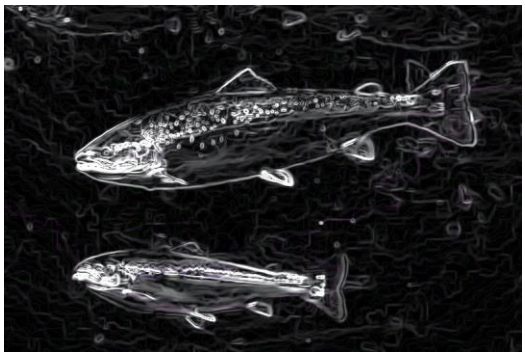


Figure 16: Illustration of the use of robotic vision to check the conditions of the fish [76].

Slaughter at on-growing farms is an alternative to slaughtering at traditional slaughterhouses. The use of special made slaughter boats in one method that is used. As mentioned earlier, transport and handling of living fish can cause unwanted stress, which in turn may adversely affect the product. With the use of slaughter boats, spread of salmon lice and other diseases will be reduced since one avoid the use of pumping systems when unloading, and eliminate the use of waiting cages.

Traditional well boats, together with the industry has evolved to become even greater. In order to transport the fish alive to slaughterhouses, the well boats must constantly contain large quantities of seawater. A normal tank in a well boat contains from 15 to 18% fish, while the remaining volume consists of seawater. When slaughtered at on-growing farms, a tank may alternatively be filled with 70% fish and only 30% seawater. As a result, a boat can be up to 60% cheaper while maintaining the same transport capacity.

With slaughter boats, the fish is moved from a cage to a sorting board on the boat with the use of a vacuum pump. The sorting tray is equipped with holes in different sizes, which allows the fish to be sorted by size. After the sorting tray, the salmon meets a counter-current in the water. The counter-current causes the salmon to instinctively swim against the current. The fish then reaches a sluice that triggers the anaesthesia procedure. Inside the sluice the fish is given a blow to the head, which results in unconsciousness, before a knife intersects the main artery between the gills. The fish is then transported into a tank with water temperature at approximately 0,5 degrees Celsius. By killing the fish without affecting its stress level, one avoids rigor mortis in the fish.

Figure 17: Salmon fish swimming counter-current against the anaesthesia process [73].

When the boat reaches the slaughter and processing facility, unloading can be carried out automatically. A signal cable is connected to the boat and unloading can be carried out from the control room in a boat, which in turn eliminates the need for operation at the dock office. The vacuum pump that is located at the bottom of the tank is used to transport the fish over to conveyors, which afterwards transport the fish further to production. The control room at the boat can supervise the transport of the fish with the use of cameras, while simultaneously cameras inside the slaughterhouse counts and register the number of fish delivered. Maintaining necessary cleaning and hygiene standard at slaughter boats is time-consuming and challenging, but in continuous development for reducing work hours, finding more environmentally cleansing products, and detecting of possible dead zones [49].

Alternative solutions for on-growing farming

Access to sufficient sea area is a potential limitation for expansion and development of aquaculture. Sea farms are a potential solution to develop a sustainable aquaculture industry, while using sea areas that previously was not exploited. Utilization of these areas will be necessary for the industry to grow and develop, while maintaining sustainable framework within the environment and welfare of the fish. With moving the position of on- growing farms further out at sea one will experience waters with greater depth and with other current conditions that will provide good conditions for production, environmental safety, and fish welfare.

Figure 18:Picture of a sea farm at sea that is towed by tugs. [77]

A dynamic version of a sea farm will also have the advantage that it can be moved between different geographic areas, depending on factors such as climate, season, or wind conditions. The sea farm will hold position without traditional mooring, but instead use dynamic positioning along with propulsion systems to maintain given position. Positioning of on-growing farms further into the sea can also reduce the risk of salmon lice. The sea farms are designed / constructed to protect the fish from unwanted factors such as strong winds, waves, and ocean currents [50].

Ocean Farm 1: is the world's largest floating fish farm. The plant is developed in Norway and built in China. Ocean Farm 1 had an investment cost of approximately NOK 690 million, with a height of 68 meters, a diameter of 110 meters, and a volume of 250,000 cubic meters. The fish farm is equipped with new digital technology that, together with harvesting of big data, will be able to improve the process considerably. Enhanced camera monitoring, sensor development, automation, navigation equipment, power management, along with new decision support through 3D visualization and real-time analysis will give production a new boost.

Figure 19: Hua Hai Long transporting the floating fish farm, Ocean Farm1 [78].

With extra consideration on the environment and fish welfare, Ocean Farming, along with several actors (SINTEF Ocean, Marine Research Institute, Kongsberg Maritime), will analyse and optimize management of aquaculture facilities. Data information from the environment, feeding, and the fish will provide increased knowledge and understanding, and be the basis for preparation of mathematical models that can help improve the industry. First fish at the plant were registered in Norway in September 2017 [52].

Ocean Farming, a company in the SalMar Group, has as goal of Ocean Farm 1 to be used for testing, learning, research, and development. The research part will have a special focus on fish welfare and biological conditions, with a view to reducing the pressure on the environment, finding solutions to the challenges with lack of coast area (fish farming further out at sea), and improving the overall well-being of the fish [53].

2.4.1 Projects in conjunction to fish farming

Stingray: Stingray technology can help solve the lice issues in fish farming. This technology makes it possible to kill the parasites quickly, efficiently, and without harming the host. A buoy is attached to a wire, which is stretched over fish cage. On the underside of the buoy there is a node with corresponding Stingray technology mounted. The node follows the fish up / down the water column of 30 meters. 3 camera sets with high-tech machine vision, along with an advanced laser, will detect the salmon lice on the fish / host. Light from above and below that is adapted to the exterior of the fish helps the node to observe the parasite. The node software analyses pictures taken by the camera sets and identifies any parasites before the laser shoots and kills the lice.

The program is designed for continuous machine learning, as follows the program evolves to become increasingly intelligent, and with multiple applications such as measurement of biomass and lice counting / registration. The advanced technology allows the node to distinguish between lice and natural dots in the skin of the fish down to 2 - 3 millimetres. The laser is directed using x, y, and z-axes. The laser light kills the lice in the wat that it implodes, burns up, or causes fatal damage to the membrane, all depending on the power and the length of the laser flash.

The nodes are connected to the internet and can be followed and controlled live in a separate control room. One of the cameras on the node is designed for documentation, and the images can be retrieved to the control and analysed together with other data streams. Accompanying software can be upgraded directly from the control room, in the way the nodes can be improved without having to be taken up of fish cages.

Lice counting that is performed manually are not optimal for the welfare of for the fish. Handling can cause the fish stress, which in turn may impair the quality of the product. Automation of lice counting through camera technology will not affect the fish welfare, while the counting will be more efficient and accurate. An improved biomass measurement will provide more accurate data and information that can confirm or notify breeder about feeding and growth conditions.

Stingray technology is currently expensive, but the cost for each killed louse goes down, while systems and knowledge are increased and improved. The potential around Stingray is large and is expected and have multiple functions in the future. Fish welfare is a significant advantage, since the node is operating in the fish cage, the parasite is removed from the host without stressing or damaging it. Sea lice issue costs aquaculture industry over 10 billion a year, so effective solutions will be necessary for the industry to grow and be sustainable [55].

Figure 20:Ready-mounted node ready for shipment. [54]

Plankton technology: Norwegian aquaculture industry aims to quintuple up to the year 2050. A challenge with so significant expansion is fodder supply for farmed fish. A possibility to ensure sustainable fodder supply to the industry is the production of microalgae. Microalgae contains a high content of fat, which is an essential ingredient in

fish fodder. Opportunities in compounds with plankton and algae can in such a way be a solution for this challenge.

The structure of the Norwegian Centre for Plankton Technology is a research centre run by SINTEF and NTNU in Norway and works to find functional and effective solutions for harvesting, processing, and production. Systems for cultivating seaweeds are being tested with the purpose of ending as production facilities in the sea. Tare plants are to be placed in conjunction with fish farms, in that way the tare can live from waste materials originating from fish farming. Senior researcher Jorunn Skjermo at SINTEF has stated that a large portions of fish fodder produced on land do not possess the optimal content of fatty acids that are beneficial to the fish. A larger proportion of algae in the fish fodder will improve the nutritional content, while the fish feed on natural and healthy food [56].

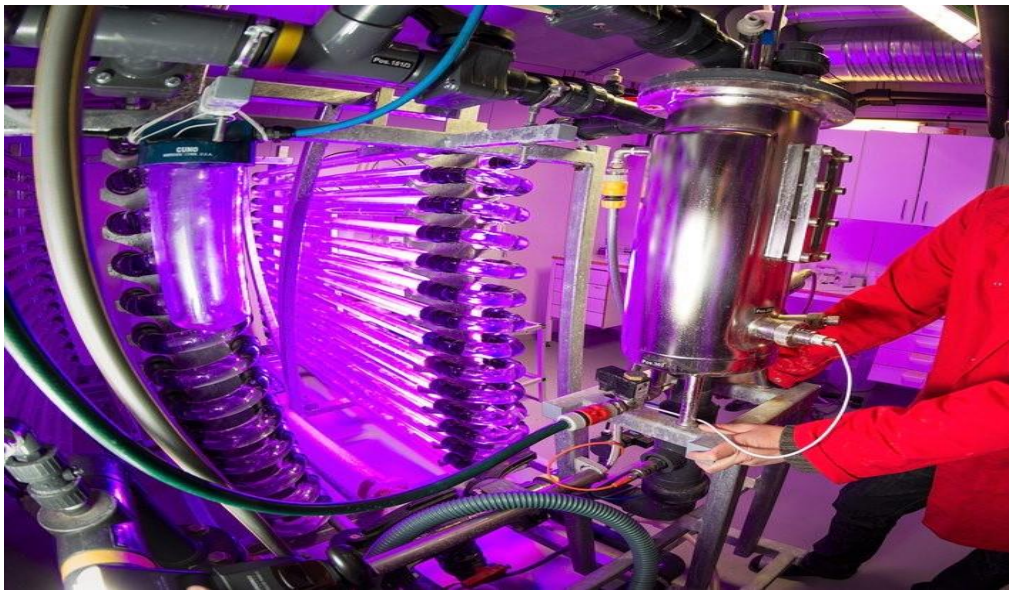


Figure 21: Micro algae exposed to different types of light to determine optimal growth [79].

2.5 Current technologies based on customer-focused service

Current technologies used for customer-focused service purposes largely include tracking and general description of product, such as weight, quantity, temperature, and price information.

