The application of the Internet of Things and Physical Internet in Norwegian aquaculture supply chains

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Preface

The aquaculture industry has since it's beginning experienced a rapid growth. It is today one of the largest export industries in Norway, exporting seafood products to countries all over the world.

During the autumn of 2015, we had a class called "Operations Management". This class covered important aspects within the scope of Supply Chain Management. Moreover, logistics and utilizing innovative solutions in the supply chain were areas that particularly captured our interest. Therefore, in cooperation with our supervisor, we decided to study how utilizing the Internet of Things and the Physical Internet could benefit companies operating in the Norwegian aquaculture industry.

The process of writing this master thesis has been conducted during the spring semester of 2016. This thesis provides a holistic view of how the industry operates. Hence, gathering and selecting relevant information has been time consuming. However, although the process of writing an assignment of this magnitude has been challenging, it also been a highly educational experience.

Lastly, we would like to thank our supervisor, Professor Jan Frick. He has been available for guidance when needed, and provided valuable inputs throughout the whole process.

Abstract

The topic for this master thesis is Supply Chain Management within the Norwegian aquaculture industry. The thesis aims to examine how the industry can make use of aspects within the Internet of Things and Physical Internet in order to improve their supply chains.

Moreover, the thesis identifies and defines three main factors affecting the customers purchasing decision; namely quality, time, and price. These factors are interconnected, and influenced by traceability and onshore transportation.

The thesis is built upon secondary sources, using data and statistics, as well as results from questionnaires, surveys, and available information about aspects we want to illuminate.

Due to increased focus relating to regularity and flexibility in deliveries, along with food safety, quality, and documentation, the need for innovative transportation- and traceability solutions has become imperative.

As a solution to this, the thesis suggests that the Norwegian aquaculture industry can benefit from utilizing concepts from the Internet of Things and Physical Internet in their supply chains. Electronic traceability systems enable transparency and efficient communication throughout the supply chain. It provides key information about the products, which in turn facilitates better decision-making.

Next, implementing the Physical Internet in the Norwegian aquaculture industry could potentially lead to significant reductions in transportation costs- and time. This can be accomplished through utilizing smart modular π-containers, an open and interconnected logistics network, as well as enabling more intermodal transportation. Moreover, through reduced transportation costs, the industry could be able to further strengthen their competitive advantage in terms of proximity to market.

The study suggests that implementing traceability and the Physical Internet can potentially contribute in significant improvements with respect to; quality, time, and price.

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1.0 Introduction:

In this chapter we will start by presenting our motivation for choice of case topic, along with a presentation of our research question and what the thesis sets out to achieve. Thereafter, we will give a historic and present view of the Norwegian aquaculture industry, followed by a presentation of a generic supply chain within the industry.

1.1 Motivation:

When we started the search for topics to the master thesis, we decided fairly quickly to look into the area of Supply Chain Management. This was an area that particularly captured our interest in the “Operations Management” class during the autumn of 2015. Additionally, we felt that this had the potential for a good and interesting master thesis. We wanted to examine how utilizing concepts from the Physical Internet (PI), and the Internet of things (IoT) could help companies improve their supply chains. Further, we felt that examining this area would allow us to obtain deeper knowledge about a highly relevant subject for potential future work applications.

Our initial focus was directed towards the petroleum industry. This was partially due to the industry´s strong position in the Norwegian industrial mix, as well as our close proximity to the industry (as students at UiS). Besides, the fact that many of our previous subjects and assignments, both at bachelor and master level, have had a strong link to the petroleum industry, made this a highly interesting industry to explore. However, in light of the recent downturn in the petroleum sector, we decided that we wanted to focus our efforts towards another industry.

After considering various alternatives, we decided to take a closer look at supply chains within the Norwegian aquaculture industry. The Norwegian aquaculture has had a formidable development since its humble beginnings in the early 1970´s, ultimately establishing itself as one of the most important export industries in the Norwegian industrial mix. Although there is a large export volume in the industry, a lot of the improvement focus has been directed towards the upstream activities of the supply chain. Therefore, this thesis will also cover important aspects of activities and processes at the downstream end of the supply chain. More specifically, how advances in onshore transportation systems along with the implementation of traceability can help improve the overall supply chains within the industry.

1.2 Topic, scope and research question

The topic for this master thesis is Supply Chain Management within the Norwegian aquaculture industry. It aims to examine how the industry can make use of aspects within the Internet of Things (IoT) and Physical Internet (PI) to improve their supply chains. Moreover, the thesis identifies and defines three main factors affecting the customers purchasing decision; namely quality, time, and price. Further, due to the time limitations of a master thesis, the main focus will be aimed at examining how the implementation of concepts within the IoT and the PI can help improve traceability and onshore transportation in the supply chain. Thus, the thesis aims to examine the entire supply chain, from the upstream- to the downstream end of the production cycle.

Moreover, our study is delimited further. We will only examine the Norwegian aquaculture industry, and not the aquaculture industry on a global scale. This was done partly due to the time limitations of a master thesis, and partly because the technology and supply-chain on a global scale differs from the Norwegian aquaculture industry. Therefore, even though some concepts can be transferable across industries, many of the concepts will be industry specific. Furthermore, there will be a substantial focus towards farming of Atlantic salmon and rainbow trout. This is due to the fact that the production of these two species accounts for about 99,6 % of the total production volume within the industry. (SSB, 2016, ssb.no)

Thus, our research question is as follows:

- ***How can the Norwegian aquaculture industry benefit from utilizing concepts from the Physical Internet and the Internet of Things in their supply chains?***

Moreover, in order to answer this inquiry, we have decided to highlight a subordinated research questions:

- ***How can the utilization of concepts from the IoT and the PI with respect to traceability and onshore transportation, help improve quality, time and price within the Norwegian aquaculture industry?***

1.3 Structure of the thesis

The thesis is structured into six chapters:

Chapter 1: The thesis starts of with an introduction where we present the motivation behind our choice of case topic, along with a presentation of our research question. This is followed by a historic and current overview of the aquaculture sector. Lastly, we introduce a generic outlay of how a typical supply chain is structured within the industry.

Chapter 2: In this chapter we will present relevant theoretical concepts. The most central being: Supply Chain Management, logistics, IoT, and the PI.

Chapter 3: This chapter contains the methodology utilized to answer our research question, along with a description of our data collection process.

Chapter 4: Here we will present our analysis of the collected data, and discuss the implications of our findings.

Chapter 5: The validity and reliability of our sources, methodology, and thesis is discussed in this chapter.

Chapter 6: In this chapter we will conclude, and provide an answer to our research questions.

1.4 The Aquaculture industry

The United Nations Food and Agriculture Organization have defined aquaculture as “the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport” (FAO, 2016, fao.org). Global aquaculture has grown considerably over the past 50 years, reaching a total production of about 90,4 million tonnes in 2012, worth US$ 144,4 billion. (FAO, 2014A)

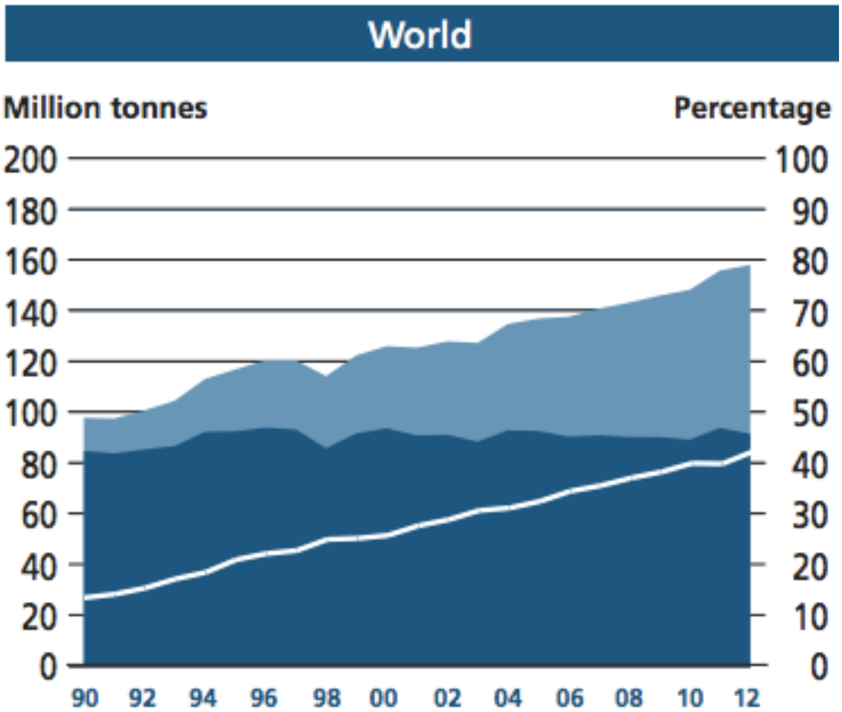

Figure 1: Share of aquaculture in total fish production (FAO, 2014A, p. 19)

Aquaculture
Capture
Contribution of aquaculture (percentage)

Furthermore, “in 2012, the top ten aquaculture producers (excluding aquatic plants and non-food products) were China (41.1 million tonnes), India (4.2 million tonnes), Vietnam (3.1 million tonnes), Indonesia (3.1 million tonnes), Bangladesh, Norway, Thailand, Chile, Egypt and Myanmar. They contributed 88 per cent of world production by quantity” (FAO, 2014B, p. 16)

1.4.1 The Norwegian Aquaculture Industry

The modern Norwegian aquaculture industry was in many ways established at the end of the 1960s, as a result of the upsurge within the Norwegian salmon farming industry. There had been experimentation with fish farming using various technologies, environments, species etc. in Norway for most of the post world war-2 period. However, it was not until the pioneers Sivert and Ove Grøntvedt, managed to come up with a way of successfully breed salmon in saltwater rather than freshwater, that the industry really started to grow. Further, "the transition in the industry from breeding of trout to salmon provided the industry with a more attractive product, thus providing the industry with better foreign market opportunities (Aarset & Rusten, 2007, p. 8). "The 1970´s became the formative years for the industry" (Hovland et al., 2014, p. 17), and "as of 1977 salmon has been the dominating species within the Norwegian aquaculture industry" (Aarset & Rusten, 2007, p. 10).

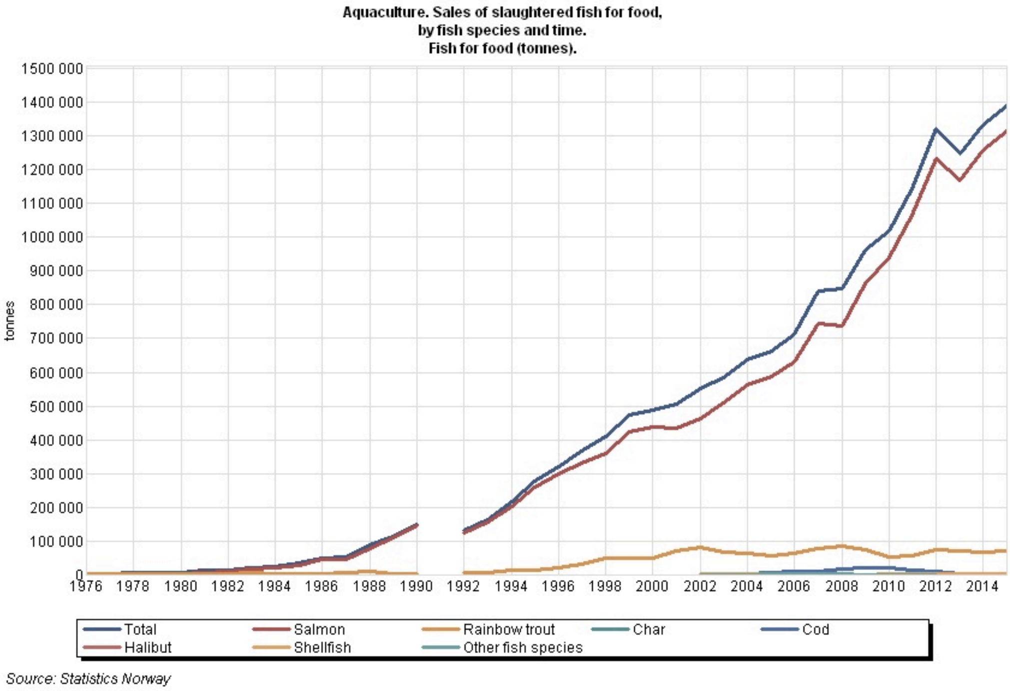

Figure 2: Sales of slaughtered fish for food, by species and time (SSB, 2016B, ssb.no)

1.4.2 Current market Situation:

Today the seafood industry is one of Norway´s most important export industries, and reported a total export of 72 billion NOK to 143 countries in 2015 (SSB, 2016A, ssb.no). Approximately 50,1 billion NOK, originated from the aquaculture industry, with sales of salmon accounting for roughly 94,5 percent of the total export. This corresponds to roughly 1,314 million tonnes worth of fish (SSB, 2016A, ssb.no). This makes Norway the world´s largest exporter of salmon. Furthermore, as shown by table 1, Norway´s by far largest export market is Europe, accounting for about 71 percent of the total Norwegian export. Poland, France, and Denmark being the main contributors. (Ytreberg, 2016, dn.no) (Lilleby & Molnes, 2016, e24.no)

10 LARGEST EXPORT MARKETS

	NOK BN	Change	MILL TONNES	Change
POLAND	6.4	+0.7	189 578	+7%
FRANCE	5.7	-0.2	140 824	-6%
DENMARK	5	+0.6	360 060	+38%
UNITED KINGDOM	4	+1.2	130 159	+22%
RUSSIA	3.4	-3.2	133 035	-55%
CHINA	3.2	+0.7	194 706	+19%
SWEDEN	3.2	+0.5	76 301	+9%
JAPAN	3	+0.5	125 065	+21%
HOLLAND	2.9	+0.7	132 081	+38%
GERMANY	2.5	+0.3	90 614	+11%

Table 1: Top ten exporting markets for the Norwegian aquaculture industry (SjømatNorge, 2015)

Moreover, the domestic consumer market for the Norwegian aquaculture industry is relatively small. The total consume of seafood "only" reached 90 306 tonnes in 2014. Thus, the domestic consumer market constitutes 6,5 percent of the total production within the industry. Making the export market decisive for the Norwegian aquaculture industry. (Norges Sjømatråd, 2015, seafood.no)

There are four major leading aquaculture companies operating in the Norwegian industry. These are: Lerøy Seafood, Cermaq, SalMar, and Marine Harvest. Moreover, Marine Harvest is the worlds largest aquaculture company, accounting for about 25 percent of Norway´s total production of salmon (Halvorsen, 2014, dn.no). The industry currently employs about 6730 people, with roughly 4760 working within production of edible fish, and 1810 working within the production of juvenile fish (SSB, 2016A, ssb.no). However, this does not include people indirectly associated with the industry (e.g. transport, customs officials etc.). Furthermore, the industry reported a turnover of 46,7 billion NOK in 2014, with Atlantic salmon by far being the industry`s most important product, accounting for roughly 94,3 percent of the total revenue. The remaining 5,5 percent is made up by rainbow trout (5,2 %), cod and halibut (0,1), with char, shellfish and other fish species accounting for the last 0,1 percent (SSB, 2016A, ssb.no). Lastly, 94 percent of the total export of salmon and trout in 2013 were fresh fish. (Solvoll et al., 2014, samferdsel.toi.no)

1.4.3 Transportation within the Norwegian aquaculture industry

On average, approximately 3800 tonnes worth of Norwegian fish is exported from Norwegian farmers, processors and exporters to foreign customers every day. In addition, about 170 trailers cross the Norwegian border to deliver fish to Europe on a daily basis. This corresponds to one trailer every 10 minutes (SjømatNorge, 2016B, laks.no). In 2013 the seafood export accounted for about 10 percent of the Norwegian mainland exports to the EU (Berg-Hansen, 2013, regjeringen.no). Moreover, of the 1,31 million tonnes of fresh fish exported every year, about 81 percent is transported using road- based transportation. The remaining 19 percent is made up by airfreight (11 %) and ship freight (8 %). Thus, with an average transportation cost of 2 NOK/kg for road-based transport, and a transportation cost of 11 NOK/kg and 1,5 NOK/kg for airfreight and ship freight respectively (Asche & Tveterås, 2011) (Det Kongelige Kyst- og fiskeridepartement, 2013), the total scope of transport for fresh fish within the Norwegian aquaculture industry amounts to roughly 3,858 billion NOK. (See appendix for calculations)

Aquaculture. Preliminary figures	Fish for food (tonnes)	Share	Per cent	First hand value	Per cent
			2014 - 2015	(NOK million)	2014 - 2015
2015					
Total	**1 390 906**	**100.0**	**4.4**	**46 720**	**5.4**
Salmon	1 314 584	94.5	4.5	44 323	6.0
Rainbow trout	71 991	5.2	4.4	2 191	-5.0
Char	257	0.0	:	16	:
Cod	:	:	:	:	:
Halibut	1 277	0.1	1.6	145	27.4
Shellfish	2 587	0.2	28.3	28	97.2
Other fish species	:	:	:	:	:

Table 2: Aquaculture preliminary figures (SSB 2016A, ssb.no)

Due to the fact that such a high percentage of both the total production, as well as the total revenue, are generated through the export of Atlantic salmon, it is needless to say that the Norwegian aquaculture industry is highly dependent on the price of Atlantic salmon. The price is calculated per/kg of fresh unprocessed Atlantic salmon. This is a highly volatile figure dependent not only on market supply and demand, but also on fluctuations in various currencies, both foreign and domestic. The Norwegian aquaculture industry has over the last year been experiencing a highly prosperous period with high and steady prices. This is partly due to the fact that the Norwegian economy is highly dependent on the price of crude oil. Hence, after the recent crisis in the petroleum industry, the exchange rate for Norwegian kroner also declined. In turn, this increased the relative purchasing power of foreign countries, leading to increased demand, which acts inflationary on the price of salmon (Lilleby, 2016, e24.no). Another influencing factor is that Chile at the start of 2016 experienced a high number of salmon fatalities as a result of algal blooms in the Chilean ocean. This decreased the overall supply, which in turn inflates the prices (Parr, 2016, hegnar.no).

1.4.4 Atlantic salmon price/kg development

The figure below portrays the price development of unprocessed salmon over the last two and a half years. This is the price paid to the farmers (SjømatNorge, 2016A, akvafakta.fhl.no). Moreover, the figures are calculated based on the average value of an unprocessed salmon ranging between 1 - 9+ kg.

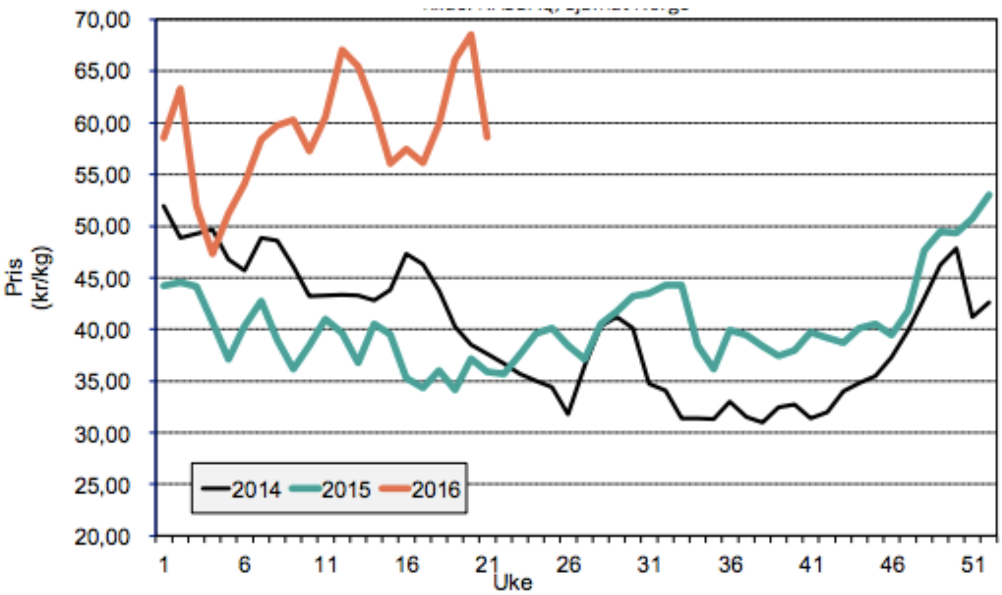

Figure 3: Development in price to farmer's pr. kg of salmon (SjømatNorge, 2016A, akvafakta.fhl.no)

1.4.5 The Norwegian aquaculture industry's supply Chain Layout

There are generally three different types of companies within the Norwegian aquaculture industry:

1. Large vertically and horizontally integrated companies, producing on a global scale with a yearly turnover of several billion NOK.
2. Mid-sized partly vertically integrated companies, producing on a national/regional basis with a turnover of several million NOK.
3. Local companies producing within their own region, with a turnover of some tens million NOK. (Asche & Tveterås, 2011)

After the liberalization of the Norwegian aquaculture act in 1991, the industry experienced an increased concentration of locations and facilities. "Smaller local companies developed into regional companies, and went from having 5 to 20 licenses, usually vertically integrated with hatchery production backwards and processing facility forwards in the chain" (Hovland et al., 2014, p. 249). “After the Norwegian government relaxed their regulation on horizontal integration in salmon farming in the beginning of the 1990´s, a mergers and acquisitions process started that changed the industrial structure significantly. Several hundred farms were integrated into larger companies” (Tveterås et al., 2004, p. 12). In turn, this development led to an industrialization of the industry, “where every link of the value chain was streamlined through close relationships between the farmers, the feed and equipment vendors, and various research institutes” (Hovland et al., 2014, p. 249)

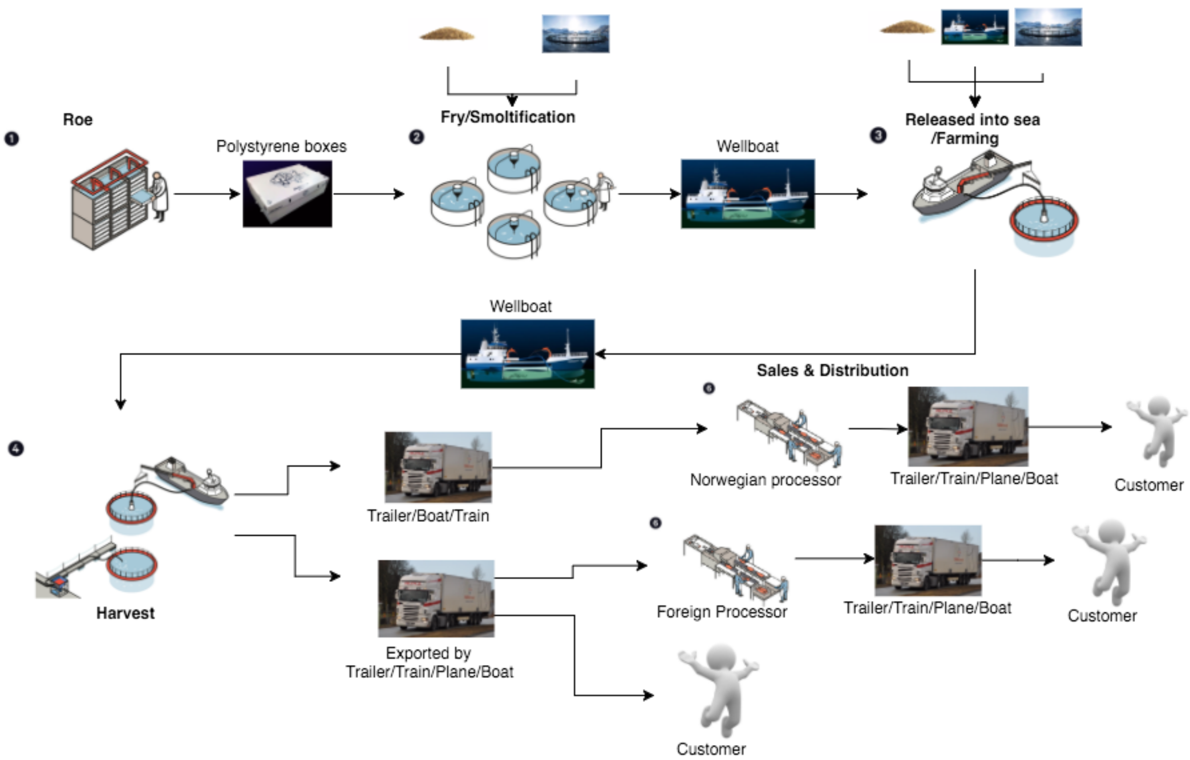

Figure 4: Generic supply chain layout of the Norwegian aquaculture industry (Marine Harvest, 2015, p. 30)

The generic supply chain model in figure 5 is based mainly on “type 1” companies. This is large vertically and horizontally integrated companies that keep most parts of their supply chain “in house”. This also encompasses subsidiary companies within the consolidated financial company. Furthermore, as the figure illustrates, the supply chain starts in onshore incubators with the production of roe. In this process eggs and sperm are collected from parent fish and put together in order to produce roe. The parent fish, referred to as broodstock, are fish that are specifically chosen due to specific desirable genetic abilities such as; high growth rate, maturation rate, fat content, etc. (Aquagen, 2005, aquagen.no). Moreover, these fish are used for artificial precreation purposes only. The company will either have its own broodstock strain, or insource roe from another company. This process has a total production time of approximately 60 days.