2.5.1 Barcode

Barcode is a method (optical machine-readable representation of data) to code information through a visual pattern that can be read by software and hardware. Black and white elements represent different text characters and by changing the sequence of elements one will also change the information within the barcode. Barcodes can be read by scanners that registers alternating black and white elements that follows a given algorithm, which encodes the text / information. Information is transmitted from the scanner to the computer, in the same way as with a keyboard. Information regarding the given object is stored in a database, and with the help of software and hardware, you can easily and efficient find desired information. The database may contain information such as price, weight, history, quantities, and the like. Barcodes are used primarily for identifying and / or tracking an object.

There are a number of different types of barcodes on the market. To select the correct type of barcode, there are several factors that should be considered:

- Quantity and type of information, which character set must be supported.
- Desired barcode size / space on product packaging.
- Purpose and limitations.
- Price.
- Sender and receiver.
- What materials should the barcode be printed on.

Barcodes can be manufactured in any desirable size, down to 1/8-inch square (2D). Smaller barcode will have the advantage that it does not interfere with product packaging or other marking on the item. The disadvantage with small barcodes is that reading, and scanning becomes more challenging. It will require a high-resolution label printer to write and produce smaller labels.

2.5.1.1 One-Dimensional (1D) Barcode

One-dimensional barcode (1D) is the most common barcoding today. This type of barcoding is used for different purposes, where some models only can code numbers, while other models can tag any keyboard symbol. The barcode represents data with different spacing between parallel lines. The lines can be referred to as one-dimensional or linear, and the information in the code is organized horizontally from left to right. One-dimensional barcoding has several different types of codes and includes traditional barcodes like EAN and UPC. If the barcode is damaged in a way so it cannot be read by hardware (scanner), the digits below the code to use to identify the object in the database.

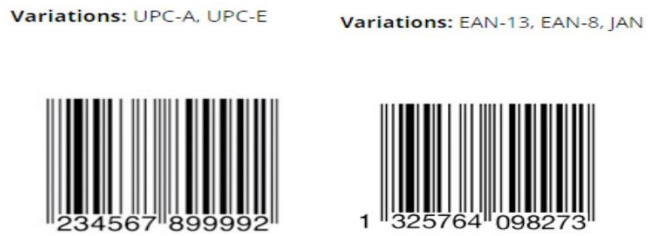


Figure 22:Illustraion of bar codes [80].

2.5.1.2 Two-Dimensional (2D) Barcode

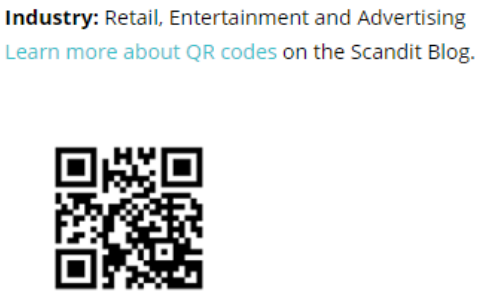


Figure 23: Example of QR code [81].

Two-dimensional barcoding (2D) is similar to the linear 1D bar coding but has the advantage that it may represent a larger amount of data per unit area. 2D-barcodes represent the data as two-dimensional symbols, making it more complex than the traditional 1D-encoding in the way that it organizes information both vertically and horizontally. This organization enables two-dimensional barcoding to take less space than the 1D barcode and contain significantly larger amounts of information / data. 2D barcodes can hold up to 2000 different characters, but the amount of information on the given barcode will affect the physical size of the label. 2D coding also comes in several different types and includes PDf417 code types, and the known QR code.

1D barcodes can be read / scanned with a standard barcode scanner. This is not possible with 2D barcoding. To be able to read 2D barcodes one will need a so-called 2D Imager. A common barcode scanner reads the code by reflecting light and black horizontal lines, while 2D Imager takes a picture of the line and analyses and decodes the information. Image processing is necessary since data is organized vertically and horizontally relative to 1D where it is only represented horizontally [27] [28].

2.5.2 Radio frequency identification

Radio Frequency Identification (RFID) is a common term used for wireless transmission of identification. Information and data can be read and written by small devices (RFID chips). The module / chip is built up of antennas and an integrated circuit that allows to receive and respond to frequency signals. The frequencies of the signals range from 125 kHz to 2.45 GHz, as follows it has many different frequency ranges. The main principle is the same regardless of used frequency. Desired information is stored in the module and can be written to / read of by writing and reading stations. All modules have a fixed-code (for identification) that the user cannot change. Desired information is written and read in the memory area of the circuit.

All transmission of information occurs inductively, which means that the module is not built with its own power supply, in that way data / information transfer can only occur when the module / chip is within an inductive field (were read / write hardware is set up). As follows, hardware that sends and reads data needs a power source for the system to be operational. An advantage of RFID is that the chips are recyclable.

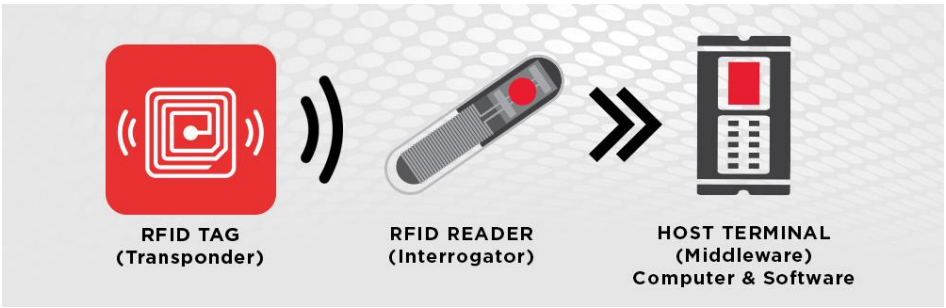


Figure 24:Illustration om RFID technology [82].

The chip can either be attached to the desired object or it can be built in under fabrication. RFID has extensive applications and is used in tracking systems, security, access control systems, human and animal identification and logistics, to name a few. RFID can improve the efficiency in logistics and product processing through automated processes, and enhanced notification systems. Improved logistics, inventory and tracking control could positively affect the supply chain.

Examples of improvements through RFID are:

- Placement of "Geofencer's" along the routs allows observation of cargo during transportation and can notify the receiver in advance of delivery.
- Checking and registering the temperature during transport to ensure that the cargo have kept the desired temperature (insurance for the receiver), and at the same time the carrier may be alerted if the temperature reaches unwanted value, thus making it possible to make a correction before an undesirable event occurs.
- Products can be automatically registered upon arrival at terminal and can in that way save unnecessary time usage (manual scanning).

RFID is a known technology and, as mentioned, has many and different usages. Although technology can help the supply chain be more efficient, it will also require investments in the organization's infrastructure. Therefore, it is necessary to assess if the technology is necessary for the given function [29] [30] [31].

2.6 Digital possibilities

In today's society, technology is developing each day, and the digital possibilities are becoming almost endless. There are many possibilities for companies / industries to choose from in order to store and process information and data within their organization.

2.6.1 Big Data analytics

Big Data analysis is about creating new insight through collecting and processing information / data from different data sources (internal as well as external). Technology, like big data, enables quick and accurate analysis of large, complex amounts of data. Such analyses and accompanying results can provide organizations with new insight as a basis for decision support.

Big Data can be described with ***4 V's***, and are as follows:

- **Volume**: Quantity of data available. The amount of available data increases continuously, and IBM estimate that by 2020, 2.3 trillion gigabytes will be generated each day.
- **Variety**: Variation of data available (structured *vs* unstructured). Various information is available from a variety of sources. Increasingly connection between data sources and the Internet expands the access and variety of data.
- **Veracity**: Reliability of gathered data. All collected information has some uncertainty regarding it, and therefore it is important to know the quality and veracity of data before analysing it.

- **Velocity**: Speed of collected data (batch vs stream). Data comes with increasing speed and volume, and it is advantageous to be able to collect data most approximate real time.

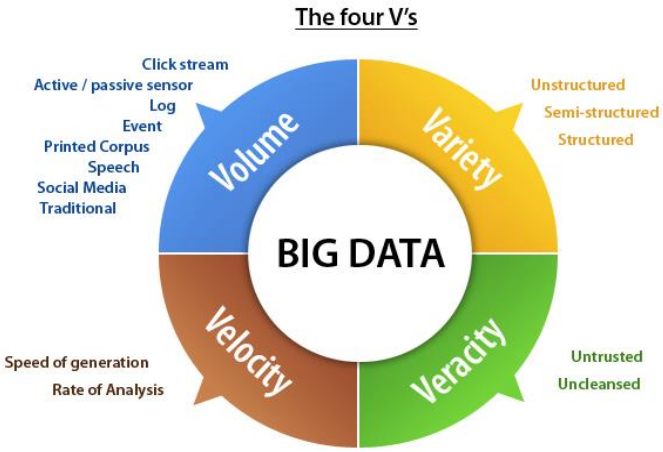


Figure 25: The 4 V's of Big Data [83].

Many organizations today are sitting on large amounts of data regarding products, transactions, and customer information, together with other internal and external data information. Big data analysis can be of help to these organizations in order to organize and analyse this information, which may explain various events and provide insight the organization previously did not possess. Many companies have in recent times realized the potential of processing this information flow (Netflix, ext.).

Processing and analysis of data and information is not a new term and it stretches all the way back to 3000 years BC where Egypt and Mesopotamia performed logging of everything from commercial transactions, to material management in constructions of buildings. However, because of the huge amount of information and data circling the world today, it is of importance that organizations are able to store data and process it within a given time. Big data can be defined as the sum of large amounts of structured and unstructured data:

- **Structured data**: Transaction information, customer bases, financial systems, and the like.
- **Unstructured data**: Information that cannot be structured into tables, such as images and text.

Today's technology makes it possible to collect and store large amounts of data both quickly and cost-effectively. The information that results from analyses gives new insights and contexts that contribute greatly to any decision-making. The value of big data analysis comes from when an organization manages to use information flow to generate visualizations and presentations of complex analyses of relevant information.

Examples of using big data analysis:

- **Media**: Used for marketing and product development, information about what, when and how long consumer reads can be used to create a picture of the consumer's wishes. Examples are online and newspaper news.
- **Insurance**: Used to create models that can provide the basis for marketing, pricing, composition of the insurance portfolio, and the like. An example is sensors on the car that make it possible to analyse driving patterns.
- **Health**: Big data makes it possible to retrieve diagnoses based on symptoms instantly and efficiently. Can improve quality as well as speed of treatment.
- **Authorities**: Used for disease and crime fighting.

Examples of businesses that have taken advantage of the great benefits associated with the use of big data are Netflix, Facebook, Twitter, Google, Yahoo, and IBM. All these companies have in common that they reach out to millions of users / consumers and their information, and therefore are in need to be able to store their habits / behaviour, and the accompanying information. Several Norwegian companies that compete in a globalized market have also become aware of these opportunities that Big data gives (example Telenor). Being able to gain an advantage in the marked or at least keep up with other competitors' technology and innovation will be of great advantage. Big data can also help organizations understand what resources that are needed both within focus and improvement areas. Understanding and utilization of information streams can provide increased insight into the customers' wishes and behaviour and can result in more cost effective and targeted marketing. Big data can help to make important strategic decisions faster and more accurately.