Furthermore, the hatched larvae are then transferred in polystyrene boxes to onshore fresh-water fish tanks, where they are going through a transition period in order to get ready to be released into the ocean. This process is called smoltification. This can either be done “in house”, often by a subsidiary company, or outsourced to companies that specialises within the area of smolt production. This entire process takes between 10-16 months. (Marine Harvest, 2015)

After the smoltification process has ended, the fry are transferred to seawater locations. This is done by wellboats. The wellboats are often insourced from other companies specializing in transportation of fish. The smolt is then kept in sea for about 12 months until it has reached 4-5 kilos, and is ready to be harvested. Both during the “farming” and the smoltification process, the production is relying on various inputs from wellboat vendors, feed vendors, and service- and equipment vendors. This encompasses all from feed and transportation between offshore facilities, to net-cages, feeding machinery, and surveillance systems. The production time is highly dependable on sea temperature, as the growth of salmon will stagnate under suboptimal sea temperatures. Thus, the growth phase in sea may vary as much as from 12-24 months, increasing the total production cycle time by another 12 months. Hence, the total cost of the various inputs will increase the longer the production cycle. (Marine Harvest, 2015)

The next step in the supply chain is the harvesting process. The fish is transported by wellboats from offshore facilities to an onshore facility. Here the fish is euthanized, gutted, and packed in cooling boxes. The product is then either shipped abroad directly, or delivered to a Norwegian processor for further processing. This is usually carried out by trailers, trains, ships or by planes, depending on the destination of the product, as well as whether the product is fresh or frozen.

Normally, farmers will deliver head on gutted (HOG) fish to the subsequent stage in the supply chain, where it is processed further. However, this is also product dependent, as the utilization and application of the “products” varies across different species. Furthermore, the processing includes primary- and secondary processing. The primary processing (e.g. fileting) is often conducted by a Norwegian processor, while the secondary processing (e.g. smoked salmon) is usually performed by foreign processors. For vertically integrated aquaculture companies, this stage is performed “in house”, often by a subsidiary company. This is typically outsourced for non-vertically integrated companies. Both the integrated and the external processors normally buy the fish on a spot market prize. This essentially means that they´re key input is exposed to a lot of risk in terms of price variations, variable delivery times, and variation in size and volume. The processors then sell the product to retailers, wholesalers, or distributors. This is often arranged through prearranged contracts, with strict requirements in terms of delivering in accordance to timing, regularity, quantity, price and quality. In the downstream end of the supply chain, the product is linked to the customer through retailers, wholesalers, or distributors. Nowadays, retailer's accounts for as much as 60-90 percent of the purchase of imported salmon in many European countries. (Tveterås et al., 2004) (Marine Harvest, 2015)

Lastly, as figure 5 illustrates, transportation is a vital element of the aquaculture supply chain. In general, fresh fish has a durability of approximately 2-3 weeks from the time the fish is harvested. As most of the fish is sold fresh, both farmers and processors operate within a tight timeframe in order to reduce lead-times in the production cycle. Thus, they are highly dependent on both an efficient and reliable transportation system. (Marine Harvest, 2015)

2.0 Theory

As previously mentioned, the purpose of this thesis is to identify how the Norwegian aquaculture industry can benefit from utilizing IoT and the PI in their supply chain. The theoretical foundation will therefore primarily be based around relevant aspects of Supply Chain Management, IoT, and the PI. Moreover, this chapter will include theory regarding:

Table 3: Overview of theory

Supply Chain
Forecasting
Inventory Management
Just-In-Time
Logistics Requirements Planning
Logistics Management
Facility and Warehousing
Operation of Facilities
Transportation
Sourcing
Vertical- and Horizontal Integration
Internet of Things
Physical Internet

2.1 Supply Chain

"A *supply chain* consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves" (Chopra & Meindl, 2013, p. 13). Moreover, the supply chain describes the process of delivering a product or service from start to finish. To produce a product or deliver a service, companies often need to depend on their suppliers complete the order. In addition, depending on the scope of producing a product/service, a company`s supply chain can be complex networks. Factors such as cooperation, communication, and supply chain decisions are therefore essential to deliver the final product as agreed, on time without any defects and waste. Moreover, Feller et al. (2006) defines the supply chain as a process where the flow of goods and materials moves downstream, starting with the suppliers and ending with the finished good at the customer.

Furthermore, it is important to define the distinction between a supply chain and value chain to clarify the differences. Feller et al. (2006) describes that a value chain flows the opposite way of a supply chain, namely upstream. "The customer is the source of value, and value flows from the customer, in the form of demand, to the supplier" (Feller et al., 2006, p. 4). Moreover, they explain that "the primary difference between a supply chain and a value chain is a fundamental shift in focus from the supply base to the customer. Supply chains focus upstream on integrating supplier and producer processes, improving efficiency and reducing waste, while value chain focus downstream, on creating value in the eyes of the customer" (Feller et al., 2006, p. 4).

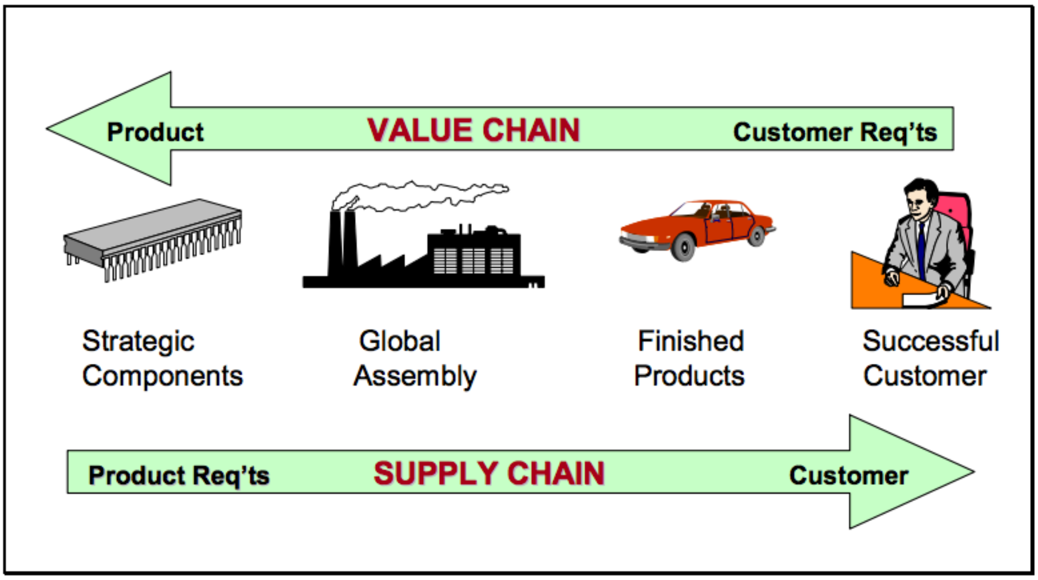

Figure 5: Comparison of a Value Chain with a Supply Chain (Feller et al., 2006, p. 2)

Next, Supply Chain Management (SCM) is the integration of all the activities in the supply chain. Moreover, SCM can be defined as "a set of activities through which we can arrange and integrate the stakeholders of the Supply Chain Process, as follows" (Siddiqui, 2010, p. 7-8):

- Suppliers
- Customers
- Distributers
- Transporter
- Warehouse
- Production

Furthermore, Mentzer et al. (2001) defines a supply chain as *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, and/or information from a source to a customer"* (Mentzer et al., 2001, p. 4). Based on this definition, they classified three types of supply chains based on degree of complexity:

- Direct supply chain
- Extended supply chain
- Ultimate supply chain

Figure 6 pictures the differences between the supply chains, and the increasing complexity and collaboration between third-party providers from direct to ultimate supply chains.

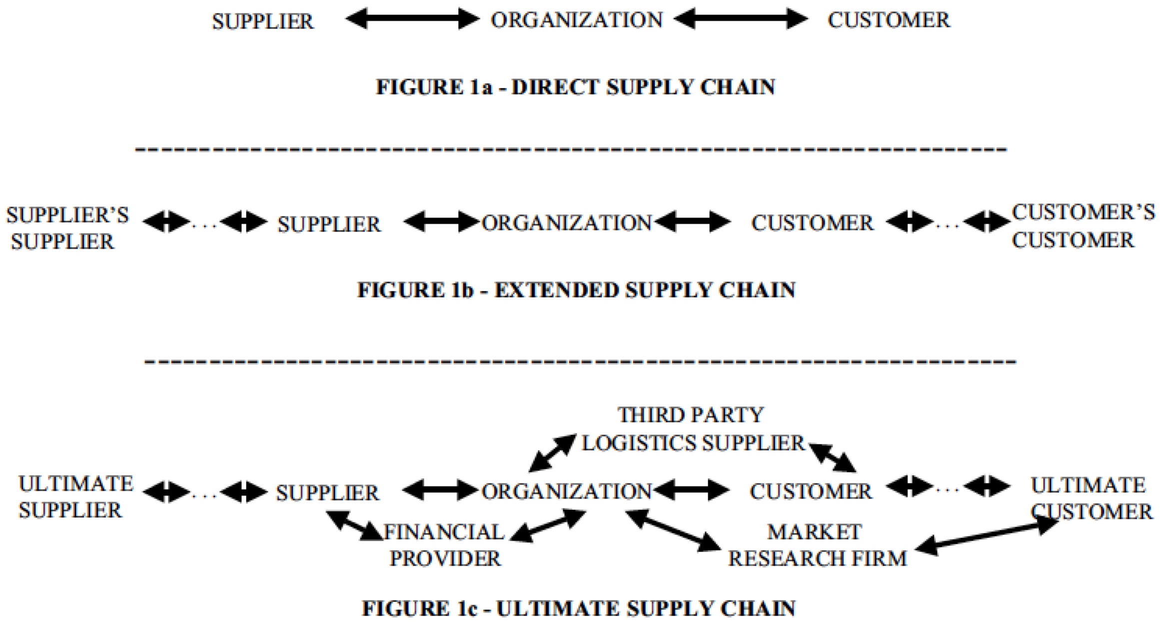

Figure 6: Types of Channel Relationships (Mentzer et al., 2001, p. 5)

First, a direct supply chain is defined by a supplier, organization and customer, which all partake in the activities of producing a product. Secondly, the extended supply chain is somewhat similar to the direct supply chain. However, in the extended supply chain the suppliers have their own sub-contractors and the customer is reselling the finished good. Lastly, the ultimate supply chain consists of a more complex network of activities. In the ultimate supply chain, the focal firm might be outsourcing some services to a third-party provider. This makes the different activities more complex, where many parties depend upon each other in the process towards finalizing a product.

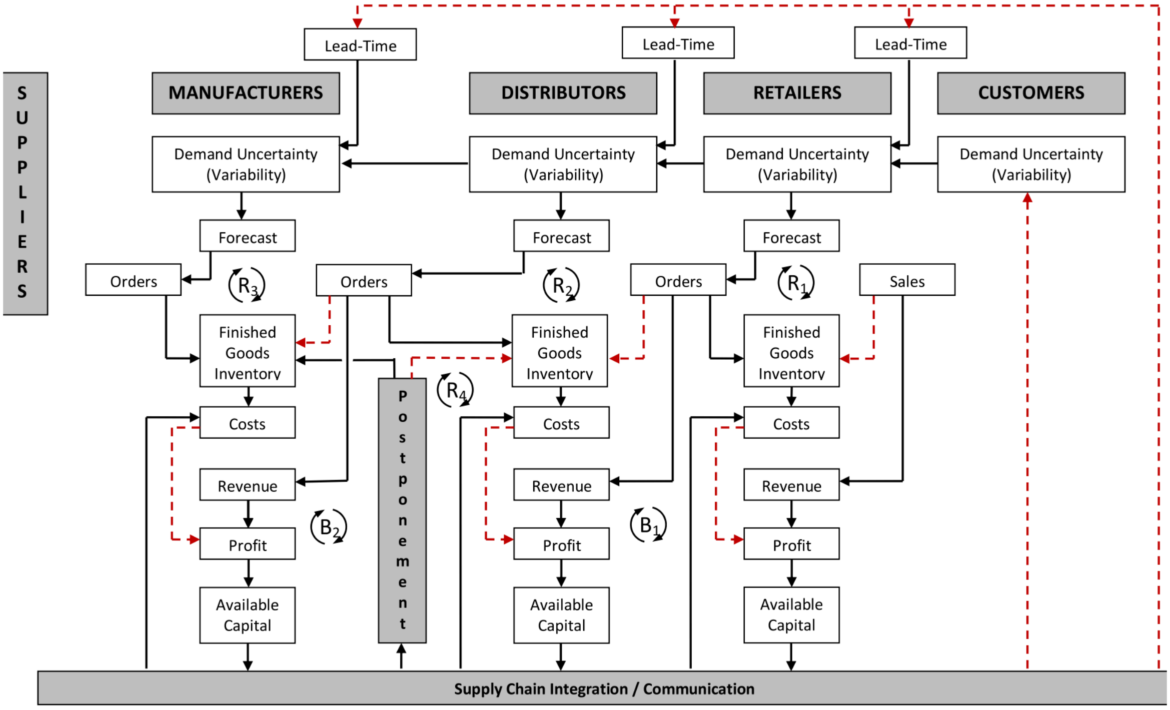

Figure 7: The closed-loop effect of supply chain integration in the food supply chain (solid lines denote direct relationship, dashed lines denote inverse relationship). (Kumar & Nigmatullin, 2011, p. 2154)

The figure above (figure 7), displays supply chain integration in a food supply chain. Moreover, Kumar and Nigmatullin (2011), explain that supply chain integration "allows lowering lead-time, leads to reinforcing relationships (higher supply chain integration and communication lead to lowering demand variability, which helps improve forecasts and reducing inventory. Lower inventory leads to lower costs and higher profits, thus, increasing available capital)" (Kumar & Nigmatullin, 2011, p. 2154-2155).

Furthermore, supply chain integration strengthens the relationship and communication between the different actors in the supply chain. This in turn helps to prevent variability of demand and the "bullwhip effect". Further, reduced variability contributes to lower inventory level and storage costs, which results in increased profits and available capital. This process can be seen in figure 7 as reinforcement loops (R1, R2, and R3). Moreover, Kumar and Nigmatullin (2011) also points out that supply chain integration forms balancing loops (B1 and B2), "where improved retailers' forecasts lead to reducing orders from distributors; which leads to reducing distributors' profit and available capital. A similar balancing effect occurs in the loop B2, which links the distributors' orders and manufacturers' profits" (Kumar & Nigmatullin, 2011, p. 2155).

Managing the supply chain and its components is a key factor in every organization. It helps to sustain a smooth flow of materials and products, which in turn will enable one to deliver high quality products on time. We will in the remaining paragraphs of the theory chapter discuss central concepts of the supply chain individually, and lastly describe important aspects of IoT and the PI.

2.2 Forecasting

Demand forecasting is an important activity in all organizations. Two important terms in this context is the push vs. pull processes. A push strategy is based on the expectation of future demand, long-term forecasts and current inventory levels. In contrast a pull strategy is based on the actual demand, and can be referred to as "make to order". Regardless of chosen strategy, forecasting and planning the level of activity is imperative.

Characteristics	Push portion	Pull portion
Objective	Minimize cost	Maximize service level through flexibility
Complexity	High	Low
Demand	High certainty	High uncertainty
Focus	Efficient resource allocation	Effective responsiveness
Lead time	Long	Short
Process	Supply chain planning according to forecast	Order fulfilment
Product	Standard	Customized or differentiated

Table 4: Characteristics of the push and pull portions of supply chains (Wessel & Vogt, 2012, p. 63)

First, it is virtually impossible to forecast one hundred percent accurately. That is when supply equals demand. However, the main purpose of forecasting is to generate good projections on average over time. Additionally, focusing on minimizing uncertainty and forecasting errors, will contribute to optimal utilization of the information and data available. Moreover, short-term forecasts are normally more accurate than long-term forecasts. This mainly due to the fact that short-term forecasts include fewer uncertainties. Furthermore, quantitative forecasting models can be applied if one has adequate historical data and information from past events. There exist two main categories of forecasting models within the category of quantitative forecasting. These are time series and explanatory models. Models for time series data are based upon the idea that future demand can be estimated from past values, while time series are a sequence of data made over intervals. Explanatory models on the other hand, incorporate relevant variables that will contribute to predict the variable of interest (e.g. demand). It is also possible to utilize qualitative methods in forecasting. These methods are relevant to apply if quantitative methods involve a high degree of uncertainty, or if one has inadequate historical data. Qualitative forecasting methods are a result of accumulated knowledge and judgment, which requires trained and skilled employees. However, if possible, both qualitative and quantitative methods should be combined to minimize uncertainty and make the forecast accurate. Lastly, it is important to forecast with respect to both short- and long time horizons. Organizations typically divide their forecasting into four categories. (Wessel & Vogt, 2012)

Table 5: Overview of forecasting

	Day-to-day forecasting	Short-term forecasting	Mid-term forecasting	Long-term forecasting
Scope	0-4 weeks	3-12 months	1-3 years	3-5 years

2.3 Inventory Management

Inventory management is an important part of the supply chain. The stock of raw materials, WIP, finished goods etc., can be an unfortunate expense if not utilized and organized effectively. Thus, an important aspect of inventory management entails balancing the trade-off between holding inventory as a precaution, versus the cost of holding it. Accurate forecasts can in this respect assist decision makers in planning optimal inventory levels. Wessel and Vogt (2012) explains that the important functions, and reasons why organizations hold inventory are:

- "Decoupling
- Balancing supply and demand
- Buffering against uncertainties in supply and demand
- Geographical specialization
- Preventing the cost of a stockout" (Wessel & Vogt, 2012, p. 218-219)

Thus, inventory is necessary for most organizations in order to maintain smooth operations. This can for instance be related to seasonal variations, peak demand, and various uncertainties in the market. However, holding more inventory than the cycle stock often incur unwanted and unnecessary costs. The costs of holding inventory are related to; capital costs, insurance, inventory risk costs and storage costs. Inventory is an opportunity cost since the money spent could have been invested in other profitable alternatives. Moreover, holding inventory requires insurance and costs related to storage. Inventory is also exposed to risks in terms of obsolescence, damage and shrinking. Hence, the cost of holding inventory versus safeguarding against uncertainty can often be a difficult trade-off. (Wessel & Vogt, 2012)

Considering the costs and benefits above, setting the optimal inventory level is key with respect to achieving the lowest possible costs and uncertainty for demand/supply. Another important consideration in that respect is:

- How much, and when to order?

One commonly applied method in inventory planning is called "economic order quantity" (EOQ). This method assists in balancing the costs of ordering and the costs of holding inventory, and calculates how much one should order with respect to minimize costs.

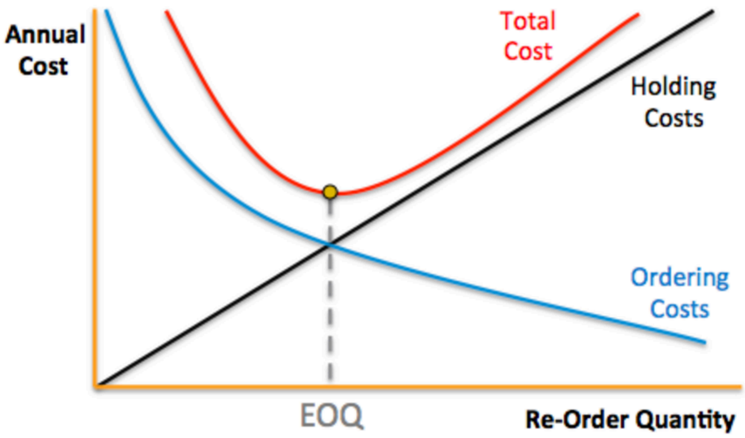

Figure 8: The economic order quantity (Dowling, 2014, eazystok.com)

Moreover, when quantity to order is determined, one has to decide when to order. The reorder point (ROP) defines when the reordering should take place. This implies that when the inventory reaches a certain level, a new batch of stock should be ordered. Hence, the ROP is defied in terms of demand and lead-time. Furthermore, one can separate between fixed-order and fixed-period systems. In a fixed-period system, new batches of inventory are being counted and ordered at the end of a set period. On the other hand, a fixed-order system is characterized by new batches of inventory being ordered when the stock reaches the ROP. Lastly, another important aspect of inventory management is the safety stock. The safety stock is a buffer to hedge against stockout. Thus, one has to take factors such as uncertainty and variability in demand into account. The main purpose is to prevent a decrease in service level during the lead-time. (Wessel & Vogt, 2012)

2.4 Just-in-time (JIT)

JIT is another popular inventory strategy firstly introduced by Toyota and their production system called TPS (Toyota Production System). The sole purpose of JIT is to reduce inventory and the associated holding costs. Moreover, JIT focus the attention on rapid throughput and short lead-time, which is characterized by the pull system mentioned previously in the theory chapter. This implies that "materials arrive *where* they are needed only *when* they are needed" (Heizer & Render, 2014, p. 664). Furthermore, another important feature of JIT is the fact that the approach focuses on problems, meaning that the method seeks to improve all parts of the supply chain. Non-value adding activities should be removed. "By driving out waste and delay, JIT reduces inventory, cuts variability and waste, and improves throughput" (Heizer & Render, 2014, p. 664). This in turn can potentially result in a competitive advantage, offering flexibility in the supply chain with rapid response and high quality at a low cost.

Conventional system	JIT system
Push system	Pull system
Satisfied with status quo	Continuous improvement
Fixed lead time	Reducing lead time a continuous challenge
Product range is a sales issue	Product range reduction an inventory issue
Stock in case of customer demand	Purchase to meet demand rate
Convenient purchase batch size	Buy singly or small quantities

Table 6: Difference between conventional and JIT systems (Wessel & Vogt, 2012, p. 243)

2.5 Logistics requirements planning (LRP)

"Logistics requirements planning (LRP) is a scheduling technique that ensures that the right goods are available at the right place, at the right time and in the right quantities. It is a logical integration of distribution requirements planning (DRP) and material requirements planning (MRP) across the supply chain" (Wessel & Vogt, 2012, p. 238). Furthermore, MRP is a method that applies bill-of-material (BOM), inventory and a master production schedule (MPS) to determine the amount of material needed. DRP on the other hand is defined as a" time-phased stock-replenishment plan of for all levels of a distribution network" (Heizer & Render, 2014, p. 608). MRP is a dependent demand technique, whereas DRP revolves around independent demand. The difference between independent and dependent demand is the fact that independent demand is not related to demand for other items. Moreover, independent demand can be calculated, while dependent demand must be forecasted. The objective of LRP is to "reduce total inventory in the supply chain by reducing the reliance of the demand for all items on forecasting" (Wessel & Vogt, 2012, p. 239). LRP and the relationship between MRP and DRP are illustrated in the figure below. MRP is visualized in the box described as "material management", and DRP as "business logistics".

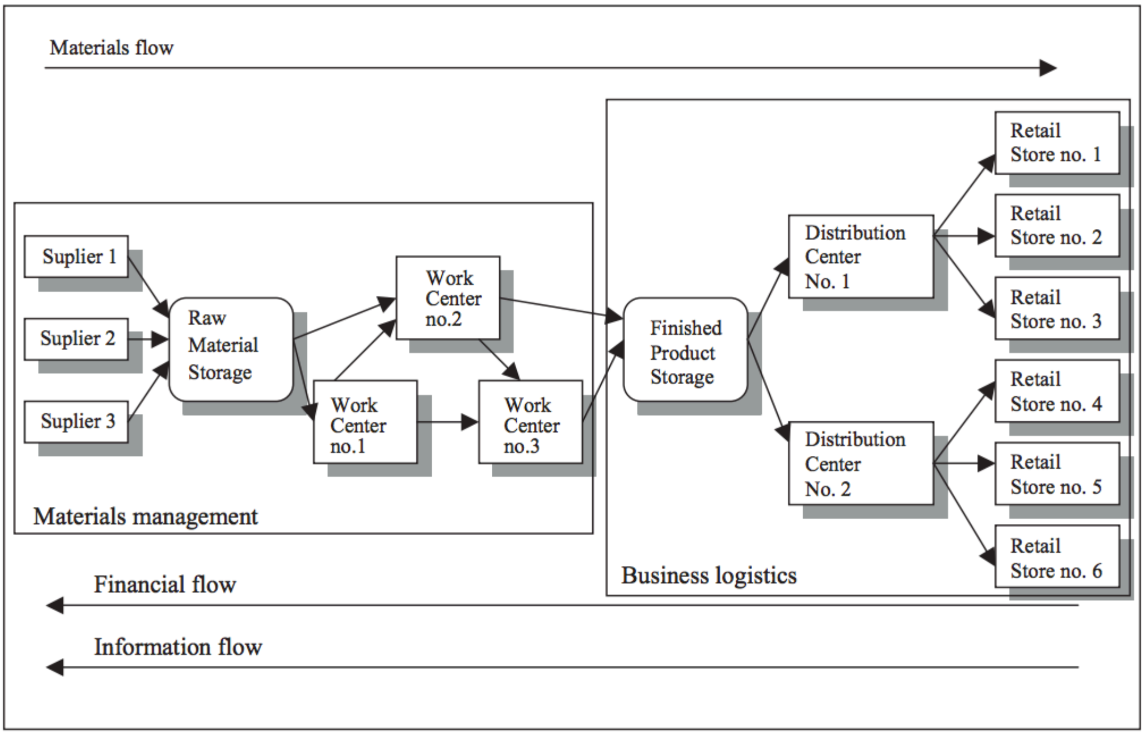

Figure 9: Scope of LRP (Bogataj & Bogataj, 2004, p. 148)

2.6 Logistics Management

Logistics can be defined as "*the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from their point of origin to point of consumption for the purpose of conforming to customer requirements*" (Kannegiesser, 2008, 29). Thus, the main objective of logistics is to manage and allocate resources efficiently throughout the supply chain, from supplier to customer. Additionally, Kannegiesser (2008) divides logistics into four categories pictured in the figure below.

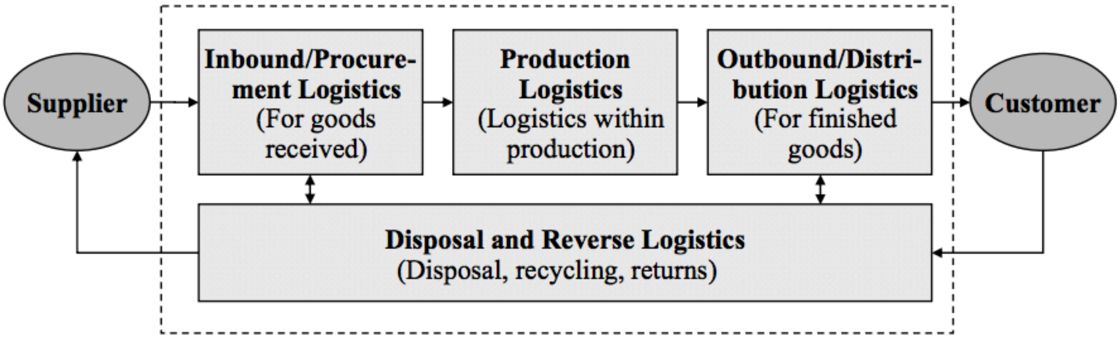

Figure 10: Types of logistics (Kannegiesser, 2008, p. 29)

Furthermore, the research conducted by Islam et al. (2012) stresses that there could be confusion about defining the term logistics. This as a result of a wide array of terminologies trying to describe the application of logistics. However, the authors point out that "logistics involves an integrated approach with the integration of information, transportation, inventory, warehousing, material handling, and packaging, and recently added security" (Islam et al. 2012, p. 4). Moreover, they explain that there are five central elements in logistics management:

- Transport
- Warehousing
- Inventory
- Packaging
- Information processing

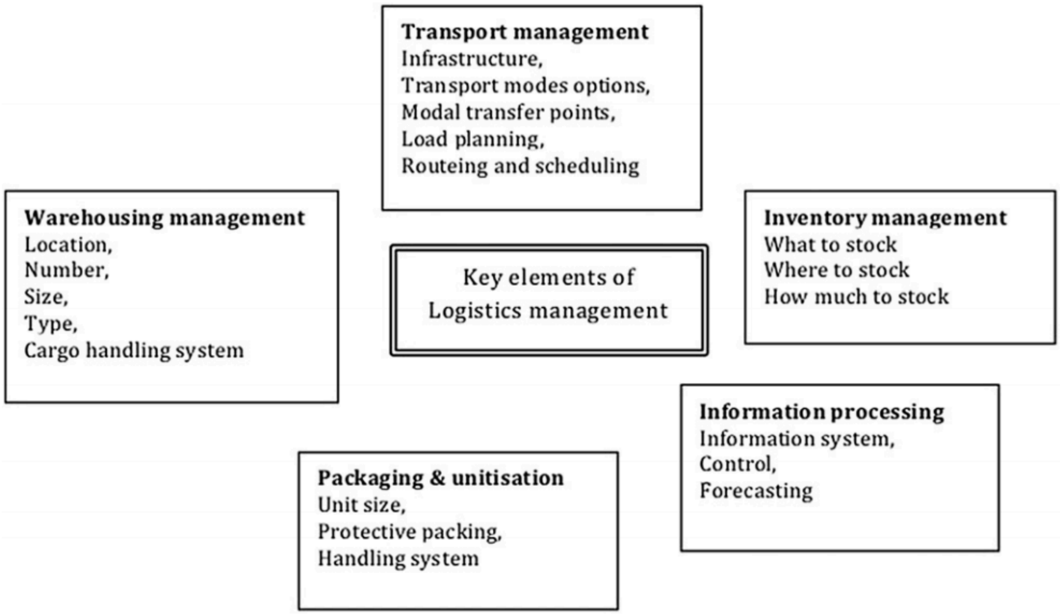

Figure 11: Key elements of logistics management (Islam et al, 2012, p. 5)

2.7 Facility and warehousing

Wessel and Vogt (2012) explain that physical facilities are key in logistics networks. The most commonly applied facilities are with respect to storage, manufacturing, warehousing and distribution centers. Decisions regarding design and layout of these facilities can be decisive for an organizations survival. These decisions affect the flexibility and ability to deliver in the long term. Layout and design of facilities are also important as markets and demand for products change. It is therefore imperative that the design of a facility can be transformed in line with market changes, to maintain its efficiency with respect to costs as well as resource and space allocation. Additionally, Wessel and Vogt (2012) explain that two important features concerning design and layout of a facility are:

- The purpose of the facility
- The growth forecast for the facility over its lifetime

Facilities are long-term investments and an important part of the supply chain. Having the opportunity to expand and keep efficient operations is key. Further, additional factors that affects the cost regarding size of facilities are:

- “Customer service levels
- Size of market(s) served
- Number of products marketed
- Size of the products
- Materials-handling system used
- Inventory turnover
- Aisle requirements
- Office area requirements
- Production lead times
- Types of racks and shelves used
- Level and pattern of demand” (Wessel & Vogt, 2012, p. 258)

Wessel and Vogt (2012) explain that variation in market conditions can result in new requirements for any of these factors. This implies that forecasting as well as layout and design of facilities are important to minimize costs as markets change. Moreover, location of the facilities and proximity to transportation routes are important logistical decisions with regards to distribution. This will be reviewed later in the theory chapter.

2.8 Operation of facilities

“The functions of a warehouse are conceptually very simple: to receive goods into the facility, to store these goods and, when required, to dispatch the goods” (Wessel & Vogt, 2012, p. 311). However, managing these activities is often more challenging, since the flow of processes must be performed perfectly. It is therefore key to monitor and control the movement of inventory to prevent errors. Moreover, Wessel & Vogt (2012) points out that the most important factor in the warehouse is the stock. Further, they explain that stock is managed by a process consisting of three steps:

- “Each pick and delivery of stock must be completed accurately and recorded accurately as completed
- Each receipt of stock must be completed accurately and recorded accurately as completed
- Stock must be audited continually (i.e. counted, and the physical goods matched to the information recorded in the system) via cycle counts” (Wessel & Vogt, 2012, 314)

Furthermore, as mentioned, there exist different warehouses all serving their own purpose. Common for these facilities are the fact that they all have receive and dispatch operations, and they store and track the stock. However, there is one exception, namely facilities operating as cross-docks. Application of cross-dock facilities is often related to distribution centers (DC), where the goods are being sorted and subsequently transported to the next destination. The efficient operation of sorting goods in a cross-dock facility implies that the goods are being organized without any storage. "A cross dock differs form a warehouse, in that it is more like a continuous process of removing goods from one inbound transport and sorting them directly into an outbound transport" (Wessel & Vogt, 2012, p. 315).

Further, Wessel and Vogt (2012) emphasize that efficiency is key for the operations within a facility. "There are only two desired areas of storage in a facility: the long-term storage areas (including the pick faces) and the dispatch assembly area, where goods are accumulated to build a load" (Wessel & Vogt, 2012, p. 317). Storing goods in other areas is considered inefficient. Besides, tracking and monitoring the location of the goods at all times are essential for efficient delivery and operations.

2.9 Transportation

The transportation of goods is an important part of the supply chain, and often a costly and expensive activity. Moreover, there are three common methods of moving freight; by land, air and water. These transportation methods can again be divided into sub-categories. Transportation by land is usually utilized through roads and rail, whereas water transportation can be divided into carriage by sea and inland water transportation (e.g. rivers and canals) (Wessel & Vogt, 2012)

2.9.1 Road transportation

Transportation by road is a common approach for carrying freight over long and short distances. This because of available and widespread road networks, and the fact that the method offers point-to-point service. In turn, accessibility with respect to infrastructure makes this form of freight transportation flexible and versatile. Besides, transportation by road offers reliable service with a low degree of damage/waste during transit (Wessel & Vogt, 2012)

2.9.2 Rail transportation

Rail transportation is a dominant method of carrying freight in large parts of Europe and Asia. In contrast to road transportation, which offers point-to-point service, rail transportation provides terminal-to-terminal service. This implies that freight transportation by rail is limited to fixed routes, and it is less flexible than road transportation and the extensive road networks. However, rail transportation is a cost efficient method of carrying freight relative to weight (Wessel & Vogt, 2012)

2.9.3 Sea transportation

Transporting freight on the ocean can be a cost efficient approach for long distance transportation, especially with respect to high-volume batches. However, ocean carriage has become a highly specialized practice, meaning that vessels often are being constructed to carry one specific commodity. This implies that ocean carriage in most cases involves large investments with respect to the acquisition of vessels. Nevertheless, one has the opportunity to achieve a low costs advantage by applying freight transportation on the ocean (Wessel & Vogt, 2012)

2.9.4 Air transportation

Airfreight is the carriage that offers the shortest time in transit of the mentioned transportation alternatives. However, this method of transporting goods is also one of the most expensive options. Moreover, airfreight is frequently used to transport perishable commodities due to quality issues and transit time. Additionally, transporting goods by air can be utilized to deliver urgent consignments, and deliveries to remote locations. (Wessel & Vogt, 2012)

Table 7: Strengths of the different transportation options

Road transportation	Rail transportation	Sea transportation	Air transportation
Flexible point to point service	Cost- and energy efficient over long distances	Long distance	Long distance
High degree of accessibility	High capacity	Low costs if one is carrying high volumes over long distances	Short time in transit
High frequency	Can carry most types of commodities	High capacity	Standardized packing units
Short lead-times over small distances	Low risk with respect to weather conditions	Standard intermodal containers	Cargo is not exposed to harmful in-vehicle conditions for long periods

Road transportation	Rail transportation	Sea transportation	Air transportation
Limited carrying capacity	Long transit time	Long transit time	High unit cost per consignment
High environmental impact and energy consumption	Low frequency	Low frequency	High environmental impact and energy consumption
Vulnerability to external factors (traffic and weather)	Low flexibility (fixed track)	High risk with respect to weather conditions	High risk with respect to weather conditions

Table 8: Limitations of the different transportation options

This demonstrates that several factors must be carefully assessed when considering different transportation options. “The lower the cost per unit of output (without sacrificing service quality) in relation to the value or price of the delivered product, the greater the efficiency of the logistics process” (Wessel & Vogt, 2012, p. 352). Further, transportation is closely related to the facilities and their proximity to road networks, terminals, airports etc. Proximity influences flexibility and mobility by narrowing and restricting some transportation alternatives. Lastly, Wessel & Vogt (2012) points out that the most important aspects that influence the transportation costs are:

- “in-transit care – necessitated by the intrinsic properties of goods;
- density of goods – represented by their mass-to-volume ratio;
- size and divisibility – determined by the physical dimensions of a consignment;
- stowage ability and ease of handling – determined by the form of goods; and
- potential liability of goods, determined by their value-to-mass ratio, fragility, susceptibility, to theft and pilferage, and potential hazardous characteristics” (Wessel & Vogt, 2012, p. 341)

2.10 Sourcing

An important supply chain decision with respect to logistics is choosing the correct sourcing strategy. First and foremost, sourcing address the decision of “make or buy”. “Outsourcing refers to the process whereby activities traditionally carried out internally are contracted out to external providers” (Domberger, 2008, p. 12). In other words, sourcing concerns the decision of keeping selected activities in-house, or sourcing the process to external providers. Furthermore, “sourcing decisions are crucial because they affect the level of efficiency and responsiveness the supply chain can achieve” (Chopra & Meindl, 2013, p. 66). This implies that choosing the right sourcing strategy can be crucial for the competitiveness and survival for an organization. Moreover, before deciding to outsource an activity one should identify the organizations core competencies. The core competencies are the skills and capabilities, which gives the organization a competitive advantage in the market. After identifying the core competencies, one can outsource the activities that does not add value.

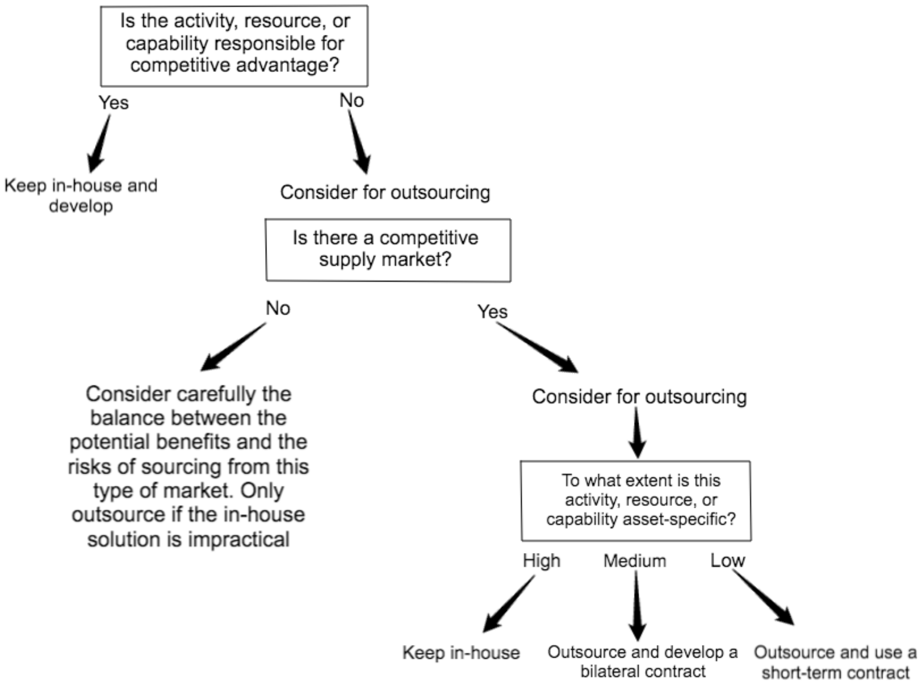

Figure 12: Logistics outsourcing (Brewer, Button & Hensher, 2001, p. 255)

2.11 Vertical and horizontal integration

Vertical integration refers to a company`s acquisition of another company, which is either up- or downstream in the supply chain. This is done in order to decrease dependability of suppliers, and /or to reduce costs. A vertical integration can be either forward or backward. Forward integration refers to acquisition and control of the post-production process (distribution and sales). On the other hand, a backward integration is characterized by acquisition of actors producing inputs (pre-production process). (Tarver, 2016, investopedia.com)

Horizontal integration concerns acquisitions of about equal companies operating in the same industry. Moreover, horizontal integration is not characterized by new operations, but rather an extension of existing operations. "When a company wishes to grow through a horizontal integration, it is seeking to increase its size, diversify its products or service, achieve economics of scale, reduce competition, or gain access to new customer markets" (Tarver, 2016, investopedia.com).

BASIS FOR COMPARISON	HORIZONTAL INTEGRATION	VERTICAL INTEGRATION
Meaning	When two firms combine, whose products and production level is same, then this is known as Horizontal Integration.	Vertical Integration is when a firm takes over another firm or firms, that are at different stage on the same production path.
Objective	Increasing the size of the business	Strengthening the supply chain
Consequence	Elimination of competition and maximum market share.	Reduction of cost and wastage.
Capital Requirement	Higher	Lower
Self-sufficiency	No	Yes
Strategy used to exercise control over	Market	Industry

Table 9: Comparison Chart (Surbhi, 2015, keydifferences.com)

2.12 Internet of Things

Haller et al. (2008) defines IoT as "*a world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these "smart objects" over the Internet, query their state and any information associated with them, taking into account security and privacy issues*" (Haller et al., 2008, p. 2). IoT has been a widely used term since its first introduction by Kevin Ashton in 1999. Ashton worked at Massachusetts Institute of Technology, and the main/first research of IoT was based upon RFID infrastructures. However, since the origin of IoT, the application and features have expanded. IoT is an important asset in terms of creating new business opportunities, and achieving a competitive advantage in the market. We will now address the most important aspects and applications of IoT. (Wortmann & Flüchter, 2015)

2.12.1 RFID and WSN

First and foremost, radio frequency identification (RFID) and wireless sensor networks (WSN) are important features of IoT. RFID is a technology, which enables the identification of objects through wireless communication (radio waves). RFID technology can yield significant improvements with respect to efficiency, warehouse management and operations in general, by enabling automatic tracking of goods. WSN technology is related to sensors and the ability to collect, analyse and monitor data from environmental conditions. (Gubbi et al., 2012) Moreover, Haller et al. (2008) explains that this type of technology enables real-world visibility. This implies that one have the ability to track and monitor goods and performance in real-time. Besides, data collected from sensors enables management to control what was previously uncontrollable through finer granularity. Furthermore, “the increased accuracy and timeliness of information about the business processes provides competitive advantages in terms of process optimisation” (Haller et al., 2008, p. 3).