Internet of things (IoT) is a key term when discussing Big data, and it comes with large amounts of structured and unstructured information. In modern time, a large part of everyday life is connected to the Internet, and huge amounts of data are exchanged through mobile phones, TV's, computers, cars, and many other application software. Analyses of these examples can tell one about everything from purchase and web habits, to driving patterns and favoured TV shows.

Big data analysis is often perceived as only analysis of unstructured data, as it alone generates huge amounts of information each day. Although, the majority of information is unstructured, big data is a about how to put together information from internal sources along with structured and unstructured data, and how to create new insights through such analysis.

A challenge with big data analysis is that collected information can result in sensitive user information. Although data information is not perceived as sensitive, total aggregation can give a sensitive result. Re-identification is another risk. An individual who is initially anonymous can be identified through analysed data sets. Proper use for privacy is therefore highly necessary [32][33].

2.6.2 Internet of Things

The expansion of internet and broadband access, along with reduced technology costs, has provided an increasing number of products with built-in sensors and Wi-Fi function / connection. This expansion has led to Internet of Things (IoT) being a highly relevant topic in data and information collection. Analysts firm Gartner has stated that by 2020, the number of connected devices will exceed 26 billion. As mentioned earlier, there are large amounts of information and data that comes with IoT that can be used for managing processes, increased understanding and verification, and give insights through these analyses.

Simply put, the concept is a connection of any device with an on / off switch, and also has the possibility to internet connection, such as mobile phones, coffee machines, portable devices, even a person with heart monitor implants. The concept also covers components in machines such as drills on oil rigs or engine components. IoT is a massive network that includes interconnections with objects and people interchangeably.

With IoT, there are almost endless possibilities for different connections to occur. With these connections follows great opportunities, and some challenges. Security is one of these challenges, and

with many devices connected to the same network it will be vitally important to take necessary security measures. Privacy and data sharing must always be considered and protected adequately.

IoT technology is used in several industries, such as:

- Building management.
- Health services.
- Transport.
- Energy.
- Farming.
- Production.

[34] [35]

2.6.3 Cloud computing

Cloud computing provides data services such as storage, databases, networks, analyses, servers, and software. Companies that deliver such services are often referred to as cloud providers, and usually charge customers based on usage, equivalent to water and power services.

Operations that can be performed using cloud computing:

- Construct and develop applications and services.
- Backup, save and retrieve data.
- Host blogs, websites, and the like.
- Stream sound and image.
- Deliver software.
- Analyse data.

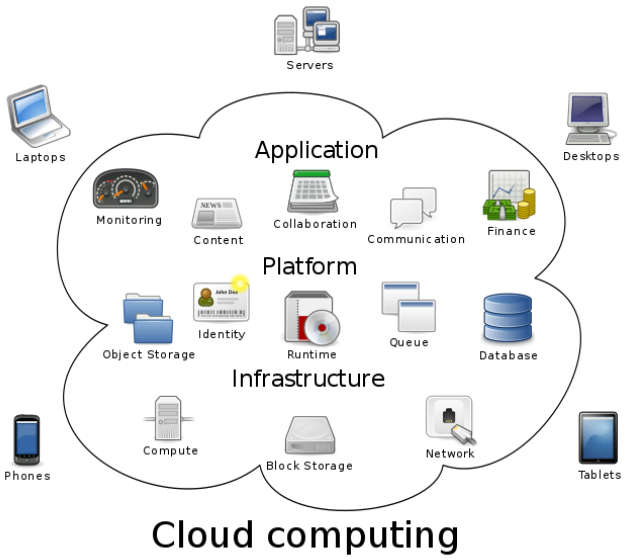


Figure 26:Cloud computing with assosiated connections [84].

Cloud computing differs from how people traditionally thinks about IT resources. There are several advantages off using Cloud computing:

- **Cost**: Expenses for purchases of machine and software are eliminated. Costs are reduced as well as less power consumption (round-the-clock electricity for power and cooling), and IT expertise regarding infrastructure and maintenance.
- **Speed**: Cloud computing services are provided self service and on demand. This results that significant data resources can be delivered at a very fast tempo, and with only a few keystrokes. Such services give businesses greater flexibility and reduce pressure on capacity planning.
- **Global scale**: Advantage of cloud computing services is that one has the ability to scale elastic. Only desired / right amount of IT resources will be delivered. For example, increasing or decreasing in storage or data power when required, and from the correct geographical location.

- **Productivity**: Data centre requires hardware setup, software upload, and other time-consuming IT tasks. Cloud computing eliminates this work and hence the time spent, so organizations rather can focus on core activities instead.
- **Performance**: Cloud computing is often run on a worldwide network of secure data centres, which are regularly upgraded and maintained. The advantage over a single enterprise data centre is reduced network latency and greater economies of scale.
- **Reliability**: Reliability for data storage, disaster recovery, and business continuity can be performed easier and less costly since data can be mirrored at multiple redundant sites [36] [37].

2.6.4 Cyber-physical system

Cyber-Physical Systems (CPS) is an integration of several different processes (networks, physical operations, and calculations). Computers and networks are used as tools to control physical processes. The monitoring and controlling is often regulated with the help of feedback loops, which alerts the system state. Through integration between physical processes, networks and software, CPS provides design, modelling, and analysis techniques for the integrated wholeness.

CPS systems can help to improve and develop everything from emergency preparedness, traffic management, power production / delivery, to improved healthcare.

CPS is applicable in several technological terms, including:

- IoT.
- Smart cities.
- Smart Grid.
- Internet for industrial use.
- «Smart» solutions within manufacturing, hospitals, cars, etc.

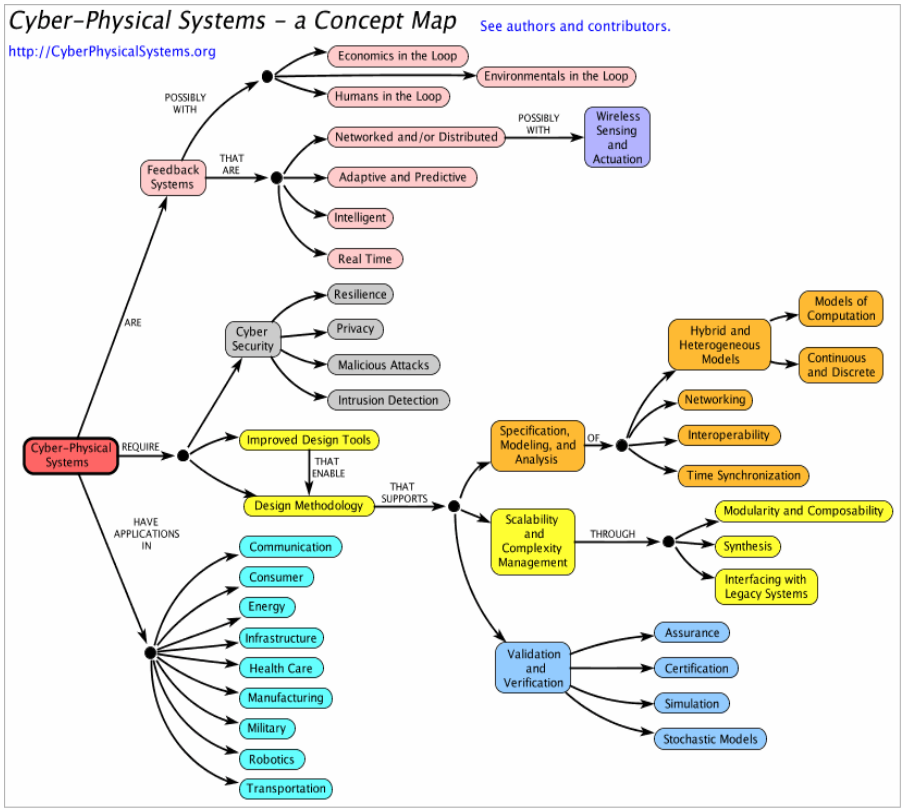


Figure 27: Example of the structure of a CPS system [43].

The potential of such systems is massive and not realized either socially or economically currently, and there are immense investments in technology development [42] [43].

3 Case study: Fish producer in northern Norway

3.1 Introduction

The background for carrying out a case study was to get a deeper insight into a supply chain at a fish producer in northern Norway. The literature review provides a general overview of production of farming / aquaculture in Norway but does not tell sufficiently enough about specific operations within the supply chain. A case study was therefore able to say something about a single entity, in this case a manufacturer. Chosen producer was of interest as it has activity in all parts of the supply chain, i.e. from smolt to finished salmon product. This case study will not reveal how all producers in northern Norway operates, but will give a picture of how a relevant supply chain functions. To acquire knowledge on how the supply chain operates in the daily was of great relevance when designing the solution to thesis. An up-to-date and functional solution must be able to be implemented in operation as it works today without major changes in existing infrastructure.

3.2 Delimitation and problem statement

The case study is delineated by looking at one relevant fish producer in northern Norway, with specific questions directed at information flow, communication, use of digital technologies, product tracking, and supplementary services. It facilitates the possibility of expanding the scope of the case study if new information during execution causes this to be necessary. Beyond that, the selected main points are to be focused on. Problem statement for the case study is; "How supply chain management is operated within a fish producer in northern Norway”

3.3 Method

In order to carry out the case study, a relevant company / producer was contacted by mail and telephone. After repeated dialogue, specific questions were designed to the selected company. The questions were designed to illustrate how the supply chain of the company responds to various challenges within daily operations. At the request of the company, the case was anonymized in this thesis.

3.4 Results

The company is today an integrated aquaculture company who performs activities in all parts of the value chain, from the production of fingerlings to finished salmon product. The company supplies several different salmon products (fillet, fresh / frozen, oil of residues, and more). The results have validity for thesis and are as follows:

3.4.1 Information Flow

Communication within the supply chain:

The company operates internally with a joined production- and deviation system. The systems operate as a basis for internal dissemination of production data and any deviations. Production meetings are also conducted to schedule day-to-day logistics for different operations (slaughter, smolt, and similar operations). Regular visits, seminars and deployment are also carried out within the value chain between different sections of the company. This is done to exchange experiences and knowledge between the different joints in a more traditional manner.

The communication degree with suppliers varies for the different joints of the supply chain. Necessary equipment is purchased in traditional manners, based on purchasing routines such as specifications and tenders. Suppliers who collaborate with the company in product development, or optimization and further development of equipment have a closer communication degree with the company than other suppliers. Examples of includes IT systems, feeding supply, equipment geared directly to farming, and competence development and coursing.

Communication and collaboration down the supply chain is based on product specifications from the customer. This includes certification schemes. Information exchange regarding the properties of product, along with product quality, takes place in the form of a CV. The CV follows the products together with quality data such as microbiology and other sampling. The company also cooperates with the customers (resale) about the brand itself, and the number of inputs on production conditions, such as environmental impact and feeding conditions, has increased.