2.12.2 Architecture of IoT systems

Wortmann and Flüchter (2015) explain that the implementation of IoT-systems consists of several multilayer stacks of technologies. This includes a combination of software and hardware components. The IoT technology stack is pictured in figure 13. Moreover, the architecture of IoT-systems differs between companies with respect to application and industry respectively. However, the stack of technology generally consists of three core layers:

1) The thing or device layer
2) The connectivity layer
3) IoT cloud layer

The device layer includes hardware and software. This may be RFID tags, sensors, GPS etc., and the software to control and operate the functionality of the physical object. Next, the connectivity layer contains communication protocols between the physical object and the cloud. This can for instance be accomplished by utilizing Message Queue Telemetry Transport (MQTT), which is an ISO standard. The final layer concerns the IoT cloud. At the cloud, “ device communication and management software is used to communicate with, provision, and manage the connected things, while an application platform enables the development and execution of IoT applications” (Wortmann & Flüchter, 2015, p. 222-223).

Furthermore, analytics tools are employed to analyse the collected data. Lastly, the IoT stack of technology also involves including identity and security aspects, and integration with other business systems and external sources of information. (Wortmann & Flüchter, 2015)

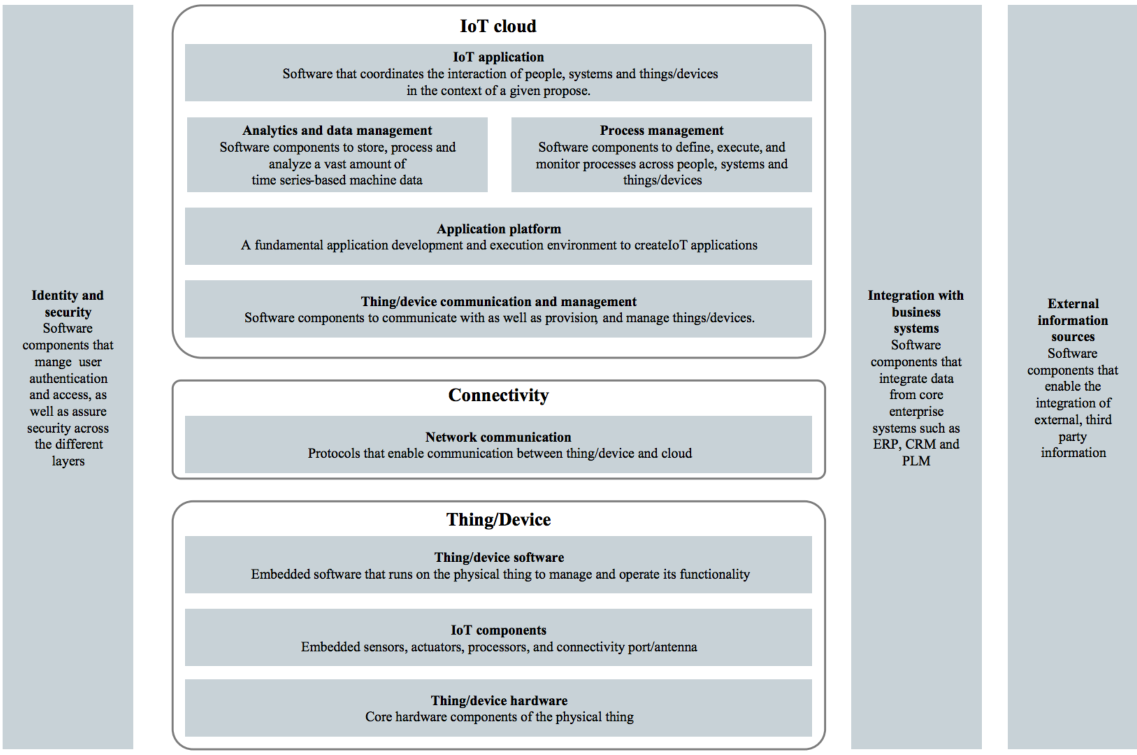

Figure 13: IoT technology stack (Wortmann & Flüchter, 2015, p. 223)

2.12.3 Supply Chain integrity

Furthermore, Haller et al. (2008) explain that utilizing technology such as RFID, GPS, and WSN, contributes to ensure complete integrity of the supply chain. As mentioned, this includes traceability systems to track the location of physical objects (RFID and GPS). However, to obtain complete integrity throughout the supply chain, other IoT features must also be included. This can be accomplished by integrating WSN technology (sensory technology). Achieving complete integrity of the supply chain ensures that the products have been handled according to contractual agreements and best practice. Furthermore, Haller et al. (2008) mentions a couple of examples that underlines the importance of complete supply chain integrity. First, sensors ensure that the products not have been exposed to any harming environmental conditions (e.g. temperature and humidity). Moreover, IoT ensures the integrity of transportation routes. Lastly, RFID and WSN sensors guarantee the integrity with respect to subcomponents of the final product. This implies levels of emissions and carbon footprint of transportation and production.

2.12.4 Application of IoT

The application and utilization of IoT are numerous, and divided across areas of use and industries. "The applications can be classified based on the type of network availability, coverage, scale, heterogeneity, repeatability, user involvement and impact" (Gubbi et al., 2012, p. 9-10). Moreover, Gubbi et al. (2012) categorize the application of IoT into four main domains:

- Personal and home
- Enterprise
- Utilities
- Mobile

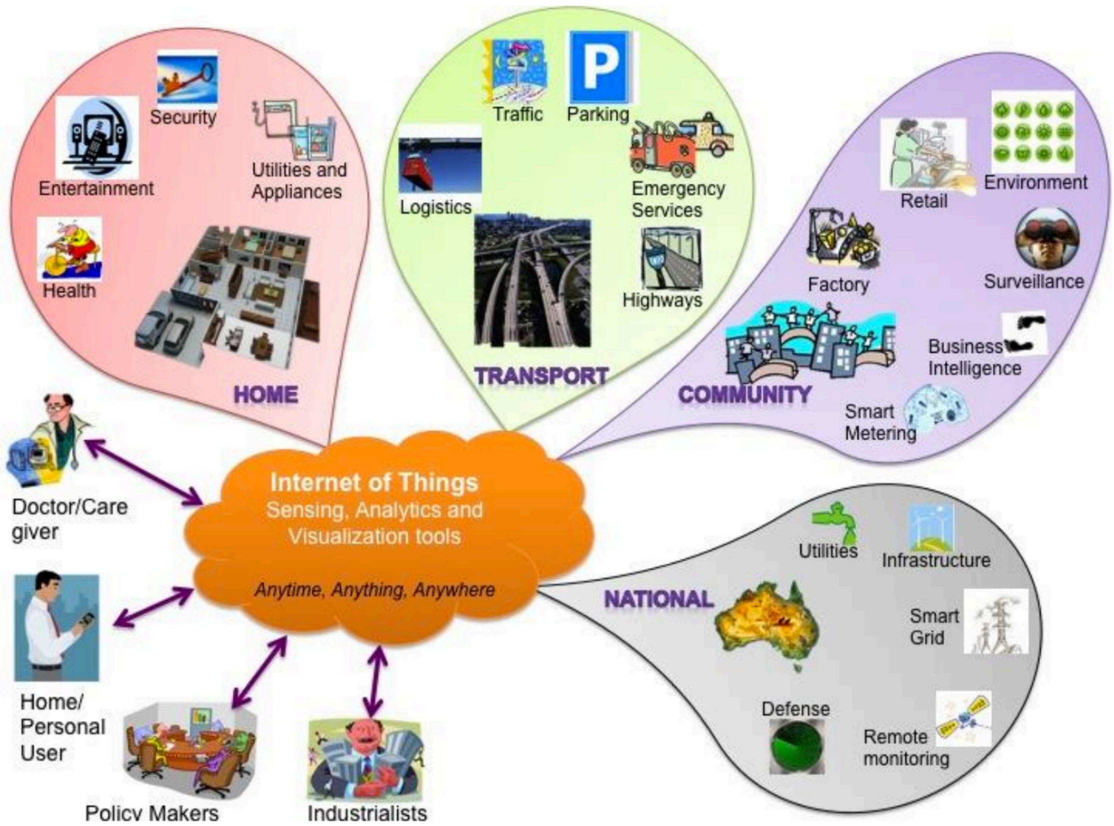

Figure 14: Applications of IoT (Gubbi et al., 2012, p. 3)

Despite the widespread areas of applications, the most interesting field of IoT-application in this thesis concerns transportation and logistics. Lacey et al. (2015) explain that applications of IoT within transport and logistics can be divided between demand and supply.

Environment monitoring & management	Threat detection & prevention	Real-time traceability
Systems that can monitor and adjust the temperature at which a package is maintained	Tools that can help detect unauthorized openings of shipping containers, helping to prevent and reduce theft	Systems that can track and track not just vehicles or shipments but individual items

Table 10: Common applications of IoT for logistics demand (Lacey et al., 2015, p.6)

Capacity sensing	Planning & reporting	Route optimization	Energy management	Fault detection & resolution
Systems that can detect and communicate open spaces in a warehouse, port, or parking lot	Systems that can detect and analyze events such as traffic accidents within a delivery network, allowing for more accurate delivery dates	Tools that can map the shortest or most fuel-efficient route for delivery vehicles, for example	Tools that monitor and enable decision making about the use of fuel, lighting, and heating/ cooling within vehicle fleets and facilities	Systems that can monitor fleets of vehicles, aircraft, or ships for faults and maintenance needs, improving uptime for the fleet

Table 11: Common applications of IoT for logistics supply (Lacey et al., 2015, p. 5)

The demand side of IoT-applications concerns the transportation of goods. “The value to customers is determined by the time, security, traceability, and condition of their cargo” (Lacey et al., 2015, p. 5). Hence, IoT can as previously mentioned contribute through RFID and WSN technology to provide high quality traceability throughout the supply chain. On the other hand, “the supply side includes warehouses, where goods are stored and forwarded; a transport network (roads/tunnels/sea/air); and the vehicles/vessels/crafts that are used to move goods from suppliers to warehouses and, ultimately, the customer” (Lacey et al., 2015, p. 5). IoT can on the supply side contribute by reducing costs, increase efficiency, reliability, optimize transportation routes etc.

2.12.5 Outlook

Macaulay et al. (2015) explain that there in 2020 is estimated that over 50 billion devices will be connected to the Internet. Moreover, these estimations indicate that 83 % will be related to IoT. Additionally, "in a study conducted with Forrester Research, enterprise IoT deployments have grown by 333 percent since 2012. According to the survey, 65 percent of respondents had deployed IoT technologies in the enterprise in 2014, compared to only 15 percent in 2012" (Macaulay et al., 2015, p.4). Furthermore, Macaulay et al. (2015) explain that 8 trillion dollars will be generated from IoT in Value at Stake over the next decade. Value at Stake can be defined as new profit stemming from markets created by IoT, which never could have existed without its presence. Besides, 1,9 trillion dollars will be generated from application of IoT in logistics. This implies that IoT potentially can contribute significantly with respect to improvements, cost reductions, and increased profits for the logistics industry.

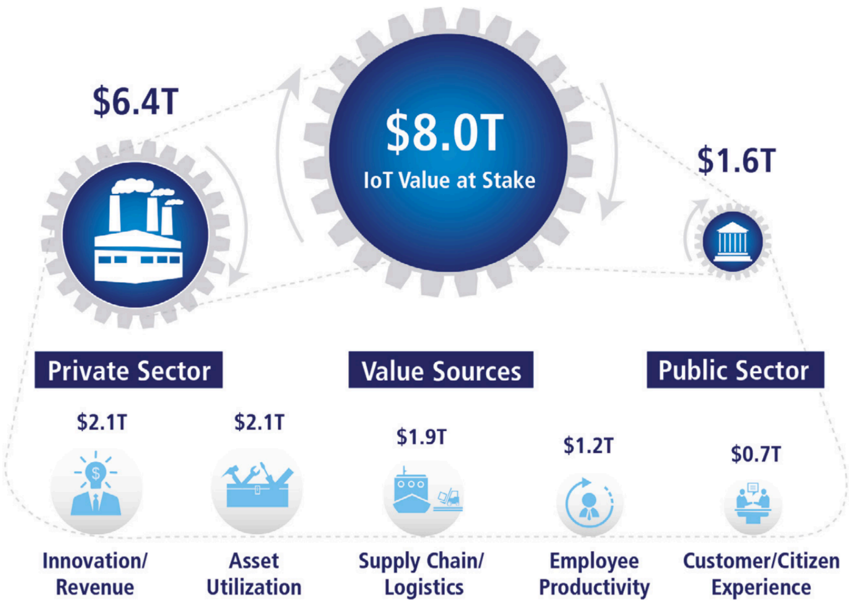

Figure 15: IoT Value at Stake (Macaulay et al., 2015, p. 5)

Further, it is key to invest in R&D of IoT to ensure a stable and rapid technological development. As a final comment, figure 16 displays the already existing benefits of IoT, as well as expected future applications.

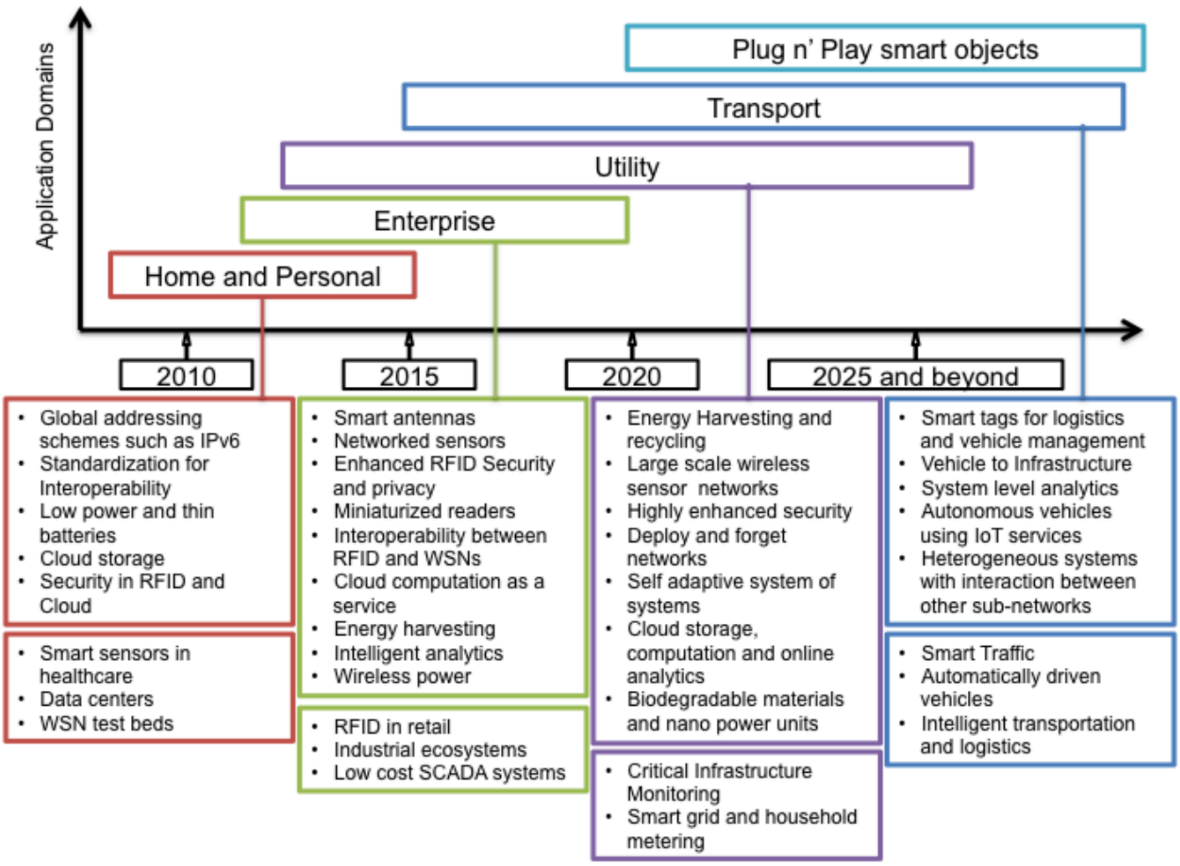

Figure 16: Roadmap of key technological developments in the context of IoT application domains envisioned (Gubbi et al., 2012, p. 20)

2.12.6 Industry specific theory of traceability

2.12.6.1 Architecture of traceability system

The architecture of a modern traceability system is described in figure 17 below. This system consists of four main components:

- Data input, RFID readers and Sensors
- Capture and query applications
- EPCIS repository and sensor database
- Web services

As the first component, RFID readers, sensors and data input devices are key to monitor location and relevant parameters of the fish. RFID readers are utilized to keep track of batch size and location, whereas the application for sensors (WSN components) monitories environmental conditions (e.g. temperature and humidity) during transportation and warehousing. Second, capture and query applications functions “as a connector to the traceability repository of the physical data received form the hardware devices and, at the same time, they allow external software to perform queries” (Parreño-Marchante et al., 2013, p. 100). Third, electronic product code information system (EPCIS) and sensor database are applied to store data from the performed operations. “In order to relate traceable units with their monitoring sensors or RFID data loggers, each EPCIS event is linked to the information stored in the Sensor Database using the timestamp and the unique identification (ID) of the sensor” (Parreño-Marchante et al., 2013, p. 100). Finally, as the last component, web services provide relevant data and information to the customer. This is carried out thorough a web browser, or/and mobile application.

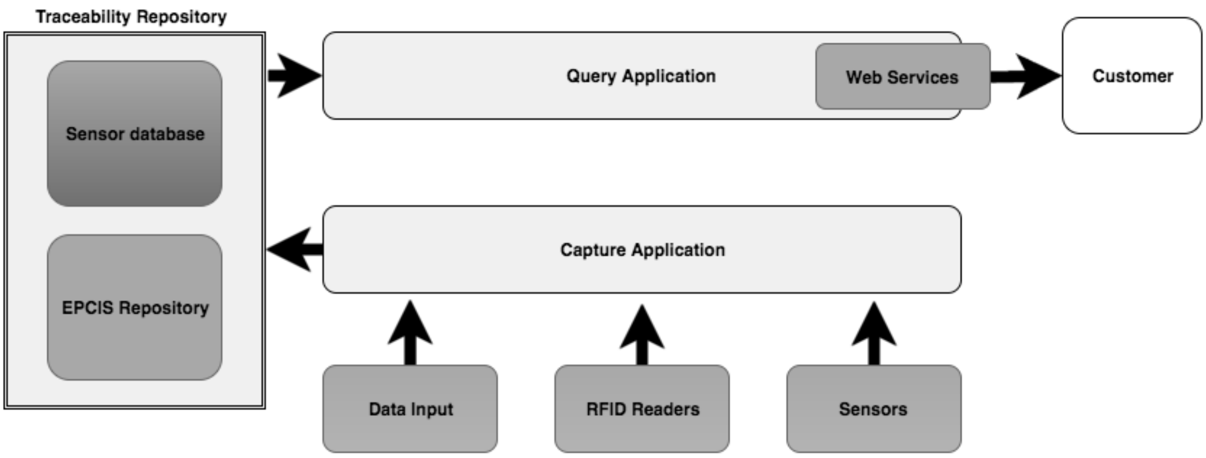

Figure 17: Architecture of the traceability system based on the EPC global network architecture that uses RFID and WSN technologies to collect information (Parreño-Marchante et al., 2013, p. 101)

In contrast, a manual traceability system is pictured in figure 18. In a manual traceability system, the information and data is collected by manual inspection. The information is filled into paper logs as the product flows throughout the different processes in the supply chain. Furthermore, at the end of the supply chain, the collected data are transferred from paper logs into Excel spreadsheets, or other relevant information systems. Thus, manual traceability is an inconvenient and time-consuming activity. Moreover, these processes are ineffective and can from a JIT perspective be regarded as waste. Furthermore, the transcription of information from paper logs to IT systems are susceptible for errors and loss of crucial data, which in turn will impact the quality of the final product.

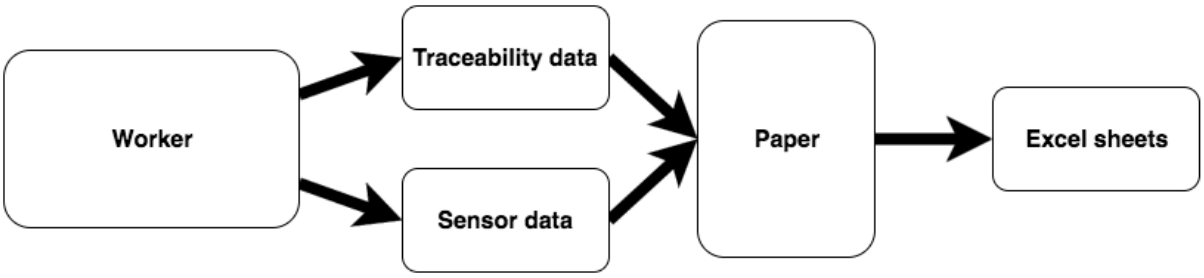

Figure 18: Traceability system based on manual collection of information (Parreño-Marchante et al., 2013, p. 102)

2.12.6.2 Granularity

Karlsen et al. (2010) explain that traceability can be implemented with respect to different levels of granularity (fine or coarse) depending on the scope. In turn, chosen level of granularity will influence the accuracy of traceability. “The level of granularity is determined by the number and size of batches. The granularity level will increase (finer granularity) with increased batch numbers and decreased batch sizes” (Karlsen et al., 2010, p. 8). Moreover, finer granularity enables more information to be assigned to the product, which results in greater control. However, finer granularity entails more work hours and thereby increased costs. This implies that defining level of granularity is a delicate balance of identifying the costs and benefits associated with the traceability system.