Deviation management:

In case of deviation, it is especially important for proper and adequate communication down the supply chain, as well as registration of the given event. The product quality has specifications that the manufacturer must take in to consideration when producing the product. Deviations from these specifications may affect the applicability of the product with customers, and hence the profitability of the manufacturer directly. The consequence of delivering products outside specification is usually complaints and / or claims geared toward the manufacturer.

Any deviations in production, such as illness or increment give direct consequences for the established production plans. Deviations must therefore be registered so corrective measures can be taken for the next part of the chain.

Logistics deviations may in worst case result in a product not reaching the recipient (customer) at the right time. Such anomalies may be expensive, to the extent that one loses valuable time, time that may have negative consequences for the freshness and quality of product. Delays may also have consequences for the customer's further supply or production planning. Even with such logistical deviations, company from case study usually finds either alternative application / customer, or alternative transport to avoid excessive losses. With some transportation methods, such as airplanes, it may produce undesirable additional costs for the manufacturer. Deviations in the form of damage to goods during transport are treated as a complaint / claim by the manufacturer (only where the manufacturer is responsible for transport).

Manufacturer alerts down the supply chain for any errors with product, or if there are any failures during shipping. There are established procedures at the manufacturer for deviation handling, and it is regulated that, as examples, food should be traceable, and which duties that are required when providing an alert / notification. In case of deviation during transport, the carrier (transporter) notifies the manufacturer, who then must notify the customer. In cases where customer is responsible for transportation, notification goes directly to customer.

Product Information:

All production data follows the fish, from roe processing until slaughter. The manufacturer has full tracking of product with and a coordinated production system. There are also several statutory requirements that needs to be followed, such as, fishing certificates before fish is set out at sea, sampling results for smoltification, waybill, counting of individuals at fish farm (cage), and more. Normal commercial documents such as order confirmation, invoice, crate lists, and CV also follow the fish. Information that follows the CV with the fish is as follows:

Breeder:

- Company.
- Address, and other relevant information.

General:

- Species.
- Certification.
- Size at slaughter, number of fish and biomass in cages.

Slaughter:

- Slaughter date.
- Last day of lining.
- Temperature.
- Slaughterhouse.
- Density at start-up of fasting.

Fish farm:

- Location and permission no.
- Date.
- Transport vessels.
- Number of fish.
- Average Size.
- Biomass.

Smolt:

- Producers (company).
- Location and permission no.
- Tank / tub no.
- Generation.

- Hatching date.
- Type of smolt (0-year, 1-year-old, etc.).
- Time-period in water.
- Certification.

Vaccination:

- Type.
- Batch no.
- Time.

Feeding:

- Fish fodder (type).
- Amount.
- Fat and protein percentage.

Quality tests:

- Fat and colour samples.
- Methodology and results.
- Date.

CV, with other documents and production data (internally, and between roe producers and fish farms) are done on paper by using data files (production management system). Internally in the company, production management system follows the fish with all documentation all the way to slaughter. Customers receive documents on paper (PDF) and on data file (crate lists) for use in own trade and production management systems. Information from feeding-suppliers also comes on paper (invoice, product specifications, and the like). In this area there is room for improvement if the process could be automated by transferring data and information directly to the company's production management system, in that way making the process more efficient and reducing time usage and improving the quality and quantity of this input factor.

3.4.2 Communication

Internal:

The sales and marketing department, together with the quality department is responsible for dialogues with customers regarding quality, complaints, and so on. Complaints are handled internally by the Quality Department, and the Sales Department in common. The company does not sell products directly to the consumer / end user. The company only deals with B2B (business-to-business). Some customers purchase a private label from the company, so products are ready for direct deployment in the store.

External:

The manufacturer preferably retrieves feedback from B2B customers in the form of surveys, dialogues, and the like. A significant part of this dialogue is the collaboration between product and market development.

3.4.3 Digital technology

Handling / analysis:

The company collects, handles, and analyses large amounts of data from the production. There are no systems implemented in the company to handle or analyse such big data. All analysis and optimization occur in the traditional way in the sense of systems or operators generates reports that are subject to review and provide the basis for potential changes and optimization.

As mentioned, there is currently no automated compilation of production data from different systems (production data from farming / smolt and quality data). Even though the company has not prioritized systems that allow more automated handling of large amounts of data, the company finds such technology interesting. The challenge for the company is to construct a system that enables suppliers internally and externally to communicate and analyse data capture across systems.

Marketing:

The company does not market products directly to consumers, but to B2B customers. This marketing is based primarily on "old channels" like meeting customers, personal relationships, and history. Today, digital communication solutions like email, websites, social media are used, but these are about relationship marketing. The company has ambitions to move further down the value chain, closer to consumption eventually, but are not active on this part today.

3.4.4 Tracking:

Product Tracking:

Products tracking within the company is based on listings in the production management systems. It is only possible to track products at group level, therefore it is not possible to trace a single fish individually. Tracking information is based on fish group number, and vessel and cage number. Further down in the production chain, a location number or fish group number could be split into smaller groups based on delivery date from transport (batch), waiting number, production date, and lot number at slaughterhouse. The company can in such a way track the fish up and down in the supply chain (with full history). It is always the case that a lot number can be traced back to a fish group, as follows tracking is always taken care of.

Transport:

Different methods of transport are used for various tasks in the supply chain. Cars and trucks are the preferred transport method when transporting fertilized roe. The roe is delivered in Styrofoam boxes (chilled). Well boats are used when transporting fish to or from fish farms. Completed fish products are transported to customers with the use of cars, trucks, trains, airplanes, and boats. Tracking information, is as mentioned earlier, based on entries in the production management systems. When the fish arrives in boxes, trace information such as box number, pallet number, location and lot number is labelled physical to the box. This information is then used to track the fish back in the chain. To date, there are no automated systems for reporting of freight, time usage, or positioning after shipment is sent to customer. Registration within the company is done manually in production management systems when the fish is alive and during slaughter.

3.4.5 Services:

Currently the company has no services that complement its products (recipes or similar). It has been considered earlier to develop / automate a certain exchange of information with the customer, such as open some parts of the production management system. In order to achieve such an exchange of data, the company is dependent on an IT-supplier. This could help reduce time spent on dialogue with customers (phone, and similar). There is also being tested technology for logging and tracking of temperature during transport, to be able to document product durability in a better way. Such technology can be implemented in a label or box.

3.5 Analysis and discussion

The company has an extensive production and deviation system, which together with daily meetings encompasses the entire company's production. These systems cover the needs that accompany daily production and ensure product quality. Communication with suppliers varies from different joints, as it often does in a supply chain. The company has a closer link with selected suppliers, such as suppliers that work on product development and / or further development of equipment. Such cooperation is positive for both parties, as the company can specify their wishes better, and the supplier receives feedback on the equipment they deliver. Information related products follows all the way down to the supply chain in the form of CV. Such a CV contains all relevant information about the product and the method seems effective. Communication with customers regarding environmental and feeding conditions is increasing. Which in turn benefits the company as there is still a greater and greater focus on these things in the media and not least with the consumers.

The company's transactions are in the form of sales to B2B customers. By moving even further down the value chain to the consumer / end customer, the company will be able to gain an even greater customer base and have the opportunity for new communication that can provide even greater feedback on their products.

It follows large amounts of data and information sources with both production and from different customer bases. This information is handled and analysed in a traditional manner (not automated). Such information is of greatest value when it is "fresh," it would be desirable to process these data as fast as possible. An automated system will be able to analyse and provide feedback to production faster than current methods, while communicating with both customer and consumer (feedback from digital behaviour as example). Developing such a system may be demanding and may require collaboration with, for example, an IT supplier. The company's multiple digital communication technologies can be more widely used. With society's increasing use of social media, it is possible to exploit these channels to different forms of marketing (new products, product information, environmental issues, etc.).

Production management systems make it possible to track the fish at group level up and down the supply chain. With this, the company has complete control over fish tracking (with history). With the possibility to track the fish in such a group level one can see the conditions the fish has had during breeding (treatment, medication, feeding etc.). It is considered as little practical to make the production tracking more detailed than it is today, as it is sufficiently accurate, and this will only result

in increased time usage and cost of production. It is not operated with automated systems that can report events during shipping, time usage of transport, or positioning. A possible cooperation with the carrier will provide an increased customer experience in terms of better tracking of products. Here, of course, cost assessment must be evaluated, in cases where the customer is responsible for transportation, the company will not participate. Transport methods will also determine where and when different solutions are available.

The company does not provide any additional services to its products, instead, priority is given to traditional production. There can be great unused potential here. Quantifying the value of such services can often be difficult. At the same time, an increased customer experience will again provide added value for the entire supply chain in terms of increased value on the product itself. The company has assessed the exchange of information with customer, which shows that valuations are being considered in this area.

3.6 Conclusion

Fish farming industry in Norway has been developed over several years, which the production and related systems illustrates. Production technology is precise and comprehensive. The company has a well-functioning production, satisfactory communication, and practical cooperation within the company and with suppliers. Product data and information together with the tracking capabilities provide an accurate supply chain and corresponding product overview. Digital technology such as communication to / from consumer, and analysis tools are not optimized.

To gain insight on how the flow of information, notifications, tracking, communication, technology use, and the offer of supplementary services that are relevant to current industry was of great help. It is concluded that industry related to the aquaculture industry is large and extensive, but at the same time similar to other traditional production industries where production is still primarily prioritized. Utilizing of available technology may help the industry to provide new services and help secure a sustainable future.

4 Consumer

A consumer can be defined as a physical person who buys a specific service or item. Consumer purchases are in such a way distinguished from traditional transactions between businesses and institutions. The Consumer Buying Act legally defines a consumer as; *Consumer buyer is defined as "selling items to a consumer when the seller or seller's representative acts in business activity"*.

Consumer Protection Act together with the consumer laws exists to ensure that consumers have rights in the event of a purchase, in which the professional party (acting in business) can not deviate from. These rights are intended to protect the consumer (legally) against the other party's stronger negotiating position, hence preventing the private party from being exploited in any way.

Consumers are entitled to receive good and adequate information about the current service or product on the market, as well as accompanying rights. Such information is in that way promoting consumer power and helping consumer taking enlightened choices.

Buying behaviour among consumers is a complex topic. Needs and wishes can vary greatly, and it is desirable to have a Portfolio which covers the largest share of these desires. In order to properly assemble and develop the Portfolio, information about the consumer is of necessity. Knowledge regarding the customers and their needs along with general theory of buying behaviour helps companies understand and solve these tasks.

To be able to succeed in marketing of a service or a product, it will be necessary to know what stimulates and affects the consumer. This can be challenging since the consumer can vary by age, gender, ethnicity, culture, interests, etc. Therefore, to better understand how consumers are exposed to stimuli, which in turn is processed, it is designed a stimulus-response model named the black box. Process of stimuli is directly involved in influencing the customer's final-conclusion whether to buy or not to buy given service or product. With a simplified description, you can share the black box in two, buyer characteristics, and buyer decision process.

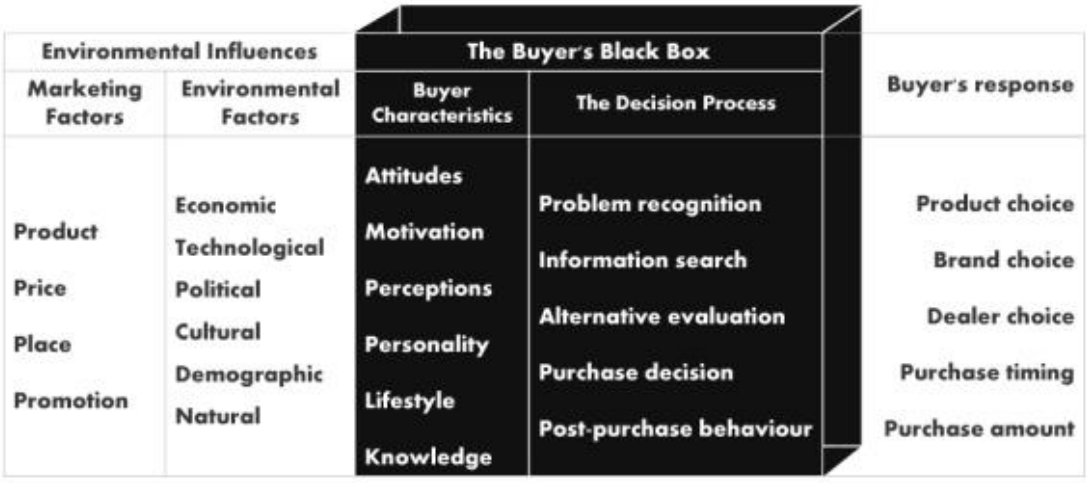


Figure 28:Illustration of The Buyer's Black Box [85].

The behaviour of a consumer depends on several factors that are important to consider. The model below illustrates 4 different explanatory factors, cultural, social, personal, and psychological. All these factors directly influence consumer and buying behaviour.

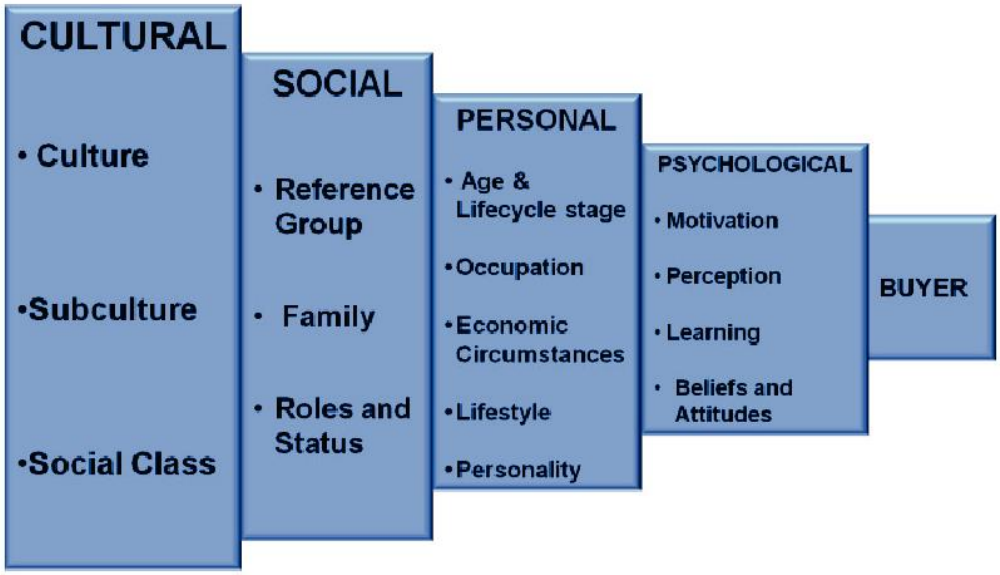


Figure 29:Consumer behaviour model [86].

Cultural factors: Culture can be divided in several sub-cultures, and they are fundamental values / norms in a society. Part- and subculture can be anything from urban culture, youth culture, and so on. To carry out successful marketing, local cultural conditions must be considered and taken into consideration.

Social factors: A social class is defined as people with equal value, behaviour, and lifestyle. Occupations and assets can be seen as indications of which class an individual belongs to. There are several factors / groups that influence the consumer, with different intensity. The primary group (family and friends) has the strongest influence on the consumer, then follows the secondary group (fellow students, co-workers, and the like). Various social / formal groups relate to general individual behaviour as well as buying behaviour.

Personal factors: Where one is in the life cycle has a significant influence on buying behaviour of everyone. Priorities for senior citizens, teenagers, single, married, parents, and so on will vary greatly. Occupation and economy (purchasing power) also significantly influencing consumer behaviour.

Psychological factors: Learning, motivation, and opinions will also influence the behaviour of the consumer. Everyone has needs that must be covered, although these can vary widely. Some contexts recur, and there are many different theories regarding this subject. Maslow's demand pyramid is a well-known theory that illustrates the needs of each human being. This illustration can be used as a basis for understanding different needs, and their connection to buying, selling, marketing, and consumer behaviour.

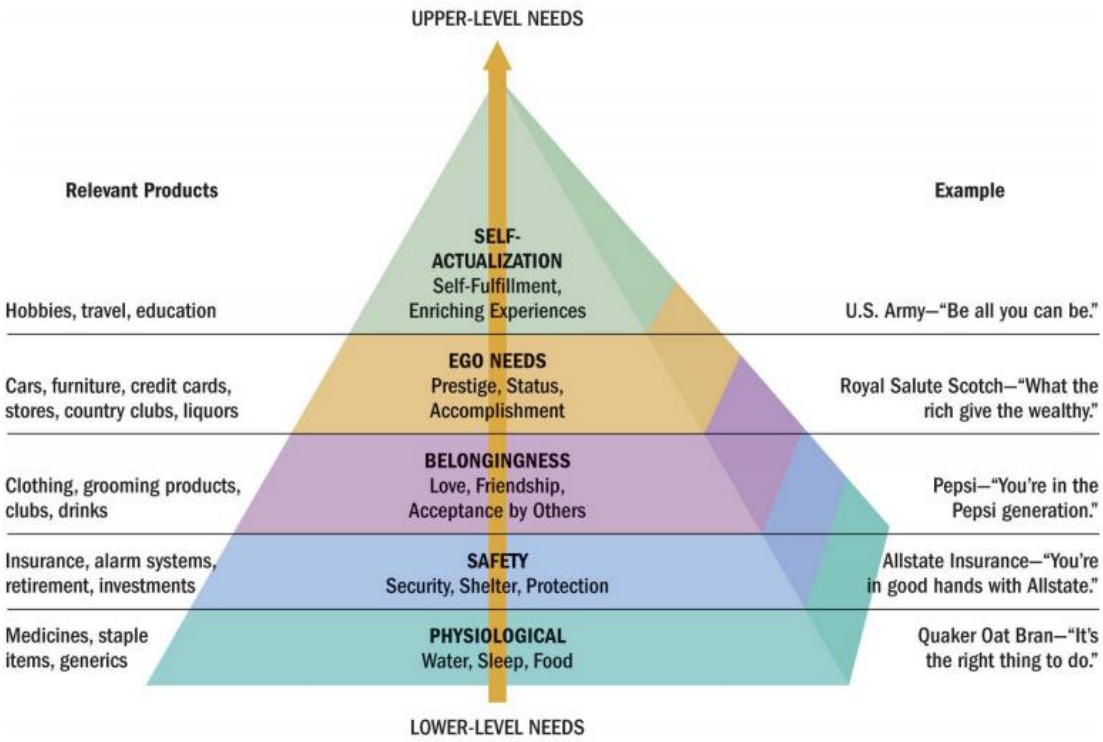


Figure 30:Maslow's demand pyramid. [87]

When designing a solution to the thesis, there will be focus on how private and professional parties communicate and how improved communication flow can improve customer experience and product quality, increase value creation, and provide a customized and enhanced portfolio. As well as how adding services to a product directly will add value to the entire supply chain. By covering as much as possible of consumers' needs and wishes (considerable variations depending on customer base), the customer will feel enhanced quality and, in that way, improve the total customer experience [57] [58] [59] [60] [61].

4.1 Desired information regarding product

Increasing attention to documentation, origin, and production processes follows certain ethical challenges such as fishing density in cage, slaughter and medicine methods, fish fodder production, use of additives, and more. Customers / consumers are also interested in the health aspect of consuming seafood. Former research on chemical compounds has therefore shifted increasingly to research on safe / good seafood with accurate durability, along with sustainable and ethical production.

Besides data stamping and nutritional content, fishery products currently contain little additional information. Consumers today are increasingly interested in information about the products they buy. This also applies to fish products. There are several other factors that come into play when a consumer buys a food product other than just satisfying the physical need to get saturated and gain nutrition. Besides the taste and availability of the product, factors such as lifestyle, and history around the product come into play. The Green Sector easily illustrate this where it is often marketed with affinity

to farming communities with green fields and well-tended animals. Fishery and seafood production in Norway has good reputation both domestic and global. By being able to inform consumers further about end-products, one may assure the customer to an even greater extent that quality and conditions are up to standard. Quality of end-product, which in turn depends on more than just nutritional content and date plotting.

There are many examples of information that can increasing the customer experience, for example, living conditions during breeding, how the fish has been processed, additional information about cooking, and more. By supplementing products with additional services, the consumer will have an improved customer experience, which in turn will directly result in an increase in the value of the supply chain.

The table below illustrates some consumer wishes, process steps, and what insurance it can provide.

Table 1: Consumer needs and wishes.

Consumer wishes	Process / Step	Result	Category
Processing methods	Slaughter / Processing	Provides consumer insight into how fish are slaughtered and processed	Quality
Treatment and medication	The entire life cycle of the fish	Information about vaccination, lice problems, etc.	Quality / Customer Experience
Temperature of product throughout the supply chain.	Storage / transport	Assures customer that product has not been subjected to unwanted temperature variations	Quality
When the fish is fished / processed	Process and transport within the supply chain	Informs when fish have been fished, processed, and transported.	Freshness / Quality
Information regarding preparation of product	Supplement product	Consumer gets increased insight into the preparation of product	Customer experience
Condition during breeding	On growing farms	Provides consumer the opportunity to collect further information about product.	Quality / Customer experience
Starvation length before slaughter	Slaughter	Provides an assurance of the quality of end-product (superior, etc.)	Quality
Waste Management	Entire supply chain	Gives insight into how the company operates.	Customer experience

In Norway, every year, food worth billions of NOK is discarded. Surveys of consumers show that 80% want to help reduce this number. Numbers from 2015 shows a food wastage of total 355,000 tonnes in Norway. By providing consumers with insight into waste management within the supply chain, along with an illustrated efficient transport method, manufacturers can show that it is prioritized to get products on market as soon as possible after processing, in that way help eliminate price reduction of goods due to date, along with unnecessary waste, and provide consumers with the freshest possible product. A survey from 2015 shows that as many as 65% of consumers believe that a short-lived food product must be discounted in order to buy it. All steps performed down the supply chain will influence the consumer [62].