2.12.6.3 Internal vs. whole chain traceability

TraceTracker, is a leading company providing software solutions within the boundaries of asset tracking, product traceability and business intelligence. They stress that the aquaculture industry is facing serious challenges related to complex supply chains, regulations and competition. As a solution one can utilize electronic traceability systems. (TraceTracker, 2016A, tracetracker.com) (TraceTracker, 2016B, tracetracker.com)

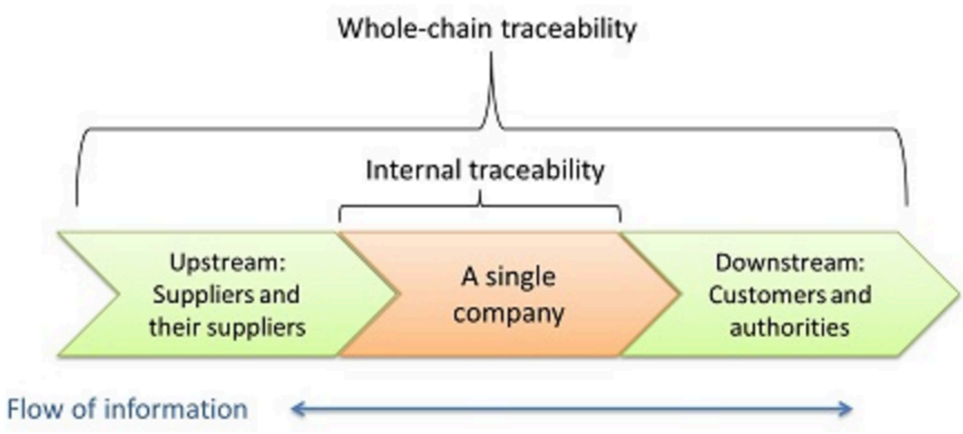

Figure 19: Levels of traceability (TraceTracker.com, 2016C, tracetracker.com)

Figure 19 displays that the application of a traceability system can be internal, or include the whole supply chain. The scope of internal traceability includes data from integrated IT systems within a single business unit or organization, whereas whole-chain traceability extends the scope by integrating the entire supply chain. This implies that one incorporates suppliers upstream and customers downstream. Further, the application of traceability can according to GS1 (2012) be implemented to cope with various needs, such as:

To comply with regulatory requirements and guidance on recalls
To reduce business risk above and beyond legal compliance
Product recall and withdrawal (notably to achieve a greater degree of precision, to demonstrate control, increase efficiency and reduce the cost of product recall or withdrawal)
To comply with a trading partner`s specification
Efficient logistics management
Effective quality management
To support product and/or patient safety
To provide information to end users and trading partners
To verify the presence or absence of product attributes
Brand protection
Product authentication
Anti-counterfeit policies
Visibility in supply and demand chain

Table 12: Features of traceability (GS1, 2012, p. 6)

2.13 Physical Internet

The Physical Internet presents a new way of transporting goods. The vision utilizes the metaphor of the Digital Internet, and transforms that into a Physical Internet vision. PI can be defined as an "open, global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols" (Lamerson, 2015, mhisolutionsmag.com). We will now address the most important characteristics and features of the PI.

First and foremost, the purpose of the Physical Internet is not to copy the Digital Internet. As previously mentioned, the aim is to exploit the Digital Internet metaphor to develop a Physical Internet vision. "Montreuil based the concept of the PI upon the digital internet and the way that data moves through that network in packets of information. Following TCP/IP protocols, these information packets encapsulate all of the routing information required to get them to the right destination, always moving along the most efficient available pathway" (Lamerson, 2015, mhisolutionsmag.com,). Furthermore, the PI vision is based upon a framework consisting of eight foundations. This framework is pictured in figure 20.

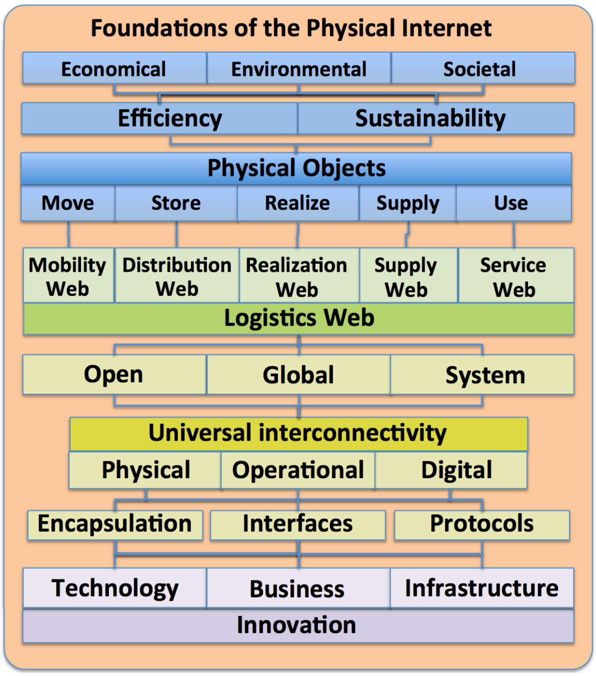

Figure 20: Physical Internet Foundations Framework (Montreuil et al., 2012, p. 1)

Moreover, these eight foundations are summarized into 13 points characterizing the PI:

	The Physical Internet vision characteristics
1.	Encapsulating merchandise in world-standard smart green modular containers
2.	Aiming toward universal interconnectivity
3.	Evolve from material to π -container handling and storage systems
4.	Exploit smart networked containers embedding smart objects
5.	Evolve from point-to-point hub-and-spoke transport to distributed multi-segment intermodal transport
6.	Embrace a unified multi-tier conceptual framework
7.	Activate and exploit an Open Global Supply Web
8.	Design products fitting containers with minimal space waste
9.	Minimize physical moves and storages by digitally transmitting knowledge and materializing objects as locally as possible
10.	Deploy open performance monitoring and capability certifications
11.	Prioritize webbed reliability and resilience of networks
12.	Stimulate business model innovation
13.	Enable open infrastructural innovation

Table 13: Characteristics of the Physical Internet vision, (Montreuil, 2011, p. 5-14)

2.13.1 Efficiency and sustainability

The PI vision was developed as a solution to the "grand challenge". Montreuil (2011) explains that companies' faces a "grand challenge" related to applying sustainable solutions with respect to logistics. The main goal of the PI is to support more sustainable solutions from economical, environmental, and societal perspectives with respect to logistics. "Logistics is efficient when it serves the needs for moving, storing, realizing, supplying and using physical objects with minimal economical, environmental and societal resources overall. IT is sustainable when it is capable of maintaining high economical, environmental and societal performance over the long run, capable of facing the risks and challenges associated with a dynamic, changing and fast-evolving context, contributing to a better world for future generations" (Montreuil et al., 2012, p. 2)

2.13.2 Logistics web, and PI as an open global system

Moreover, another important part of the PI is the fact that the system works like a logistics web. A web is characterized by a set of interconnected actors and networks. Thus, the PI encompasses a web, which can be defined "as a set of inter-connected physical, digital, human, organizational and social agents and networks" (Montreuil et al., 2012, p. 6). Furthermore, the logistics web can be decomposed into five components; mobility web, distribution web, realization web, supply web and service web. In short, the logistics web aims to enable more flexible and sustainable logistics solutions by allowing companies to utilize various PI-certified networks, and apply the one that meets the needs at the time needed. This in turn implies that the PI vision involves a shift from private supply chains to open and global supply chains. PI functioning as an open system also implies that new operators have the possibility to be added to the network. Being an open and global system, the PI requires cooperation between its actors. The PI "has to be based in the same conceptual framework whatever the scale of the involved networks. Networks will be embedded in wider networks, each operating according to Physical Internet principles, protocols and standards" (Montreuil et al., 2012, p. 9). A logistics system like the PI would enable organizations to be more responsive and flexible. Hence, long-term contracts and highly dependent relationships to suppliers will not be necessary anymore. The PI vision has the possibility to significantly increase quality and number of options for companies with respect to logistics services.

2.13.3 Universal interconnectivity

Next, universal interconnectivity is a key element in the PI. Moreover, "interconnectivity refers to the quality of a system to have its components seamlessly interconnected" (Montreuil et al., 2012, p. 3). Montreuil et al. (2012) explains that the aim is to allow and strive for a high degree of collaboration. However, as mentioned previously, the collaboration between actors are not supposed to be formal and rigid. The intention is to develop a set of collaborative protocols, and conclude agreements consecutively. Universal interconnectivity is supposed to be accomplished through interlaced physical, digital and operational interconnectivity. Physical interconnectivity concerns the flow of an entity, meaning that any physical entity should be able to flow seamlessly throughout the PI without any constraints. Moreover, the purpose of digital interconnectivity is to ensure the information flow between the actors in the PI. IoT is as previously stated an important tool to support efficient decision-making based on real-time information. Adopting traceability systems enables visibility and transparency throughout the whole supply chain, and between the actors in the PI networks. Operational interconnectivity deals with the ease and usability of utilizing the PI. "This includes designing and using standardized business contracts and incoterm-type modalities as well as implementing and respecting operational protocols" (Montreuil et al., 2012, p. 4).

2.13.4 Encapsulation

In the Digital Internet, information and data is encapsulated in standard packets. Moreover, "all protocols and interfaces in the Digital Internet are designed so as to exploit this standard encapsulation" (Montreuil et al., 2012, p. 4). In the same way, PI aims to encapsulate physical objects in so called π- containers, which are modular and standardized. " The Physical Internet deals directly with the π-containers, not with the freight, merchandises, products and materials that are encapsulated within them. This allows all transportation, handling and storage devices, means and systems to be designed and engineered to exploit this standard, modular encapsulation" (Montreuil et al., 2012, p. 4). Additionally, the PI also emphasizes the importance of communicational encapsulation. This is achieved by applying IoT and the accompanying technology, resulting in high quality traceability.

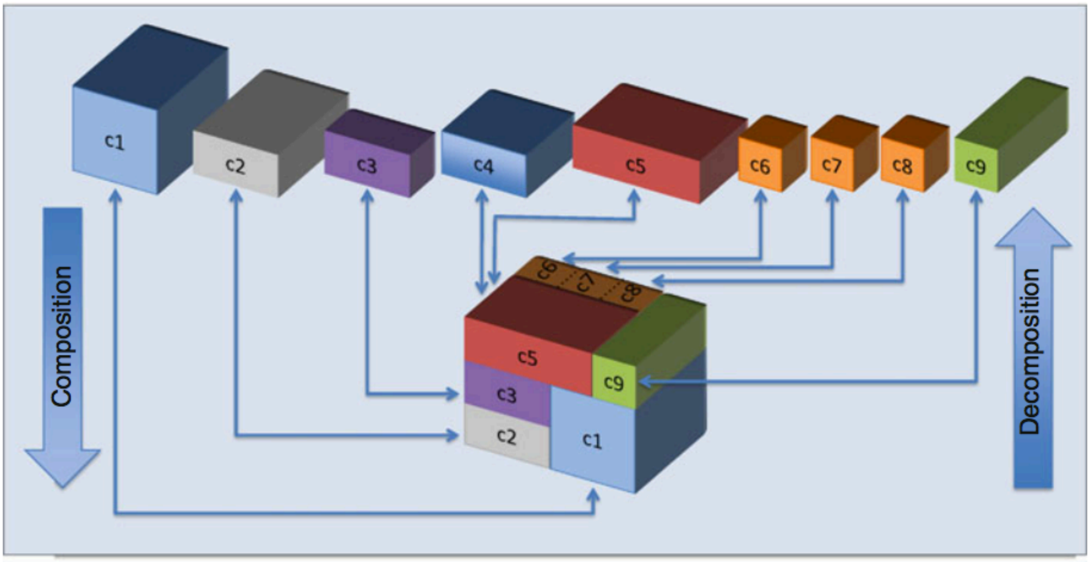

Figure 21: Illustrating the modularity of unitary and composite π-containers (Montreuil, 2011, p. 5)

2.13.5 Interfaces

Interfaces are important in terms of realising universal interconnectivity. The PI introduces four central types of interfaces; π-fixtures, π-devices, π-nodes and π-platforms.

The modularity and fixtures of π-containers are important to facilitate an even flow of physical objects throughout the PI. The π-containers are as previously mentioned modular, and the features of these containers enables one to interlock them with each other etc. (figure 22). The idea is that π-containers, π-carriers, π-conveyors and so on, have these standard features that makes transportation and logistics processes easier to carry out.

Furthermore, π-devices refers to IoT and the communication and information of π-containers. This is accomplished through traceability systems and smart tags (i.e. RFID, WSN, and GPS). The π-devices "helps ensure the identification, integrity, routing, conditioning, monitoring, traceability π-containers and security of each π-container. It also enables distributed handling, storage and routing automation" (Montreuil et al., 2012, p. 5)

Next, π-nodes are the critical interfaces of the PI at an operational level. "For example, π-gateways enable efficient and controlled entry of π-containers into the Physical Internet as well as their exit from the Physical Internet" (Montreuil et al., 2012, p. 5). Lastly, π-platforms constitute an important part for the PI in terms of information and communication exchange.

“Digital middleware platforms are pivotal interfaces in enabling the open market for logistics services in the Physical Internet as well as the smooth systemic operation of the interacting π-constituents and routing of π-containers from source to destination through the Physical Internet” (Montreuil et al., 2012, p. 5)

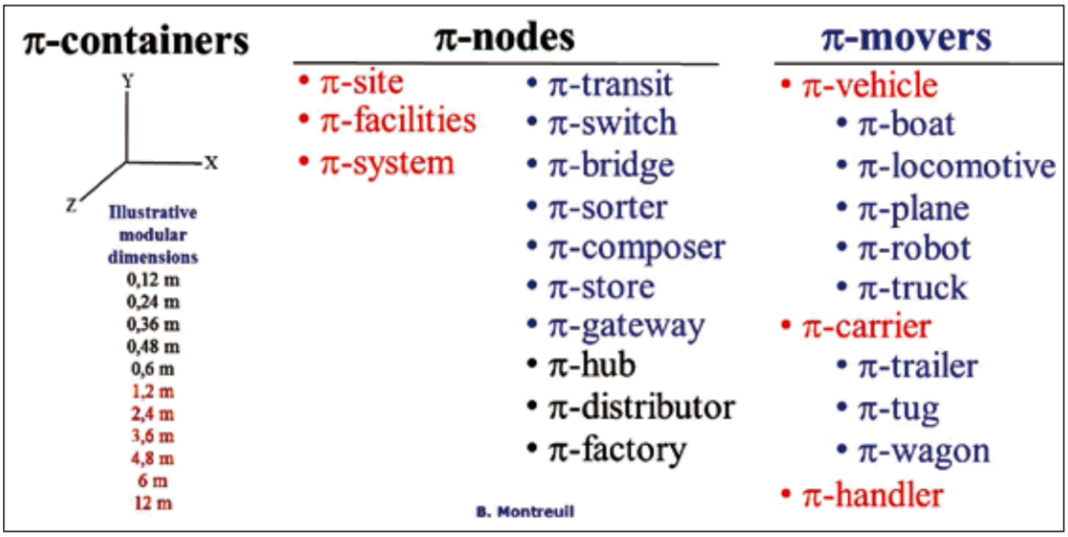

Figure 22: Elements of the Physical Internet (Lounès & Montreuil, 2011, p. 31)

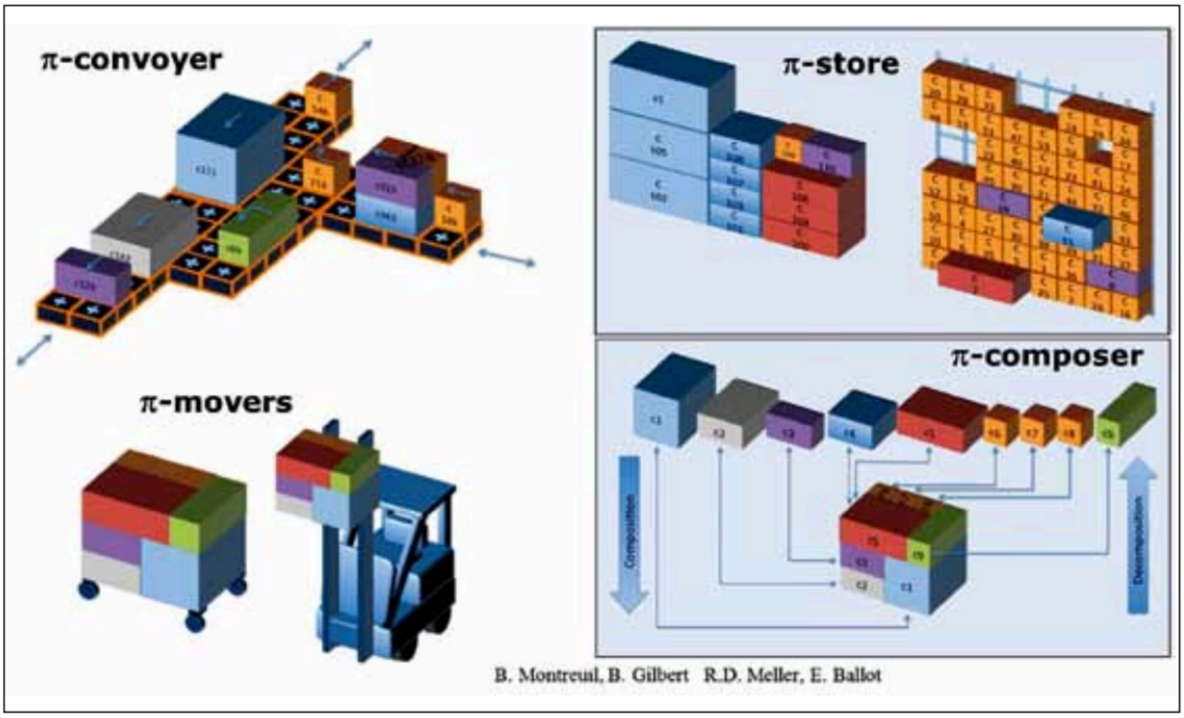

Figure 23: Evolve from material to π-containers handling & storage systems (Lounès & Montreuil, 2011, p. 31)

2.13.6 Protocols

Protocols are an integral part of the PI. The PI is based upon being an open and global system. To coordinate the flow of physical objects, there has to be a set of protocols that ensures transparency and visibility to the system. Montreuil et al. (2012) explain that monitoring of critical features like reliability, speed, service level etc. are important with respect to the protocols for the system. Furthermore, "basic protocols validate the physical integrity of π-containers and other physical π-constituents flowing through the Physical Internet. They guide the transfer of π-containers from one π-constituent to another" (Montreuil et al., 2012, p. 5). This implies that the flow and routing of π-containers through the π-networks are important to contracting protocols. Moreover, Montreuil et al. (2012) explain that the π-contracting protocols can be seen as an extension of current practice for International Commercial Terms (INCOTERMS). Lastly, "the webbing of the networks and the multiplication of nodes should allow the Physical Internet to ensure its own robustness and resilience to unforeseen events. For example, if a node or part of a network fails, protocols have to ensure that the traffic of π-containers is easily re-routable as automatically as possible" (Montreuil et al., 2012, p. 6)

2.13.7 Innovation

Innovation is a prerequisite to develop and enhance the Physical Internet vision. The current logistics practices are not sustainable according to Montreuil (2011). In order to develop the PI, stakeholders must pressure for even better logistics solutions and innovate business models, technology and infrastructure. However, despite the need for improved technology, there already exists available technology that can be implemented in the PI vision. These include RFID, WSN and GPS. This type of IoT-based technology enables smart tags on π-containers, and contributes to traceability and monitoring of physical objects during transportation. Moreover, Montreuil et al. (2012) explain that there are currently being conducted research on new solutions and technology that challenges RFID, WSN, and GPS. Furthermore, "Myriads of businesses will concurrently be using the Physical Internet, such as retailers, distributers and manufactures, or enabling its operation, such as logistics service providers and solutions providers. All of them, in their quest for competitiveness, will be adapting their business models so as to best exploit the Physical Internet to offer and deliver high-value propositions to their clients" (Montreuil et al., 2012, p. 9-10). It is therefore imperative that companies, industry and governments worldwide collaborate, to improve and support innovation and technology to incorporate the PI as an industry standard in supply chains for companies on a global scale.

To summarize, the PI is a paradigm within logistics. The vision is inspired by how packets of information is distributed in the Digital Internet, and transfers this mindset to the “real world”. The PI vision is a response to the “grand challenge”, and the goal is to develop more sustainable solutions from an economical, environmental and societal point of view. Furthermore, the PI is characterized by modular π-containers, which facilitates an easy application for different transportation means. Lastly, the PI is founded upon open and global supply chains, which in turn enables flexible logistics solutions through large transportation networks.

3.0 Methodology

There exist two main approaches within methodology; quantitative research and qualitative research. "Quantitative research employ experimental methods and quantitative measures to test hypothetical generalizations" (Golafshani, 2003, p. 597). On the other hand, qualitative research can be defined as "a naturalistic approach that seeks to understand phenomena in context- specific settings" (Golafshani, 2003, p. 600). "Unlike quantitative researchers who seek casual determination, prediction, and generalization of findings, qualitative researchers seek instead illumination, understanding, and extrapolation to similar situations" (Golafshani, 2003, p. 600). Moreover, Xavier University Library (2012) points out that qualitative research is focused around achieving a holistic understanding from smaller and not randomly selected groups. On the other hand, quantitative research is often concentrated around random and large samples where the objective is to test hypotheses and study specific variables.

This thesis can from our point of view be defined as both a quantitative and qualitative study. However, we have not analysed "big data" and the relationship between different variables (quantitative approach), or conducted any form of interviews, surveys, or questionnaires from smaller samples of groups (qualitative approach). Our thesis is built upon already existing data and statistics, as well as results from questionnaires, surveys, and available information about aspects we want to illuminate. Thus, the methodology of our thesis falls somewhere in between quantitative and qualitative research. However, we consider our study to be more "qualitatively oriented" than quantitative. The goal of the thesis is to shed light on important factors that can contribute to improvements for the industry, through creating a holistic view of the situation. This is as previously mentioned accomplished by applying already existing research, both quantitative and qualitative.

3.1 Framework

Next, we have applied the ”interactive model of research design” presented by Maxwell (2005) as a framework. The model is displayed in figure 24.