4.2 Quality

Quality of sales goods is important to every consumer, and as follows also in industry and production. By documenting the quality of a product, one can improve the position with respect to competitors, while maximizing market opportunities to its fullest. Norwegian fishing industries has great competence, as well as access to fresh commodities. To be able to fully utilize this competence together with the raw materials and earned experience will be of great importance for companies in northern Norway to be successful and be able to drive a sustainable industry.

Quality can be defined as; delivery according to customer requirements and specifications. Here are some of the challenges manufacturers' encounter, as customers often have different opinions about requirements, quality, and product specifications. Quality of seafood can therefore be divided into two areas, primary quality (product together with its properties), and secondary quality (experience around product, such as service).

Table 2:Primary and Secondary Quality.

Primary Quality	**Secondary Quality**
❖ Quality of processing and production. ❖ Biological quality, size, nutritional content. ❖ Product quality, properties, treatment methods, time, temperature, ethics.	❖ Perceived quality. ❖ Fulfilment of requirements specification. ❖ Trade quality, delivery time, packaging, price, service, etc.

Quality regarding fish and seafood is often associated with freshness, which in turn gives the consumer a sense of high product quality. Other examples of prioritization may be that the product is natural and it that way "real / genuine", and not manipulated in any unnatural way. Some may prioritize quality of service such as species, colour, and presentation in front of freshness. All these consumer types are conscious of quality and requires satisfactory products.

Despite different priorities, product quality is usually ranked highest, since it is directly linked to the consuming of the fish / product. Product quality is one of the most difficult factors to manipulate as quality changes over time in both living and killing state, storage, and distribution. Although the quality of taste is often given the highest priority, production preferences together with suitability for processing is also be of great importance. Regardless of priority, a requirement is that the fish is safe for the consumer to consume and that the production / processing is in accordance with given ethical conditions. Ethical quality includes medicine and hormone use, killing and slaughter methods, and environmental impact. It is an increasingly focus on the production of fish products, and consumers are becoming increasingly environmentally conscious. A survey from 2016 [63] shows that 52% of Norway's population is concerned with the environment and ethics when making a transaction.

In addition to statutory guidelines and quality standards, it is in big part the consumers that helps to influence the focus on fish and animal welfare. The attention surrounding production and processing of aquaculture will often result in a win - win situation, as consumers gain access to a product they want to buy, and manufacturers, as example, can achieve desired price through documentation of product to the consumer.

Breeding in Aquaculture has the ability to manipulate the nutritional properties of fish. Everything from fish fodder, living conditions, feeding methods / quantities, breeding programs, and more. In this way, manufacturers can influence the end-product according to market demands, which means that manufacturers not only need to focus on volume when it comes to production, but also tailor specific production to reach a targeted audience. Specific quality can be red colour, fat distribution and amount, type of filleting, and right texture on the skin of the fish.

Figure 31:Illustration of different quality parameters [88].

Seafood is generally considered as healthy food, usually due to accompanying fatty acids, vitamins, zinc, iodine, along with digestible proteins. Quality of the fish and nutritional content are associated with the choice of fish fodder. There is a variation in fish fodder and accompanying feeding routines in the industry, and this factor is constantly evolving.

Fish products often have a shorter expiry date than many other food products due to nutrients and digestibility. Adequate hygiene standards through processing, storage and distribution are therefore highly necessary. In farmed fish, foreign substances and contamination through fish fodder and medication have received great attention due to concern about food safety. The industry is therefore still researching on new, more efficient and ethical, cleansing and feeding possibilities.

Examples of quality requirements and desires may be as follows:

- Clean end-product without contamination or unwanted substances.
- Responsible and sustainable production and farming.
- Ethical fish welfare.
- Consumer is familiar with product and production and can in that way make an informed and enlightened choice concerning a transaction.
- Information regarding product characteristics included (brand regulations, quality standard, certification, nutritional content.

5 Analysis and suggest solution

In order to respond to the expanding technological development and globalization, it will be increasingly important to respond adequately to customers' needs and wishes and deliver products to the consumer / customer in time and according to given specifications. With an industry with such significant growth prognoses (fivefold whiting the next of 20-30 years), It will be necessary for both small and medium-sized businesses, as well as major manufacturers to keep up with the development to ensure a sustainable future. By increasing efficiency and communication within the supply chain, improving quality parameters, increasing response time, and expanding the product portfolio, companies can achieve a sustainable production and thereby future. Automated production has been implemented in much of the industry, and this development will only continue. Automation leads to reduced labour costs, and increased production accuracy. To this extent it will be necessary for the industry to also look at other aspects than just processing and cost reductions to continue to add value to the entire supply chain.

By using today's digital technology, one can construct a digitized product service system that can give companies opportunities that are not in any ways fully utilized today. The system will be built up of software and hardware, along with several different technological solutions. Such a system must be compatible with existing technology, but also any technology that may be implemented in the future. This product service system will allow the consumer to scan a 2-Dimensional Barcode (QR) on the desired product by using an optical reader, such as a smart phone. By scanning the QR code, the consumer will automatically be forwarded to a specified web site / platform on the internet. The web site will contain an overview menu that will present the consumer with a variety of possibilities. The menu will contain links with information about the fish's origin, the fish farm, the processing of the product, quality stamp with other standards, feeding and treatment methods, temperature conditions, nutrient content, date of slaughter, cooking possibilities, and another information the consumer may find valuable.

In the case study it emerges that manufacturers already possesses the ability to trace products up and down the supply chain. The product-service system will, to the extent only improve the tracking of products through the transport from factory / warehouse to applicable resale. The system will likewise provide the end-user with an illustration of the travel route, thereby increasing the overall consumer experience. From the case study, it also appears that the communication between the different actors within the supply chain is well functioning and effective through the manufacturer's production control systems. The introduction of a product-service system will not directly improve communication within the company but can improve general access to information regarding consumers and thereby help to streamline and improve marketing, production, and similar segments in the company. Consumer patterns and desires will be able to provide the company with valuable information in the launch of new products and the development of existing products, and product Portfolio. Such improvements can give manufacturers greater responsiveness in relation to the market and thus an edge over other competitors.

The product-service system will help improve communication between the consumer and the producer, help ensure transport logistics, and provide an improved customer experience by providing the product with a supplementary service.

5.1 Digitalized product-service system

During production of various fish products, extensive amounts of information regarding the products are stored. This information is stored in the manufacturer's production management systems. Product information can be retrieved from these systems and made available to the consumers. For example, the manufacturer from completed case study stores information from all the production steps (from roe processing to finished product) in such production management systems. Since information already is available, it will not require extensive time commitment from manufacturer to provide consumers with new and informative information about the products they buy. Storing of information during different production steps will be a necessity to achieve success with the product service system. The system will be built on the following technology:

Figure 32:Example of QR scanning [89].

2-dimensional bar code (QR):

Each batch of fish is assigned a unique QR code for identification. The code will make it possible to identify this particular fish group, in order to give the right history and accompanying information. The corresponding QR code-label is applied on the packaging of the fish product during the package process. When the finished products are to leave the manufacturer, QR codes are scanned before loading, and upon delivery. This will automatically add new information to the producers' database and further to website (transport time, route, from-to, and the like). The two-dimensional barcode can then be scanned by the consumer with the use of an optical reader, such as a smartphone.

As an example, the manufacturer can have its own application that is downloadable for smartphones (from appurtenant app store), where the consumer can retrieve general information about the manufacturer, products, and with an accompanying optical reader application, that together with the camera on given device can be used to scan desired product (QR code).

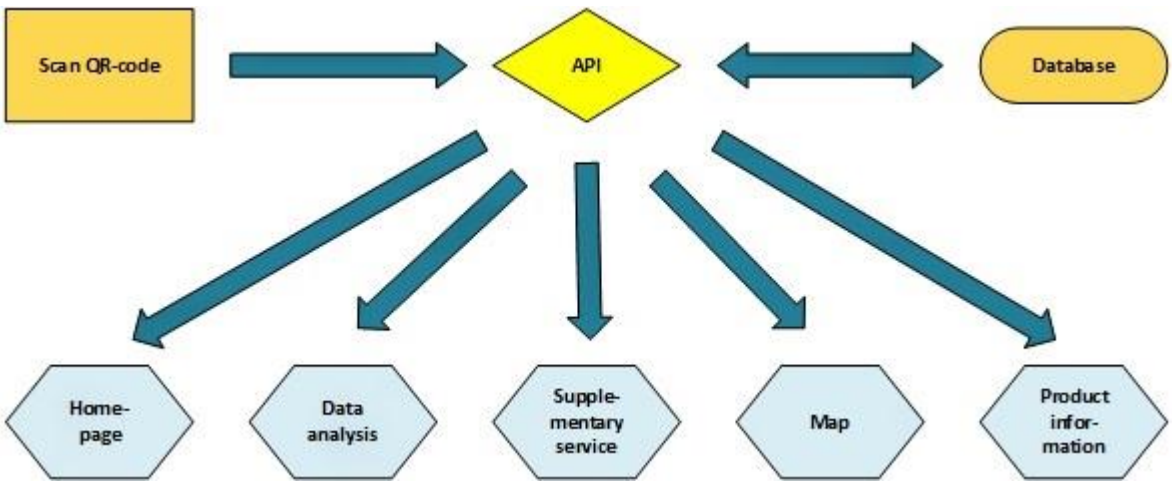


Figure 33:API in conjunction with other applications.

Each product has its own UID (unique identifier). The identifier is global and has a format that allows the applicable UID to be assigned to only *one* product. The UID is encoded in the QR code that is attached to the product packaging.

API (application programming interface) is the interface of the software. API is further based on user authentication, and the UID is used to recognize the product. The interface allows other applications to make appropriate changes, process data information, run different processes, and communicate both ways with the product database. All information concerning the products will be stored in the database. These collaborative software parts will make it possible to perform desired actions such as make changes to the website, retrieve information from the consumers internet behaviour, and update information regarding the product.

The API is developed in company with other applications that will support the product service system for the consumer:

- Homepage: Digital platform were consumer can retrieve desired information regarding product. (from database / production management systems)
- Data Analysis: Shows cooling times, processing data, transition times.
- Additional services: Recipes that shows various cooking methods, additions, with more.
- Product Map: Visualization of travel route for product.
- Product Information: Origin, package date, nutritional content, expiry date, weight, etc.
- Receipt: Custom receipt for given product.