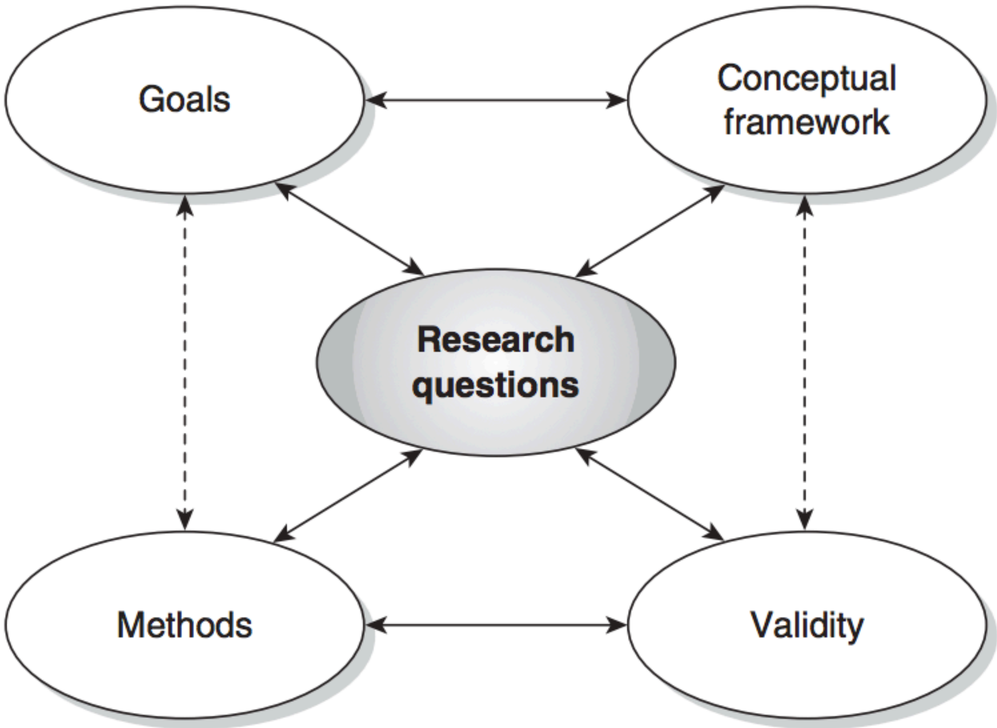

Figure 24: An Interactive Model of Research Design (Maxwell, 2005, p. 5)

Maxwell (2005) describes this model as flexible in its structure, and the elements are interconnected. However, there are five key components; goals, conceptual framework, research questions, methods and validity. The goals of the study lie within the introduction of the paper. Here one should present the motivation of the study, what issues one are going to present, and why this is important (implications in a conclusion). Moreover, this in turn leads to a natural definition of research questions. Next, the conceptual framework can be regarded as a chapter consisting of literature. The conceptual framework concerns prior research and findings. It should explain important and relevant aspects of the paper`s subject, and support the discussion in the analysis. Further, the research questions should state the purpose of the study. “What questions will your research attempt to answer, and how are these questions related to one another” (Maxwell, 2005, p. 4). The research questions can as previously mentioned be stated in the introduction, as a own paragraph after the conceptual framework, or both. The methods address what has actually been done when conducting the study. “What approaches and techniques will you use to collect and analyze your data?” (Maxwell, 2005, p.

4). The methods are often placed within the analysis of a study. Lastly, the validity should address the trustworthiness of the findings. The validity can either be placed under methods, or as an own paragraph.

We have decided to utilize the framework by Maxwell (2005) as a basis for our master thesis. However, as he explains, the structure is flexible. “Design in qualitative research is an ongoing process that involves “tacking” back and forth between the different components of the design, assessing the implications of goals, theories, research and questions methods, and validity threats for one another” (Maxwell, 2005, p. 3). We have therefore chosen to construct this thesis as we see fit, using Maxwell`s framework as a base.

3.2 Sources of information

Regarding sources of information there exists two main classifications; primary sources and secondary sources. Primary sources refer to data and evidence collected at firsthand (e.g. interviews and questionnaires). Our thesis is not a collaboration between ourselves and a company operating in the industry. Thus, the information gathered and utilized in the assignment is provided by secondary sources. This implies that the information in the analysis consists of prior research, articles, reports etc. The information was collected early in the semester, giving us enough time to thoroughly evaluate and process the information. Moreover, the gathered information provides a holistic view of how the industry operates as of today, and possible contributions and benefits the industry can adopt.

4.0 Analysis:

4.1 Industry development

In the current global aquaculture market, farmers, processors and exporters face customers with much higher demands in terms of freshness of the products, documentation, traceability, and regularity. Through the demand of fresher and more refined products, the customers are challenging the retailers to able to forecast and meet customer demand. “At the downstream end of the supply chain, retail chains have much larger requirements to fish product supply than traditional buyers in terms of timing, regularity, quantity, and quality” (Tveterås & Kvaløy, 2004, p. 8). This does in turn add pressure upward the supply chain. Additionally, “the average buyer has also become more demanding with regards to product specifications, documentation, regularity and size of deliveries, and transaction costs” (Tveterås & Kvaløy, 2004, p. 3).

The Food and Agriculture Organization of the United Nations (FAO) supports this, and states that “the growing market share of multiple retail stores (super- and hypermarkets) in the distribution of foodstuffs has significantly changed patterns of production, supply and distribution” (Josupeit et al., 2001, fao.org, p. 255). In addition, the FAO further states, “for fish and fish products, these changes have had, in many markets, a profound impact on both the demand for products from aquaculture and the production sector itself. Modern distribution channels have developed buying criteria with precise requirements for quality, portions and sizes, price and delivery times that often can only be met by aquaculture producers. This has led to the virtual disappearance of the specialized fishmonger in certain developed countries and has imposed significant changes on the profession, in operating, marketing and organizational skills” (Josupeit et al., 2001, fao.org, p. 255). This development along with the strict requirements set by governments and various organisations in terms of food safety, quality and environmental effects, has contributed to increased demand for valid and reliable information within the supply chain, both upstream as well as downstream. (Asche & Tveterås, 2011)

4.1.1 Main Factors:

1	Price	(a) Price level, (b) linkage to market prices, (b) quantity discounts.
2	Volume and timing	(a) Total volume, (b) regularity of deliveries, (c) flexibility in deliveries, e.g. in relation to "normal" volumes and times of delivery.
3	Raw material attributes	(a) Size distribution, e.g. fillets, (b) quality attributes, e.g. colour, fat, texture, taste, (c) fresh vs frozen, (d) uniform quality, (e) shelf life.
4	Product range and differentiation	(a) Fish species, (b) Product varieties, e.g. easy-to-cook, ethnic foods, healthy foods, (c) private labels / brands, (d) consumer advertising.
5	Production process	(a) Raw materials in feed, (b) environmental effects of production, (c) animal welfare, (d) third party certification, e.g. ISO, EMAS, (e) traceability.
6	Transaction costs	(a) Negotiation, (b) planning, (c) control and enforcement, (d) transportation og (e) storage.

Table 14: Buyer demands to suppliers of farmed salmon, (Tveterås & Kvaløy, 2004, p. 18)

The figure above is obtained from Tveterås and Kvaløy (2004) paper on vertical coordination in the salmon supply chain. The figure depicts the buyer's demands to producers in the aquaculture industry. Furthermore, these demands are divided into six categories; price, volume and timing, raw materials attributes, product range and differentiation, production process, and transaction costs.

We have decided to add some of these categories together, consequently creating three more generic categories. These are price, quality, and time. In this context, price is defined as all factors affecting the final price paid by the customer. This includes volume and timing of deliveries, the production process, transaction costs etc. Moreover, quality is expressed as every factor affecting the products ability to satisfy the customer's expectation and needs. This involves the production process in terms of raw materials in feed, environmental effects, traceability, etc., along with the raw material attributes of the product (colour, fat, texture, taste etc.). Lastly, time is defined as the total time spent throughout the entire production cycle from the production of roe to the sales and distribution. Here environmental factors such as sea temperature, water quality, along with planning, forecasting and transportation are pivotal factors impacting the final production cycle time.

Furthermore, as previously stated, the main focus of this master thesis will be to analyse how utilizing concepts from the Internet of things and Physical Internet can help improve traceability and transportation systems within Norwegian aquaculture supply chains. Further, it aims to examine how this in turn can help increase quality, shorten lead-times, and reduce the final price for the customer. Consequently, in the following paragraphs we will present these three factors in Ishikawa diagrams.

4.2 Quality

First and foremost, in terms of farming good quality fish, the environmental conditions are key throughout the whole supply chain. This implies biology and genetics, the right kind and amount of feed, medication, water temperature etc. These factors are certainly decisive to obtain pristine quality. However, we will not go further into these features of aquaculture farming due to the delineation of this thesis. Besides, these factors lie beyond our field of expertise. Our attention and the scope of the analysis in terms of quality will focus on improvements from an operational point of view. This means how the industry can utilize new methods to streamline processes within the supply chain in order to improve the quality of the final product.

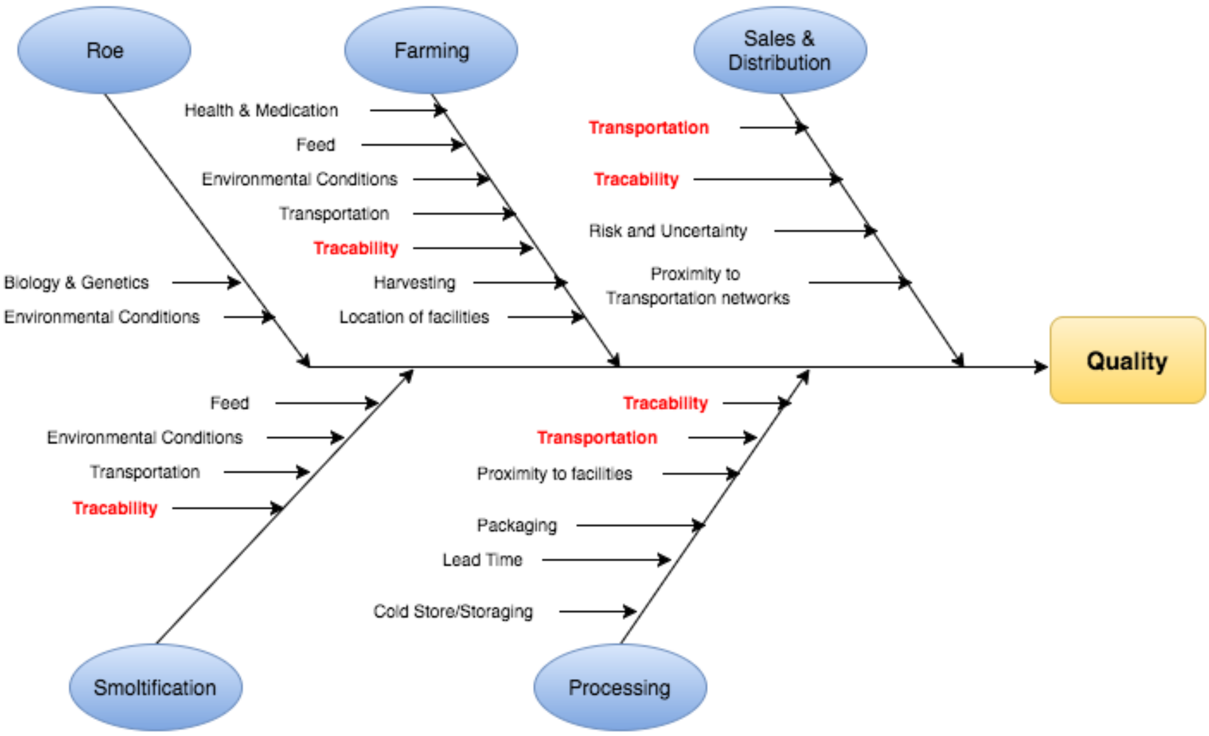

Figure 25: Cause-effect diagram, factors influencing quality

4.2.1 Roe and smoltification

As can be seen in the cause and effect diagram above, the processes throughout roe and smoltification are important with respect to quality. As previously mentioned, most activities within roe and smoltification are related to genetics and environmental conditions and will not be discussed any further.

4.2.2 Farming, processing and distribution & sales

Similar to breeding stock and smoltification, environmental conditions are also crucial with respect to the ongrowing process and farming of fish. Farming is fundamental for the growth, and may fluctuate due to environmental conditions. Controlling various inputs such as feed, water temperature, medication etc. are essential with respect to forecasting the production cycle and to minimize costs.

Further, Parreño-Marchante et al. (2013) explain that the food industry has been impaired by scandals throughout history. These scandals have in turn resulted in weakened customer confidence, and put food safety, origin and condition of perishable products on the agenda. Being a perishable product, the quality of fish must be within acceptable limits in terms of temperature and humidity. Moreover, Parreño-Marchante et al. (2013) point out that traceability can be a solution to this problem. This by effectively documenting and allowing transparency in product`s flow from origin to consumption. Furthermore, the aquaculture industry is governed by strict requirements (with respect to national as well as EU regulations), in terms of quality and freshness of products. Eden and Colmer (2010) explain that food supply chains have been required to ensure traceability by EU since 2005. However, companies operating in the food industry are free to choose which method (manual vs. electronically) to utilize in terms of traceability.

To ensure good quality, tracking the fish throughout every step of the supply chain is key. "Under EU law, "traceability" means the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution" (European Commission, 2007, p. 1). Traceability enables delivery of products with high quality, in addition to streamlined operations and increased efficiency. "Without control over internal product data and insight into product movement along the supply chain, companies are missing key business opportunities to reduce risks, cut costs, streamline operations and achieve a competitive advantage" (TraceTracker.com, 2016B, tracetracker.com). Parreño-Marchante et al. (2013) explain that new technology within tracking and monitoring are based on RFID and WSN. These technological devices within the scope of IoT are key to achieve better control, quality and efficient processes in the supply chain. Despite this new technology, many small- and medium-sized enterprises (SME) are still utilizing paper-based systems in their supply chain. This mainly due to cost barriers of modern traceability systems, as well as lack of awareness with regards to the potential benefits these systems entails. We will now discuss the importance of traceability, and why this is important for quality. (Parreño-Marchante et al., 2013)

4.2.3 In practice

Parreño-Marchante et al. (2013) have in their paper studied traceability systems in two SMEs in Slovenia and Spain respectively. They implemented electronic traceability systems as a pilot project in the two companies. Additionally, both companies partaking in the pilot projects operated in the aquaculture industry, and farmed sea bream and sea bass. However, the principles and processes are similar to the Norwegian aquaculture industry, and therefore transferable with respect to traceability and quality. Further, as shown in figure 26, traceability data are collected throughout four steps in the supply chain; on the ongrowing farm, processing, cold store and retail. Within the ongrowing farm, steps from breeding are also included:

- Reception of juveniles (smolt)
- Movement of fish between cages
- Collection of feed and medicament information
- Inspection of cages

Next, when harvesting takes place, "the catch and transportation of sea bass are monitored by an application implemented on a handheld RFID reader" (Parreño-Marchante et al., 2013, p. 103). Further, the cages are marked with RFID tags and are scanned for retrieval of information and data to each specific cage.

Subsequently, the fish are moved to processing which include two main steps; collection of orders, and processing and packaging for transportation. " The traceability data in the proposed solution are collected during the process of preparing and packaging boxes according to customer orders. To each polystyrene box an RFID label with printed information and a QR code with matching IDs is attached, and each fish is labelled with a paper tag, showing the day of the catch" (Parreño-Marchante et al., 2013, p. 103).

Lastly, the fish are transported in boxes from the processing facility to the cold store. "A fixed RFID portal (Impinj Speedway Reader) is connected to a computer at the input/output door to control the shipping and receiving logistics process. The delivery stage is implemented at the fish market with an application in a handheld RFID reader, used to read EPCs of boxes and RFID data loggers during the logistics process" (Parreño-Marchante et al., 2013, p. 103)

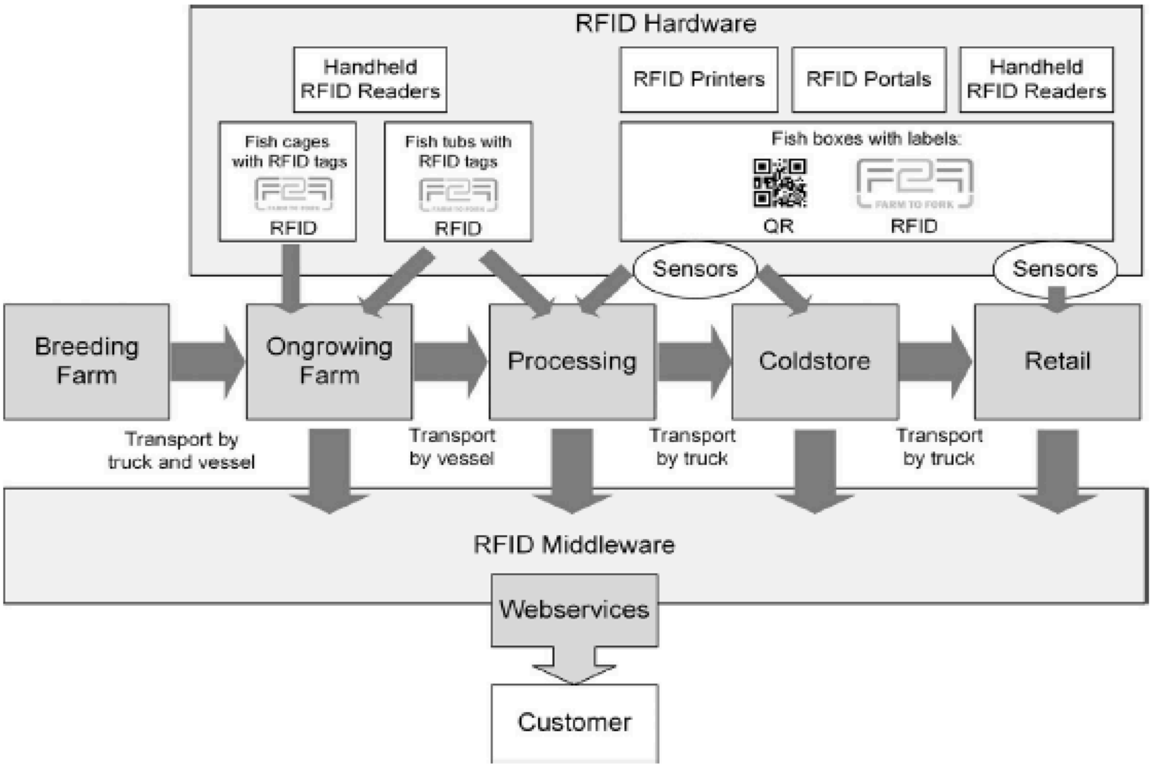

Figure 26: Traceability architecture detailing the type of hardware used, the elements that were tagged with RFID labels, the processes where sensors were used and the supply chain steps covered (Parreño-Marchante et al., 2013, p. 103)

Figure 26 represents a general layout of how electronic traceability systems in the aquaculture industry works. Moreover, it supports the cause- and effect diagram (figure 25), which explain that traceability is key throughout all processes in the supply chain.

4.2.4 Implications

Implementing an electronic traceability system ensures customer requirements from a downstream value perspective, as well as a supply chain focus upstream (figure 5 in theory). Traceability ensures the quality of the product downstream by allowing transparency in terms of origin of product, food safety, feed, medication etc. These factors are perceived as important for the customer. Additionally, traceability also contributes to integrate the focal firm and the suppliers through sharing of real-time information. Integrating sensor and traceability data allows one to utilize this information throughout the different activities in the supply chain. Suppliers and partners will through an electronic traceability system have the opportunity to easily access and retrieve information in real-time. Moreover, implementing an electronic traceability system removes the need for manual inspections. RFID technology and sensors logs and monitors temperature and humidity inside boxes during storage and transportation. This will in turn contribute to eliminate errors related to inventory control and logistics. Moreover, electronic traceability ensures that delivered products are within threshold values, which assists companies to only deliver products of high quality. Thus, improving the relationship between up- and downstream activities in the supply chain (Parreño-Marchante et al., 2013)

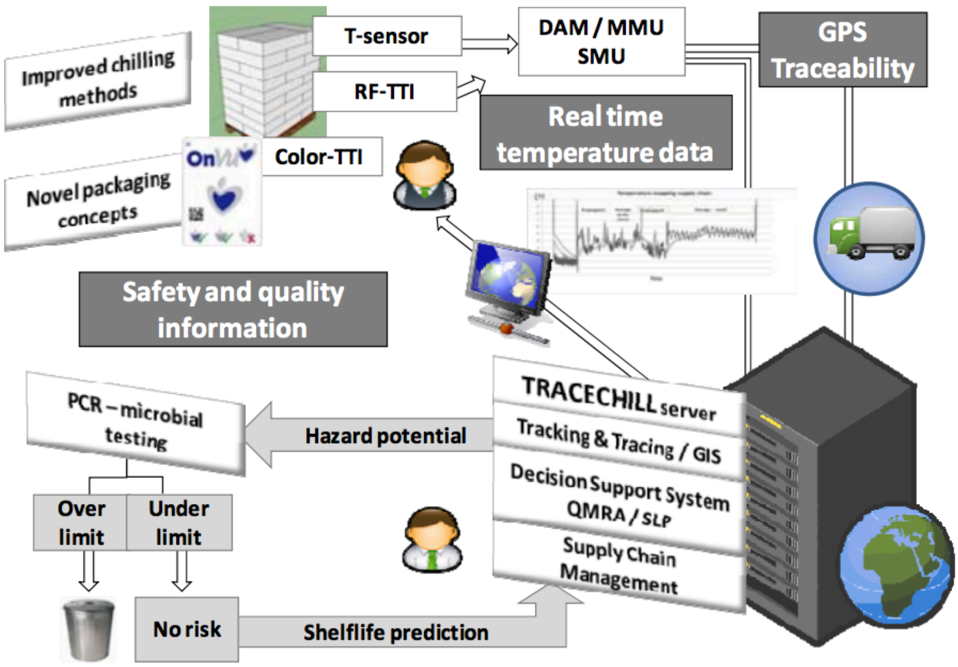

Figure 27: CHILL-ON conceptual approach to monitor quality, safety and traceability in food supply chains (Olafsdottir et al., 2010, p. 2)

Next, companies operating in the Norwegian aquaculture industry are seldom completely vertically integrated backwards or forwards. Therefore, supply chains are often complex with many dependent parties. Yet, there are exceptions, such as the most influential and biggest players in the industry. They often own the whole supply chain, or are at least vertically integrated either backwards or forwards. However, the largest companies might not always have the capacity to deliver when needed. Outsourcing of various services (e.g. logistics) are therefore common. Hence, supply chains in the aquaculture industry can be characterized as "ultimate supply chains" (figure 6), where collaboration between different actors is key towards producing and delivering the final product. Consequently, electronic traceability will function as a decisive tool to ensure efficient communication of real-time information between the parties in complex supply chains.

Moreover, only 6% of the farmed fish from the Norwegian aquaculture are exported as frozen. This implies that the vast majority of exported fish (94%) are fresh. In turn, short lead-time from farming through processing and transportation to the final customer is imperative to obtain high quality. Moreover, the aquaculture industry utilizes a mixture of push- and pull strategies. During roe, smoltification and farming, one could say that the industry operates within the boundaries of push systems. The industry forecasts the production cycle with respect to demand, and strives towards cost minimization. Moreover, in terms of farming, traceability enables companies in the aquaculture industry to optimize their LRP. The electronic tracing of e.g. feed and medication enables companies to determine when, and how much inventory they should order with respect to minimize inventory costs. Moreover, traceability integrates suppliers and customers down- and upstream in the supply chain, which mitigates the risks of the "bullwhip effect", and balances supply and demand.