These examples are just a few of the API applications. API is generally designed / shaped to serve for hosting unlimited amount of data, as example IoT or data mining applications. API can in this way provide a two-way communication and provide valuable feedback to the various links in the supply chain.

Website:

The website will act as a digital platform where consumers can find information regarding the desired product, and as a communication platform between the consumer and producer. Customers can leave feedback, wishes, and assessment of products and services, as well as provide the producers with suggestions concerning improvements. Enabling manufacturers to easily retrieve information that could improve their products, expand the product portfolio, and further work to increase additional services. The consumers' internet behaviour can also be seen as a source for the manufacturer.

Data analytical tools (Big data) can help understand consumers' preferences, for example, by analysing the click rate of the information and services on the website. High click rate can illustrate that the selected service or information is useful and / or informative to the consumer. Thus, the manufacturer can easily see which information the consumes valuables highly, and work further with this knowledge. An example here may be a recipe that results in high click rate, consequently the manufacturer can find more similar cooking methods to complement the product with. In the case of low click rate, there is a possibility that chosen cooking method or information is not as popular with the consumer.

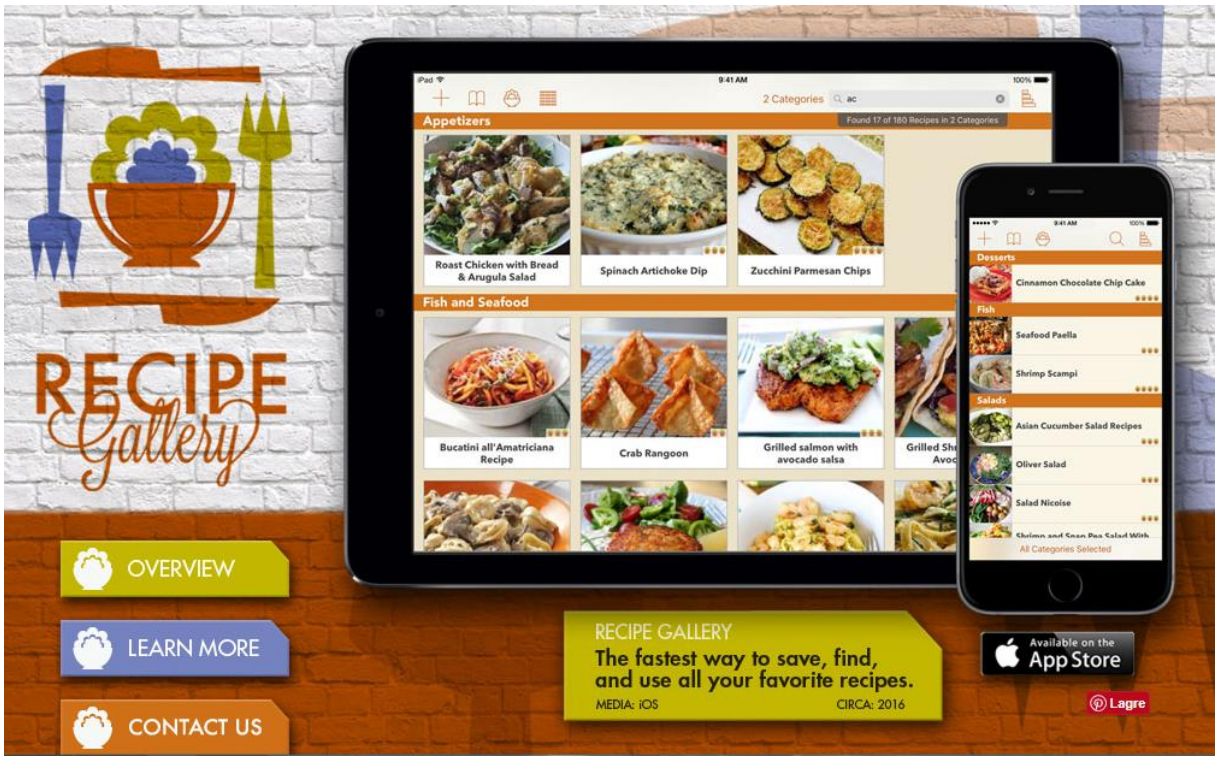


Figure 34:Example of website [90].

With IoT, there are great opportunities with corresponding amount of data information. Such information can give producers effective and reliable feedback from consumers without any intermediaries. Here it is important that associated information and data sharing are adequately protected.

Cloud computing:

For companies with limited IT knowledge and resources, the use of cloud computing can be the right way to go. By taking advantage of such a service, the company will not have to use their own resources in this field, and rather pay a third party based on the company's own consumption and necessity. Cloud providers can provide services that cover application services, data security and storage, deliver software, and analysis of data information.

This makes it possible for companies, such as small and medium-sized enterprises which does not necessary have sufficient IT resources in-house to also take advantage of the opportunities that comes along with such a product-service system. The use of cloud computing services also eliminates the purchase and maintenance of additional hardware and software, as well as operation. Such services are today both stable and flexible and can be tailored to each company's wishes and necessities. If cloud computing is to be used or not when introducing such a product service system, will depend on which resources the selected company already possesses.

Big data analysis:

As mentioned earlier, Big data analysis can provide new insight through processing of various sources of data and information. There are extensive amounts of information that can be analysed for manufacturing and marketing purposes, customer bases and consumer behaviour, as examples. Such data analytical tools can process and analyse huge amounts of data information both efficiently and accurately. By utilizing these tools, the company will gain insight into consumers' behaviour and patterns, visualize and present analyses through predictive models, statistical algorithms, and what-if-analyses, and then use the insight as the basis for decision support. Big data will also promote and improve communication internally and externally for the manufacturers. Such data analytical tools will be required to fully exploit the considerable potential that follows the product service system.

Supplementary service (recipe example):

Being able to supplement the products with services will add value to the product for the consumer, hence adding value to the entire supply chain. In addition to providing the customer with comprehensive information and history regarding the product, the product service system will provide the customer with a variety of opportunities to prepare purchased product. Here one will receive specific suggestions for preparation for each product, such as cooked, fried, or raw preparation. The recipes will include pictures, procedure, accessories, and length of operation. Replacements in different recipes may depend on click- rate, year-season, and similar factors. Here it will be possible for producers to collaborate with, for example, different chefs and suppliers. Such a cooperation may help promote both the chef and the company's products. Similar cooperation has been done in Norway between grocery chains, food producers and well-known domestic chefs [64].

Such a service will be available on an application that the consumer can download to his smartphone, tablet, or similar hardware.

Figure 35:Example of recipe search [90].

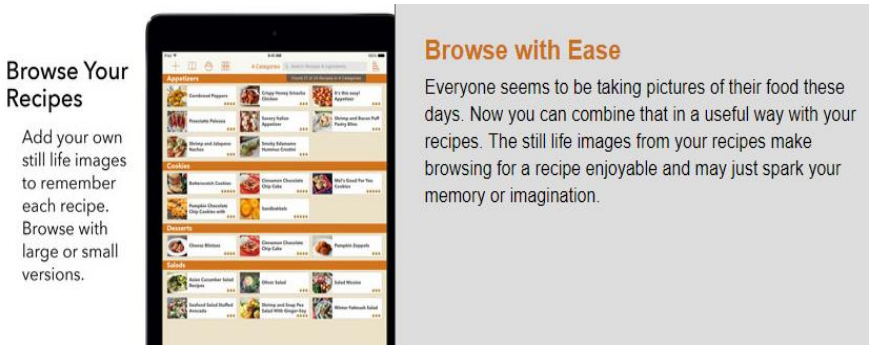


Figure 36:Example of browsing [90].

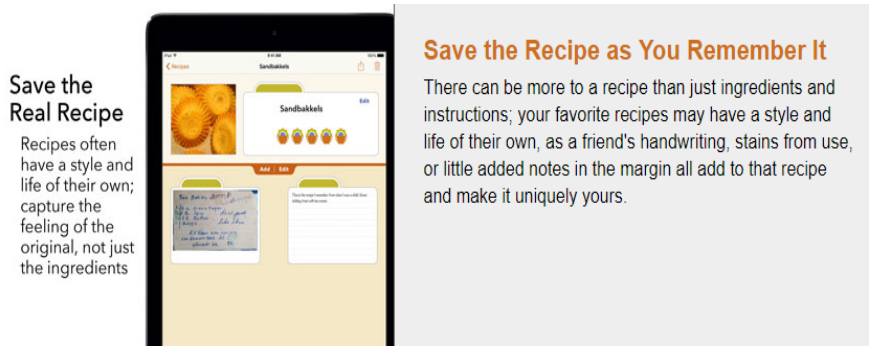


Figure 37:Example with saving of recipe [90].

Figure 38:Application example [90].

The figures above are examples of layouts of an application to a smartphone, tablet, or similar hardware. Here one can search for recipes, products, or categories, save your own recipes, find recipes from the manufacturer, and easily find new methods to prepare the desired product. The product system will ha this possibility.

Map:

By scanning the QR code on the product before it leaves the factory, and again when the product reaches resale, the itinerary can be mapped and illustrated to the consumer on the website. In this way the consumer can see how far the product has been transported, and how long the process took. This information can tell the consumer something about how fresh the product is and the origin of the product. In order to succeed with such a system, there must be a cooperation between the manufacturer, carrier, and given resale in order to update the product service system. Radio frequency identification was evaluated as solution, but since the cost of implementing such a system (both operating and installation of infrastructure) is still significantly more expensive than selected method (QR code), it was decided to exclude this technology.

Many carriers today already provide the opportunity to document temperature during transport to ensure the producer and receiver that products / goods have obtained satisfactory temperature during the entire transport process. Investing in RFID technology to cover this opportunity will therefore be an unnecessary expense to the manufacturer, and thereby not give the supply chain an increase in value. RFID also has some challenges that come with specified temperatures and with the presence of water and moisture. Producers in northern Norway must cope with both hard and variable climate. While for a QR code system, the only challenge will be readability on the label. This challenge can be solved by adding a number under the code(QR) itself to the label, in that way if the code is corrupt in any way and cannot be read by the optical scanner, this number can be entered manually, and one can identify the product.

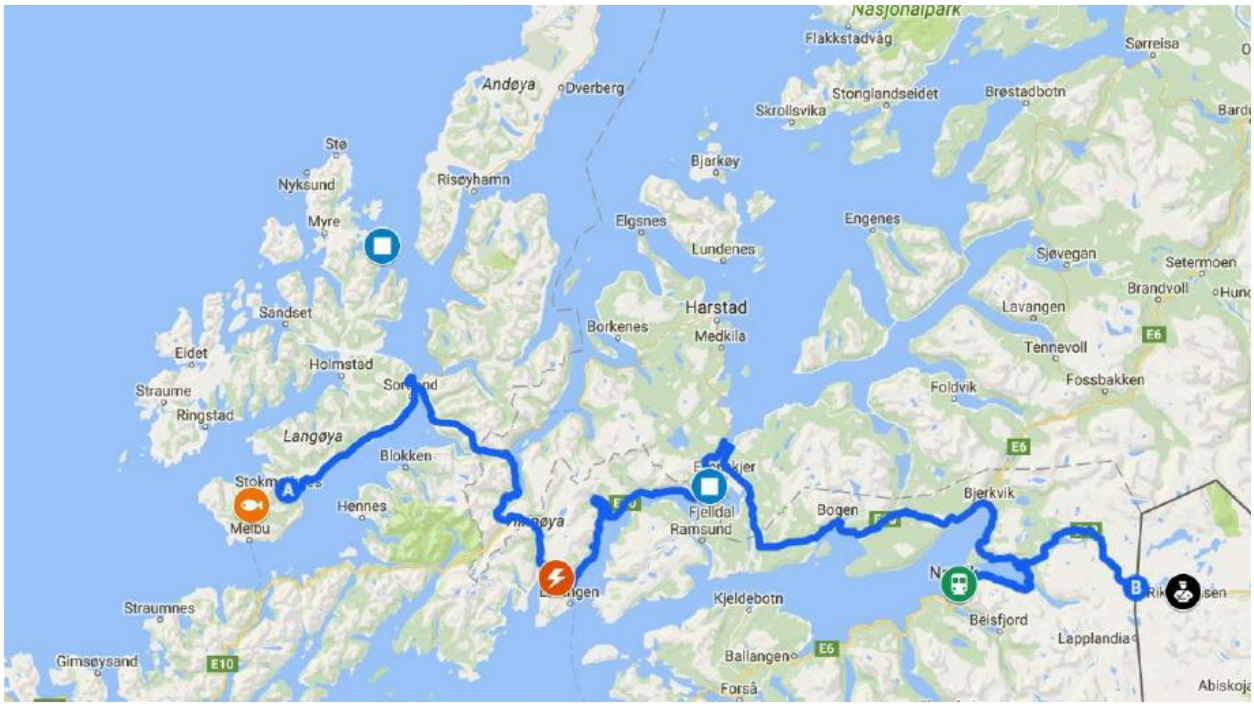


Figure 39:Map illustration over a itinerary for fish products in Northern Norway [39].

Example of an itinerary for a fish producer in Norway, from factory located in Stokmarkens in northern Norway, to customs crossing over to Sweden. The itinerary can be visualised at given website.

Product Information:

Information supplied with fish products are currently very limited, both in terms of processing and history surrounding the product. Information regarding products will be retrieved from the manufacturer's production management systems and from transport logging (database). Information that consumers find particularly interesting can be assessed from analysis of click rate and other feedback from the website.

Table 3: Information that supplementing fishery products.

Category	Information
Manufacturer:	Name of fish producer.
Nutritional content:	Protein-, fat-, calorie percentages, etc.
Species:	Type of species on purchased fish product.
Fish certificates on products:	Kosher, MSC, etc.
Quality Stamp:	Superior, or other quality.
Transport Route:	Transport method and route for product.
Temperature Conditions:	Temperature logging during transport.
Factory:	Name of factory where the fish is processed.
Slaughter date:	Date of slaughter.
Slaughter method:	Pre-rigor filleting, slaughter at sea, etc.
Last day of lining:	Specified date.
Size of fish at slaughter:	Size standard for fish at slaughter.
Boat:	Name of "fishing boat".
Location of fish farm:	Name and location of fish farm.
Medication / Treatment:	Medication and treatment methods of the fish, including salmon lice treatment.
Lining conditions	Fish fodder (type), amount, and content.
Generation and type of smolt:	Type smolt, 0-year, 1-year, etc.
Origin:	Relevant history about the origin of the product.
Certification:	Specified Certifications.

Table 3 contains examples of product information that will be possible for consumer to obtain through the website. The website will gather the information from the manufacturer's database and the accompanying production management systems.

During the design- and development phase of the product service system, it is important to consider and evaluate ongoing projects and future technology. Big data has already been implemented in Ocean Farm 1, and it is natural to think that this kind of technology only will be further developed and used in the industry. Being able to link data information from both production, and from transactions and consumers will provide an even greater overall picture of the industry. Design of systems must therefore be carried out with the regard to the fact that production methods, product platform, and market together with products can change and evolve in the future, and it would therefore be beneficial if the system can be modified if necessary. Such ICT (information, communication, and technology) production will help lift the overall fish farming production to an even higher level, in this way help improving the entire supply chain.

5.2 Improved customer experience

The wishes and needs of the consumers will always be important for manufacturers to satisfy as it will result in satisfied customers, and as follows increased profit through sold products. Even though some quality requirements are constant (meat quality, freshness, etc.), different customer bases, often results in different wishes and priorities regarding products. By implementing such a product service system, the end-customer will have an increase in several quality parameters, again depending on customer fraction and accompanying wishes.

The system will supply consumers to the extent that it covers as many as possible of customer wishes, and as follows the greatest possible segment of the complete customer base. Data regarding treatment and medication will provide the end-customer with information and thus assurance that selected product is healthy and not manipulated in any undesirably way, and in that way increase given quality parameter. Other relevant information that may increase quality parameters is requirements regarding documented quality, fish species, and accessories. All these factors will be strengthened through the implementation of the system. Environmentally conscious customers will get a positive experience by purchasing products that can be documented to have been manufactured according to a responsible, ethical, and sustainable production. New services such as the visualization of product travel, expanded knowledge regarding preparation, and history surrounding purchased products will also help to increase the customer experience.

By being able to provide feedback directly to the producer about experiences regarding products and supplementary services will provide the end-customer with an opportunity to provide both positive and negative feedback without any disturbing intermediaries. Such feedback and notification are already common in internet trading and similar transactions. Enabling a direct communication portal will give the end-customer greater responsiveness and thereby increase the customer experience through the possibility to be heard / understood. Through the application of the system, customers will also be able to be made aware of new products that the manufacturers provide.

6 Summary

The literature and case studies with accompanying results have now been presented in thesis. Based on theory, it will be possible to use the tools presented to construct and implement a product service system. Author has considered necessary technology, different phases, and potential profit for such a system. The following chapter will deal with the author's assessments on topics such as equipment, results, and accompanying possibilities.

As a conclusion, what is presented is the author's thoughts about possibilities for continuing future work and development around the subject, and reflections of the overall development of services over traditional product transactions.

6.1 Summary

In this thesis, it has been given an overview over concepts of production, accompanying technology and processes around the aquaculture industry in Norway, together with the advantages of being able to supplement existing products with additional services. The Norwegian fishing industry is traditional, but at the same time in continuous development because of considerable competitiveness, both domestic and global. Increasing values around the fish products will not only serve the last part of the supply chain, but rather give a total value increase to the entire chain. Development of the system will help several activities related to the supply chain with a concrete goal to meet maximum customer value and ensure a sustainable production and industry.

From a global perceptive, the fishing industry sits on comprehensive values, and the aquaculture industry in Norway has evolved into one of the country's largest industries, and the forecasts indicate that the trend will only continue significantly. Products from Norway enjoys a good reputation in both product quality and general production. The industry in Norway has several challenges, some that technology can solve (salmon lice, escapees), others that need to be solved by production management (decisions regarding products, services, and ability to be innovative).

The ripple effects of the industry are significant, and suppliers to the industry are increasing in line with the growth of the industry. Producers of fishery products in Norway are still largely production-focused, concentrating largely on efficiency, cost reductions, and technology development. With access to today's digital technology, and in the development of industry 4.0 (the fourth industrial revolution), manufacturers in the fishing industry must also give priority to data exchange that accompanies today's production technology.

Production in Norway is largely semi- and fully automated, and as a result, it is possible to extract large parts of information that can help serve as decision support for producers. With such an extensive industry and so many suppliers, accompanying with such a large customer base, as well as production of a product with limited durability, it will be essential to possess functional and efficient supply chain management to succeed. Production of farmed fish is extensive and detailed, and the production has many factors which can be manipulated to control the quality of end-product. Some production steps vary on the manufacturer (lining, slaughter, etc.). However, there are some steps that are always relevant, independent of the manufacturer (fish welfare, imposed conditions, etc.).

Some manufacturers have invested heavily in technology to improve production (Ocean Farm 1 as an example) and has already realized the potential that comes with the available digital technology in terms of analysis of production (animal welfare, lining conditions, environment, etc.). As a result of such a prosperous industry, there are also a number of research projects that hope to solve some of the different production challenges (lice problem and the development of a sustainable fish fodder).

Current technologies used for customer-defined purposes largely include a general description of the product, such as weight, quantity, and price information. Consumers are only becoming increasingly conscious of the products they buy and the history behind them. Information on the packaging, along with the barcode, is all that accompanies fish products as of today, which is why there is a great deficiency of information regarding the history and processing of products. Companies will therefore profit to share more information from production to the end-customer, not to mention the use of analytical tools themselves to process information from both production and information that represents the end-customer and the target audience.

Case study in this thesis confirms that relevant manufacturers have already considered such digital technology but have not reached the test or implementation phase. The case study also discloses that the systems around the production is extensive and well-functioning and possesses large amount of information about the production. The production management systems also provide comprehensive information about the products, all the way through the supply chain, but this information is not made available to the end-customer.

Implementation of a digitized product-service system will thereby add value to the entire supply chain, both in terms of improved consumer experience, and thereby an increase in value of the products, but also improved communication between end-customer and manufacturer, as well as increased information sources for analytical use. It follows many advantages to using such analytical tools, and although there will be a cost to the manufacturer by adopting this (purchase, operation, training), the potential profit is even greater.

6.2 Future work

Regard future research on theory of subject, it would be interesting to investigate further how different analytical tools can be used and the composition of these tools with a digital platform. Processing speed, as well as the development of necessary models and algorithms will also be beneficial to investigate further. Whether it is necessary to make simplifications or limitations in relation to various factors will also be very interesting to investigate further.

For a practical analysis, the next step would be to find a manufacturer who would be willing to collaborate and perform a simulation to identify and validate the potential of such a system. Such a simulation will also provide answers to which systems that are compatible, and necessities to create necessary collaboration between different software.

Necessary steps to complete system:

- Construct a real simulation of a product service system.
- Design and complete system based on simulation.
- Implement the system at the manufacturer, and with necessary collaborators.
- Analyse and evaluate profit.
- Optimize, further develop, and improve implemented system.
- Continuous documentation of operations and improvements for further work.

Author concludes that it will be both interesting and beneficial for manufacturers, and other interested parties to further explore the development of services that can supplement the products, especially considering the size of the industry, competitive degree, and extent of investment being made.

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