On the other hand, when the fish is ready to be processed and distributed for sales, the industry utilizes a pull strategy. The objective is to streamline production and transportation in order to obtain as short lead-time as possible. Time is imperative, and it affects the final quality of a perishable product such as fish. Effective responsiveness and flexibility is key in order to deliver fish with high quality when it is needed. Moreover, one can relate the processing and distribution of fish to a JIT-system, which lies within the boundaries of a pull strategy. The fish is processed, packed, and transported to its final destination without, or at least minimal time on storage. Further, traceability contributes by streamlining these processes and increases efficiency and throughput, which in turn reduces lead-time related to processing and packaging. This is also proved by Parreño-Marchante et al. (2013), and will be discussed later on. Moreover, electronic traceability reduces waste. As previously mentioned, paper based traceability is time consuming, prone to errors, and is not a value-adding activity. On the other hand, electronic traceability reduces variability and adds value to the product form a customer point of view (e.g. origin of product, living conditions, feed etc.). This in turn increases the perceived quality of the product.

4.2.5 Traceability results from aquaculture companies

Parreño-Marchante et al. (2013) constructed KPIs to measure the impact of electronic traceability systems in the pilot projects. The KPIs were divided into groups; efficiency, flexibility, and responsiveness. They calculated the KPIs, and found that the new system contributed to significant time savings for both companies partaking in the pilot projects:

Company	Pilot company 1	Pilot company 2
Efficiency	95%	89%
Flexibility	100%	100%
Responsiveness	96%	90%

Table 15: Improvements in percent as a result of electronic traceability system (Parreño-Marchante et al., 2013, p. 106)

The results displays that the companies improved the efficiency in terms of work-time utilization with 95 and 89 percent respectively. The new traceability systems enable real-time information, which eliminates the need for manual monitoring and documentation. Besides, activities at the processing facility will be conducted more efficient with respect to sorting, weighing, labeling, etc. The new system contributes to reduce time spent on supply chain activities, which in turn provides reduction in costs. Their research did not include any quantifiable numbers on cost reductions. However, they explain that significant efficiency improvements as a result of electronic traceability will provide cost reductions. (Parreño-Marchante et al., 2013)

Secondly, utilizing an electronic traceability system versus a manual traceability system allows a higher degree of responsiveness in the supply chain (time reduction of 90 and 96 percent). This as a result of real time traceability information and data, which in turn allows product recalls to be managed more efficient (Parreño-Marchante et al., 2013)

The main objective with respect to the KPI "flexibility" was to "enable customers and retailers to have visibility into traceability and condition monitoring information for relevant products, by scanning the product QR code printed on the label" (Parreño-Marchante et al., 2013, p. 106). Flexibility as a KPI has a 100 % reduction in work time in both pilot companies due to the fact that electronic traceability and supply chain visibility were introduced as a result of the new electronic traceability system. The sharing of traceability information with suppliers and customers was not a possible feature with the manual traceability system (Parreño-Marchante et al., 2013)

Moreover, Parreño-Marchante et al. (2013) conducted customer surveys to evaluate the traceability systems. This was carried out through questionnaires and interviews at the point of sale, as well as questionnaires forwarded by email. "Consumers were given the opportunity to check fish traceability data provided by the F2F traceability page on the smartphone to give us the feedback about the system by interviews and questionnaires" (Parreño-Marchante et al., 2013, p. 104). The results from the surveys are key for emphasizing the importance of electronic traceability systems, and the application such systems have with respect to customers and the perceived quality of the product:

- 70 % of their sample group are significantly concerned about food origin (Q1)
- 70 % of their sample group are skeptical of food freshness (Q3)
- 60 % of their sample group are willing to pay extra for electronic traceability (Q4)

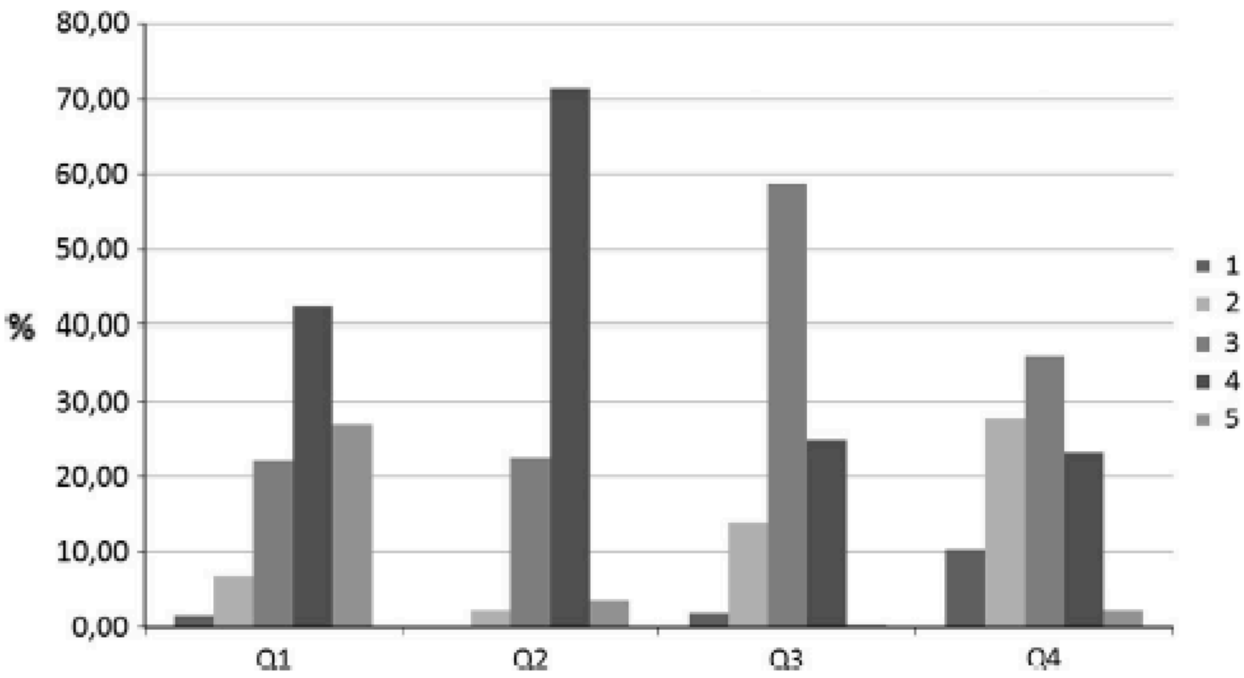

Figure 28: Questionnaire results obtained by consumers at fish market, retail and by email requests with 4 questions (Q1: Relevance of food geographic origin; Q2: Frequency of local food purchase; Q3: Level of trust in fresh food in retail; Q4: Willingness to pay for food e-trace.) and 5 possible answers (1 – the worst and 5 – the best. (Parreño-Marchante et al., 2013, p. 105)

The results from the survey indicate that consumers care about food origin and quality. Moreover, the majority of the sample group implies that they are willing to pay a price premium for a traceability service that enables information and data about origin, handling and quality of fish. Besides, an electronic traceability service will contribute to increase customer confidence and the reputation of aquaculture producers, by allowing transparency and visibility throughout the supply chain. This can in turn contribute to increased sales and profit for companies operating in the aquaculture industry. (Parreño-Marchante et al., 2013) Additionally, the EU-funded project CHILL-ON has also conducted a survey within the scope of traceability in China. The purpose of the survey was to measure customers' willingness to pay, purchasing behaviour and awareness relating to the quality of fish products. The results indicate that "consumers are willing to pay a 6% premium for safe, traceable fish products over the price of non-traced products of uncertain traceability" (Olafsdottir et al., 2010, p. 6).

TraceTracker is as previously mentioned a company that offers traceability solutions. Among their clients are Nordlaks. Nordlaks is a Norwegian aquaculture company farming Atlantic salmon and Rainbow trout. Moreover, Nordlaks had an internal traceability system, but experienced that they were unable to communicate key information electronically to customers. "We saw that in a short time the market would demand a more transparent value chain. We would need to present more information around health, sustainability, and quality of our products in a more effective way" (TraceTracker, 2008, p. 3). Further, Nordlaks was confident that an electronic traceability system would strengthen their position in the market. This because of visibility and transparency regarding quality standards, and commitment to food safety and practices. Their main objectives with the traceability system was "to comply with international traceability demands, to create a competitive differentiator, and to promote their brand name" (TraceTracker, 2008, p. 3). The solution provided by TraceTracker worked out well for Nordlaks. The traceability system fulfilled the set targets and objectives. They improved the flow of information, streamlined processes, created a competitive advantage and increased credibility and reputation. These results support our previous findings, and stresses the significant contribution of electronic traceability systems in the supply chain.

4.2.6 Concluding remarks

First and foremost, environmental conditions are key to obtain high quality products throughout roe, smoltification and farming. However, our analysis is focused on IoT and how this can contribute to improve the supply chain and logistics services. The analysis reveals that electronic traceability systems potentially can yield significant benefits for companies operating in the industry. Moreover, fish is a perishable product, which makes the industry subject to strict requirements and legislations from government and authorities with respect to food safety and quality. Being able to conduct activities and processes in the supply chain more efficiently will reduce lead-time and increase the quality, and at the same time reduce operational costs.

Further, modern electronic traceability systems are based upon RFID and WSN technology, which implies automation of key processes in aquaculture supply chains. This technology enables monitoring and tracking of products in a more convenient manner contrary to manual inspections and logging. Further, electronic traceability allows sharing of information and data in real-time with suppliers upstream in the supply chain. This can in turn can prevent errors and improve inventory management. Additionally, information concerning origin, handling and quality can be provided to customers downstream by integrating data through a web page or mobile application. Moreover, the analysis points out that visibility and transparency are important attributes for customers. Hence, electronic traceability systems can be a solution for the customer to verify the overall quality of the product, and increase customer confidence.

"The results and the benefits achieved with the new system have been shown through improvements in product control, work organisation, time management, process automation and increase in customer confidence. The solution adopted offers an example of a flexible scalable and interoperable system that can be easily transferred to any farmed fish business process, and this solution is also adaptable to other food sectors" (Parreño-Marchante et al., 2013, p. 108). Lastly, another important factor that also affects quality is transportation. Fish being a perishable product is highly dependent on in-transit-time to stay within the threshold values. However, transportation is also a key factor with respect to "time", and will therefore be covered in the next paragraph.

4.3 Time:

As mentioned earlier, one of the main factors affecting the purchasing decision for the customer is time. Time being defined as the total time spent throughout the entire production cycle, from the production of roe to the sales and distribution. As figure 29 depicts, the production process starts out with the production of roe, and ends with the sales and distribution of the product. Furthermore, there are many important factors along the production cycle affecting the total lead-time of production. However, due to the time and scope limitations of this master thesis, we have decided to direct our main focus towards traceability and onshore transportation (marked in red) in the supply chain.

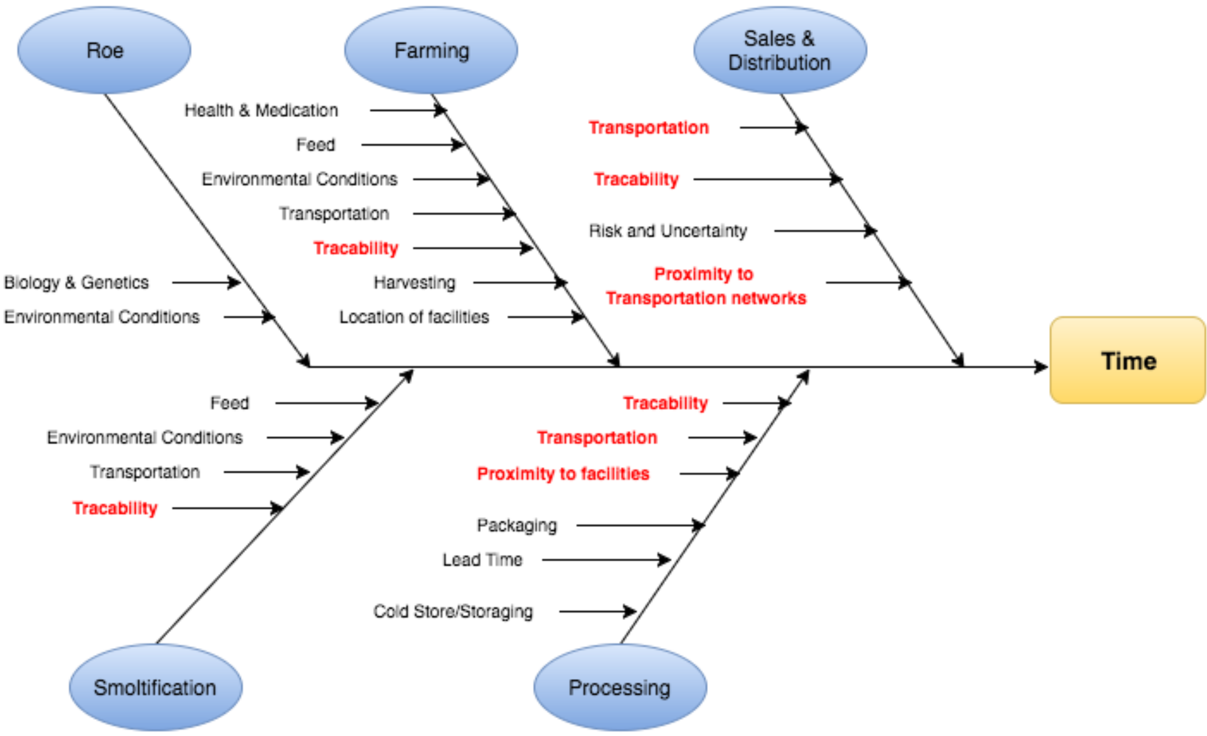

Figure 29: Cause-effect diagram, factors influencing time

4.3.1 Transportation:

As mentioned in the theory chapter, transport is an important part of logistics management. Figure 29 shows that the Norwegian aquaculture industry is dependent on transportation in various links of the supply chain, due to the different development phases in the production cycle. This includes offshore transportation (e.g. transport of smolt/fry, transport between locations, transport for harvest) by wellboats, and onshore transport (e.g. from harvesting plants to processors, or exported directly) by trailer/boat/train/airplane. As mentioned earlier, the focus of this master thesis will be directed onto the onshore transport. Moreover, there are four main transportation alternatives that are used for transporting seafood products. These are; trailer, railroad, ship and airfreight. For fresh fish transport, special thermo containers are used in order to preserve the products and extend the lifespan of the product. Furthermore, there has for a while been a mutual political objective both in Norway, as well as in the EU, of trying to transfer most of the freight transport from road to either rail or ship based transport. In spite of this, the development has in the last few years stagnated, and ultimately gone in the opposite direction. (Hovi et al., 2014A)

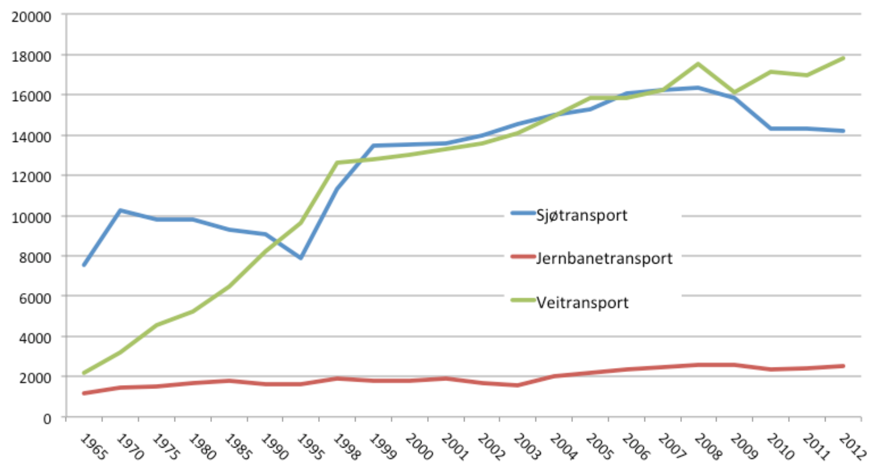

Figure 30: Development in domestic transport between 1965-2012 (Norway) (Hovi et al., 2014, p. 3)

This development is down to a number of factors like; pre-established inland goods terminals, an increased cost pressure within road transport sector, and an increased focus on just-in-time deliveries. (Hovi et al., 2014A)

As previously mentioned, the Norwegian aquaculture industry has had a formidable rise over the last decades, ultimately establishing itself as one of Norway´s most important exporting industries. Moreover, due to relatively low transportation costs (1-2 NOK/kg) and the introduction of new technology, processors are able to prolong the lifespan of frozen products. This in turn has made frozen seafood products a global commodity. However, this product segment only accounts for roughly 6 percent of the total export of Norwegian seafood. The remaining 94 percent consists of fresh fish, which makes this the most important commodity within the Norwegian aquaculture industry. Therefore, this segment will be awarded the primary focus of this master thesis. (Hanssen et al., 2014)

Furthermore, figure 31 presents the most common transportation routes for the Norwegian aquaculture industry. As shown by the figure, trailer transport (marked in red) is by far the most commonly used mean of transportation followed by train (marked in blue). Additionally, the clusters of harvesting plants are marked with purple, the flights are marked with black, and the shipping routes are marked with green. Moreover, along with the substantial increase in production volume, follows a proportional increase in the amount of aquaculture related transport. The increased production volume from the Hitra/Frøya cluster alone amounted an increased trailer transport activity of 7 790 trips to and from the harvesting plant. (Hansen et al., 2014)

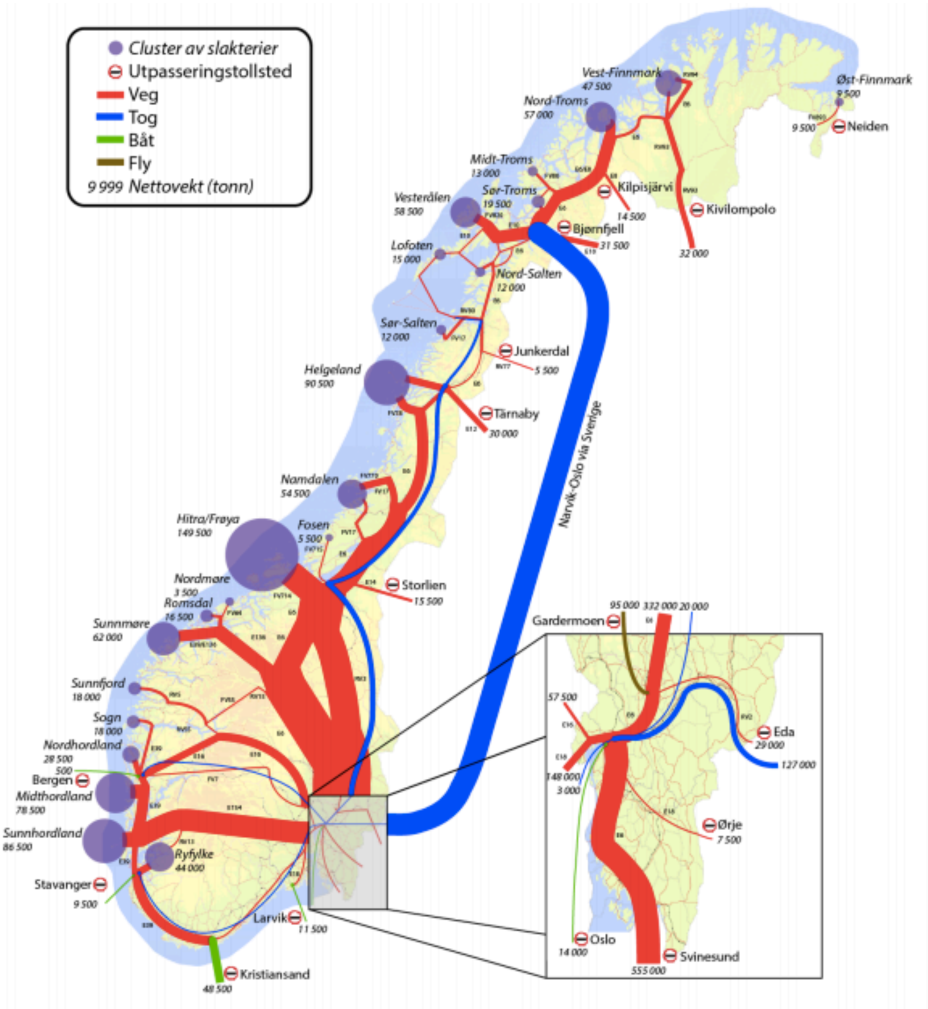

Figure 31: Transportation flow of Norwegian Seafood Products. (Hanssen et al., 2014, p. 46)

As depicted by figure 31, the "flow of fish" is primarily dominated by trailer transport. Furthermore, in 2013 approximately 730 000 tonnes worth of salmon and trout crossed the Norwegian border using trailer transport. This constitutes roughly 81 percent of the total export. The remaining 19 percent composed of air and ship freight, constituting 11- and 8 percent respectively. Even though railroad transport is an important contributor within the aquaculture distribution chain, close to all railroad transport except Ofotbanen is domestic. Hence, railroad transport is not included in the statistic. (Hansen et al., 2014)

Means of Transportation	Items	Net Weight	Item percentage	Net Weight percentage
Trailer	114 294	731 626	65 %	81 %
Plane	47 025	96 995	27 %	11 %
Ship (includes shipping of trailers)	13 197	72 962	8 %	8 %
Total	174 516	901 583	100 %	100 %

Table 16: Items and net weight of salmon/trout distributed based on means of transportation (Hanssen et al., 2014, p. 13)

Moreover, one of the most critical stages in the transportation of Norwegian seafood products is often the journey from the harvesting plant to the main roads and highways. This is mainly due to underdeveloped and old road networks. Further, Bedriftkompentanse AS calculated that a delay of a trailer transport of fresh fish could inflict the exporter a loss of between 100 000-150 000 NOK per day. (Sparebank 1 Nord-Norge, 2015) However, although there is room for improvement within this stage of the transportation process, this will not be the main focus of this thesis. This is because improvements within this stage are largely influenced and dependent on political factors relating to transport policies within the Norwegian ministry of transportation. Thus, falling outside the scope of the thesis. However, the costs associated with delayed transports etc. are highly relevant, and will be discussed later in the chapter.

4.3.2 Proximity to market:

Proximity to processing facilities as well as proximity to the market is central factors affecting the lead-time in production. Wessel and Vogt (2012) also support this, as they explain that physical facilities are key in logistics networks. In 2014 there was registered a total of 60 harvesting plants located across the entire Norwegian coastline, which represents a reduction of a total of 6 locations since 2007. (Hanssen et al., 2014) (Hovi et al., 2014B) Moreover, this is a development that is expected to continue in the future, due to industry benefits relating to economies of scale. Consequently, the fact that an increasing number of fish is produced and processed at fewer locations, in junction with the locational layout of the harvesting plants, creates implications and logistical challenges in terms of regular and efficient transportation.

With regards to the export and distribution of frozen seafood products, the locational layout of processing facilities does not create any large implications for the industry. This is due to the fact that proximity to the customer has less of a significance for frozen compared to fresh products, because of longer product durability along with relatively low transportation cost for frozen products ranging between 1 - 2 NOK/kg. This is also the reason why these products are predominantly transported by ship freight.

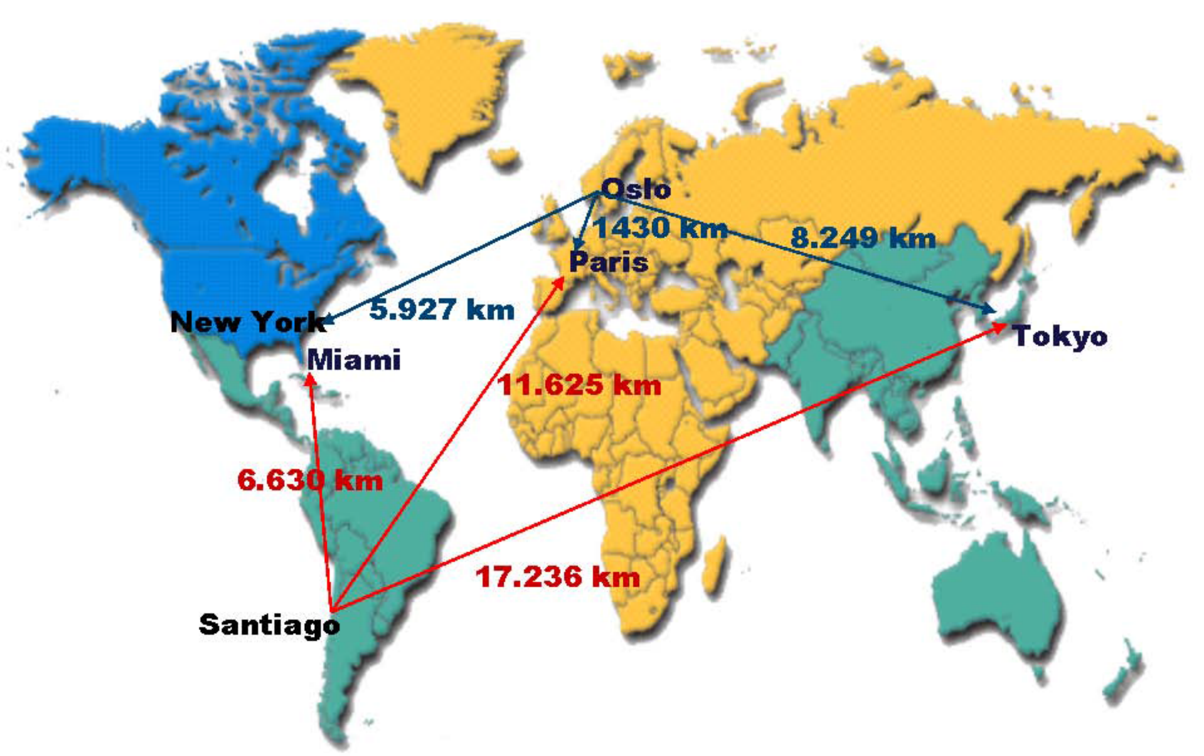

Figure 32: Distance to central markets (Asche & Tveterås, 2011, p. 37)

However, with regards to transportation of fresh products, proximity to the customer is a vital part of the delivery and distribution. A significant amount of the customers is retail based, leading to stricter requirements in terms of timing, regularity, quantity, and quality. Furthermore, as table 17 presents, the transportation costs associated with trailer transport of fresh fish from Norway ranges between 1 - 3 NOK/kg. In comparison the transportation costs associated with airfreight ranges between 7 - 15 NOK/kg dependent on transport distance, oil price, exchange rates, and amount of return freight etc. Thus, the Norwegian aquaculture industry´s relatively low transportation costs along with the close proximity to one of the worlds largest salmon markets (Europe), represent a significant competitive advantage in relation to their competitors. (Asche & Tveterås, 2011) (Det Kongelige Kyst- og fiskeridepartement, 2013)

Means of transportation:	**Transportation costs: NOK/kg**
Freight by trailer (Norway - EU) – Fresh fish	1 – 3 NOK/kg
Overseas airfreight - fresh fish	7 – 15 NOK/kg
Overseas ship freight – Frozen fish	1 – 2 NOK/kg

Table 17: Transportation costs in the aquaculture industry (Asche & Tveterås, 2011, p. 37)

Being able to deliver products with the right quantity- and quality, on time and according to a pre-set schedule, is vital for becoming the preferred supplier. Reducing the transportation time can potentially make a big difference in terms of lowering the transportation costs, and in turn be able to further utilize the competitive advantage in terms of proximity to the market.

4.3.3 Transportation routes from Trondheim – Paris

In a rapport written by Hovi et al (2014A), three common transportation routes from Trondheim to Paris were presented. These routes are depicted in figure 33. The straight line represents trailer transport, the dotted line railroad, and the dashed line represents ship transport. This is a highly relevant transportation route for the Norwegian industry due to the fact that a lot of large farming companies (e.g. Marine Harvest and Lerøy) operates in this region. Additionally, with France being the second largest importer of Norwegian seafood, they represent a significant amount of the total export market for the Norwegian aquaculture industry. Moreover, about 373 out of roughly 2926 fish dealers in France are located in the area surrounding the capital, thus efficient and regular transport to this area is highly important. (ilaks, 2013, ilaks.no)

Furthermore, the three alternatives depicted by figure 33 were:

Table 18: Overview of transportation routes (Hovi et al., 2014A)

Alternative	Transportation method	Time (Hours)	Cost (NOK)
1.	Trailer from Trondheim – Oslo → Ship from Oslo – Rotterdam → Trailer from Rotterdam – Paris.	52 Hours	18 975 NOK
2.	Trailer from Trondheim – Paris	46 Hours	40 703 NOK
3.	Train from Trondheim – Oslo → Ship from Oslo – Rotterdam → Trailer from Rotterdam – Paris	60 Hours	15 959 NOK

Figure 33: Overview of the three different transportation routes from Trondheim – Paris, (Hovi et al. 2014A p.119)

Hovi et al. (2014A) found that even with only one driver, accounting for statutory rest periods, transportation by trailer would be able to make the trip in the shortest amount of time (46 Hours). Even if railroad had been used between Trondheim – Oslo, the trip would still take longer due to the added terminal time at Alnabru goods terminal (47 hours).

Additionally, alternative two was also the most expensive alternative with a total cost per trailer of 40 703 NOK. Here the costs accounted for toll, as well as the time- and distance charge for the entire transportation chain.

As presented earlier in this chapter, trailer transport is by far the dominating transportation alternative within the industry, with roughly 81 percent of the total export being conducted by road transport. This is an interesting point, as the example clearly shows that both alternative one and three (table 18) has a significant cost advantage relative to alternative two. Both railroad and ship-based freight has a substantial advantage relative to trailer transport in terms of transportation capacity. However, both alternative one and three struggles with some of the logistical challenges associated with intermodal transportation systems, like limited flexibility, high terminal time- and costs, low frequency of departures (regularity) etc. Though, this is not the case for alternative two, as trailer transport has a competitive advantage in terms of frequency, regularity and response. Moreover, this means that road based transport is still the preferred transportation option within the industry due to superior flexibility, and regularity of deliveries. This in spite of the fact that it is as the example illustrates, by far the most expensive option. Thus, this example further illustrates the importance of timing, and regularity in deliveries within the aquaculture industry. Consequently, being able to reduce the transportation time- and cost through applying new and innovative logistical solutions, can potentially lead to creating a lasting competitive advantage. One alternative not included in the example is the case of air-based freight directly from Trondheim to Paris. Naturally, this would be the fastest transportation alternative. However, this option is not considered due to high transportation cost (7-15 NOK/kg), as well as lack of significant return freight. (Hovi et al., 2014A)

4.3.4 The Physical Internet

The PI was developed as a possible solution to the "grand challenge", meaning the challenges relating to creating sustainable logistics solutions. Moreover, as presented in the theory chapter there has been developed 13 points, which characterises the PI vision. However, due to time and scope limitations, this thesis will direct its focus towards the first five improvements named by Montreuil (2011).

These are:

1. Encapsulating merchandise in world-standard smart green modular containers
2. Aiming toward universal interconnectivity
3. Evolve from material to π -container handling and storage systems
4. Exploit smart networked containers embedding smart objects
5. Evolve from point-to-point hub-and-spoke transport to distributed multi-segment intermodal transport

4.3.4.1 Introducing Smart Green Modular π – Containers and Evolving from Material to π -Container Handling and Storage Systems

First and foremost, the PI is build around goods being transported using π –containers. These are modular, green, world-standard containers designed to streamline transportation. They are "easy to handle, transport, store, interlock, load, construct, dismantle and decompose". (Barbarino, 2015 p.14) Additionally, the sizes ranges from large cargo containers to tiny boxes. The idea behind this is to create a joint, universal and standardized interface among all actors in the logistics network. Due to the fact that the containers are modular, they can easily be dismantled into flat-packs, thus occupying minimum amount of storage space.

Moreover, currently goods both in the aquaculture industry and other industries, are managed and stored according to material. In the PI there exists only handling and storage of π – containers, regardless of their content. This enables the use of joint interfaces such as π-fixtures, π-devices, π-nodes and π-platforms as depicted by figure 23. In turn leading to reduced packaging costs, reduced handling time at each hub, as well as optimized space utilization with regards to volume and weight, both in transit and storage. Specifically for the Norwegian aquaculture, this could make a significant impact in terms of better utilization of intermodal transport. A large portion of the challenges relating to intermodal transportation are connected to "loss of time" spent in terminals during loading and offloading of goods. Hence, being able to reduce this time through standardized containers and joint interfaces, could make a significant contribution to increase the "attractiveness" of intermodal transportation. (Montreuil, 2011)

Furthermore, another important characteristic of the PI is being able to exploit smart networked containers embedding smart objects. This essentially means that the PI aims to exploit "as best as possible the capabilities of smart π -containers connected to the Digital Internet and the World Wide Web, and of their embedded smart objects, for improving the performance perceived by the clients and the overall performance of the Physical Internet" (Montreuil, 2011, p. 6). This is secured through the fact that **"**each smart π -container has a unique worldwide identifier similar to the MAC access in the Digital Internet and a smart tag to act as its representing agent. The smart tag helps insuring the identification, integrity, routing, conditioning, monitoring, traceability, and security of each π –container" (Montreuil, 2011, p. 6-7). This enables manufacturers, shippers, retailers, regulators, and customers to interact seamlessly with each other and their goods. (Mervis, 2014)

4.3.4.2 Open Networks, universal interconnectivity and traceability

In order for this to work, there need to exist a joint interface in which manufacturers, shippers, retailer, and customers are able to communicate. Therefore, the PI is build around the idea of open networks and universal interconnectivity. Universal interconnectivity essentially means a physical, digital as well as operational interconnectivity between all actors in the logistics network. IoT is as previously stated an important tool to support efficient decision-making based on real-time information. Adopting traceability systems enables visibility and transparency throughout the whole supply chain, and between the actors in the PI networks. Moreover, every π – container is equipped with a unique RFID tag enabling traceability across the entire supply chain. Thus, traceability and the use of IoT concepts are a vital part of the PI. The use of unique RFID tags enables an increased level of traceability and opens up for the flow of real-time information within the entire supply chain. (Montreuil, 2011)

In relation to the Norwegian aquaculture industry, being able to achieve digital interconnectivity among all actors in the supply chain would help to ensure a better flow of vital information. In the roe, smoltification and farming phase of the supply chain, the industry utilizes a push-based approach. In these phases increased levels of traceability would lead to improved forecasting and inventory management control. Thus, electronic tracing of e.g. feed, medication etc. enables the industry to optimize the production in terms of minimizing inventory, and optimizing their LRP. Additionally, the upstream and downstream integration of suppliers and customers all operating on a joint interface, can potentially lead to lower lead-times. This because companies are always provided essential inputs when needed. This would also mitigate the risk of a "bullwhip effect" as it enables the flow of vital information throughout the supply chain. (Montreuil, 2011)

As previously mentioned, when the fish is ready to be processed and distributed for sales, the industry utilizes a pull-based strategy. As shown by the example depicted in Hovi et al., (2014A), the production cycle time is essential. Every day the product is delayed costs the producer/exporter roughly 150 000 NOK. (Sparebank 1 Nord-Norge, 2015) Further, regularity, flexibility and responsiveness in relation to deliveries have become a pivotal part of the distribution. This is mainly due to the shift in the customer base, along with increased demand for fresh products, which in turn has increased the focus on JIT deliveries. The fish is processed, packed, and transported to its final destination without, or at least with minimal time on storage. Here traceability and universal interconnectivity would contribute to streamlining these processes in terms of optimizing loading of goods, reducing hub time, optimizing traveling distance etc. Hence, as a result one can expect reduced lead-times, increased efficiency, and improved throughput. Moreover, as mentioned in the quality paragraph, this was also discovered by Parreño-Marchante et al. (2013). They found that electronic traceability in the supply chain contributed to significant time savings in terms of increased efficiency, flexibility and responsiveness.

4.3.4.3 MODULUSHCA

The idea of developing and utilizing modular containers has been put into action by a EU supported project called Modulushca (Modular Logistics Units in Shared Co-modal Networks). They aimed "to develop a standardized, modular container for trucks and trains and the protocols needed for the container to "talk" to its handlers through radio tags and other technologies." (Mervis, 2014, p. 1105) These containers are called Modulushca boxes or M-boxes (figure 34). After conducting several simulation experiments using the M-boxes, they found for all scenarios that the implementation and utilization of the M-boxes resulted in "a reduction of up to 60 % of chain level costs or savings of 0,84€ per case and 36% CO_2 (transport). Most of the savings (about 32% of costs) come from better utilisation of transportation and handling." (Huschebeck, 2014, p. 16)

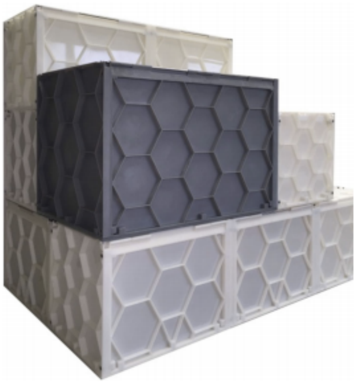

Figure 34: M-boxes: (Landschuetzer et al., 2015, p. 18)

4.3.4.4 Pooled resources, and open hubs- and transit nodes

Another vital characteristic of the PI is utilizing pooled resources, open hubs, and transit nodes spread across key locations "enabling synchronized transfer of π-containers and/or carriers between segments". (Montreuil, 2011, p. 7) "Current logistics is dominated by a combination of point-to-point transport and hub-and-spoke transport." (Montreuil, 2011, p. 7) The PI aims to change this approach by evolving from point-to-point hub-and-spoke transport to distributed multi-segment intermodal transport.

This would essentially mean a shift from private supply chains to open and global supply chains. This can be explained using the digital Internet metaphor. "An email do not travel directly from source node A to destination node B. The packets travel through a series of routers and cables (copper or optical), dynamically moved from origin to destination in as best a way as possible provided the routing algorithms and the congestion through the networks." (Montreuil, 2011, p. 7) Thus, in the same way, the PI intends to utilize existing warehouses and cross-dock facilities along with new open π-hubs. Resulting in an open mobility web aiming at shortening travel distance, limit the number of "empty travels", more effective allocation of goods, and improving the efficiency of distribution. The idea behind such a shift is to allow companies within the logistics web to utilize various PI-certified networks, in order to increase the flexibility and sustainability of their logistics solutions. (Montreuil, 2011)

Transportation within the Norwegian aquaculture industry is currently dominated by direct point-to-point road based transportation systems. The implementation of the PI could potentially have a significant impact on the efficiency and cost effectiveness of the logistics within the industry. Parts of the industry are currently (especially facilities located in the northern parts of Norway) experiencing significant challenges related to insufficient return freight. Through an introduction of a mobility web, these challenges could be mitigated with hubs, transit nodes, distribution centres, warehouses, and storage facilities located in strategic locations along key transportation routes throughout Norway and Europe. Thus, products could be distributed along the way, limiting the amount of "empty travel" and improving the efficiency of distribution.

4.3.4.5 Simulating the implementation of a π -enabled open mobility for Carrefour & Casino

D. Hakimi et al. (2012) conducted a simulation experiment aimed at examining the impact of implementing a π -enabled open mobility web in France. The mobility web used in the simulation is presented in figure 35.

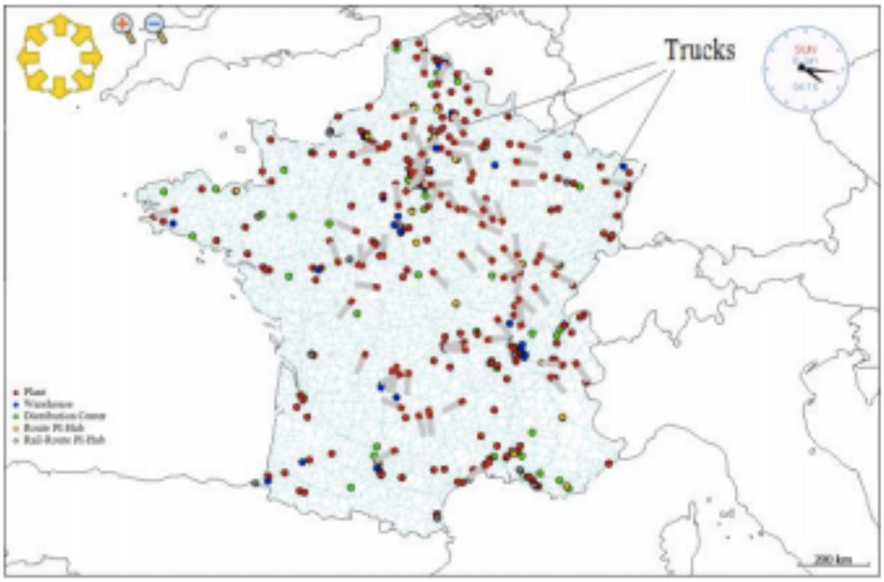

Figure 35: Mobility web (Hakimi et al., 2012, p. 8)

They conducted this experiment in cooperation with two top retail chains Casino and Carrefour, along with their 100 leading suppliers. The simulation was conducted using real transportation data. Furthermore, figure 36 shows Casino -and Carrefour´s flow of goods in the existing mobility web, whereas figure 37 presents they´re flow of goods in a π –enabled open mobility web. As the figures depict, the π –enabled open mobility web allows for a more focused flow of goods, eliminating unnecessary travel. Additionally, this is supported by table

19, which showed that the utilization of an open mobility web represented significant improvements in terms of efficiency. The total travel distance for goods was reduced with roughly 20 percent (11 million km). Moreover, “the study showed that using multimodal relay-mode transportation through a web of open hubs, using multiple players, would result in up to 32 percent in overall cost savings and about a 60 percent reduction of greenhouse gas emissions.” (Port of Montreal, 2015, port-montreal.com)

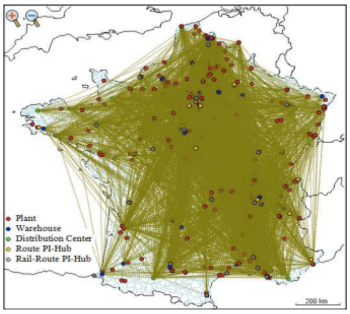

Figure 36: Flow of goods in an existing mobility web (Hakimi et al., 2012, p. 8)

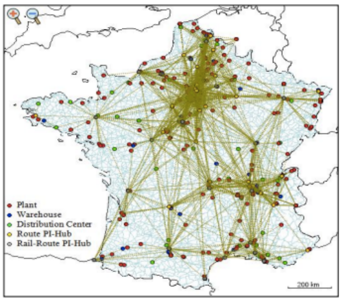

Figure 37: Flow of goods in a π-enabled mobility web (Hakimi et al., 2012, p. 9)

Table 19: Contrasting mobility web scenarios (Hakimi et al., 2012, p. 8)

	Route and Rail-Route PI-Hubs	Orders	Order Lines	PI-Containers of 2,4*2,4*1,2 (m^2)	Transport Mean Travels	Total Travel distance (Km)
Number of instances In a non PI scenario	----	211 167	282 381	----	124 618	54 725 706
Number of Instances in a PI scenario	38	211 167	868 093	677 551	270 623	43 735 190

4.3.4.6 Utilizing multi-segment intermodal transportation

Another significant contribution of enabling open mobility webs is the ability of utilizing multi-segment intermodal transportation. As mentioned earlier, approximately 81 percent of the total export of seafood from Norway was conducted by trailer transport. This in spite of it being by far the most expensive option. However, due to the strict requirements set by the customers within the industry, in terms of timing and regularity of delivery it is still the preferred option. This because it offers high flexibility, and does not suffer from the idiosyncratic challenges affecting primarily railroad and ship transport. Nevertheless, one of the main drawbacks regarding road-based transportation, is the statutory resting periods. For both Norway and the EU, the road-based transportation services are obliged to follow legal requirements concerning statutory resting periods. This is regulated in Norwegian law. Yet, these challenges can to a certain extent be mitigated through the introduction of the PI. (Hansen et al., 2014) (Hovi et al., 2014)

As mentioned earlier, "current logistics is dominated by a combination of point-to-point transport and hub-and-spoke transport" (Montreuil, 2011, p. 7). By introducing the open mobility web consisting of hubs, plants, and distribution centres, the PI is able to utilize the potential in multi-segment intermodal transportation. Montreuil (2011) illustrates this by an example. In this example, a company wants to transport a fully loaded trailer of goods from Quebec in Canada to Los Angeles in the USA. The trip is depicted in figure 38. Utilizing the current transportation arrangement the trip would take 120 hours + each way. This corresponds to roughly 240 + hours in total. However, by using several trucks and drivers along the way, the PI is able to reduce the transportation time by roughly 50 percent (120 hours). This is accomplished by changing the truck and driver at each hub, eliminating the downtime (statutory resting periods) along the way. This implies that the average driving time per driver is reduced from about 96 to 6 hours per driver.

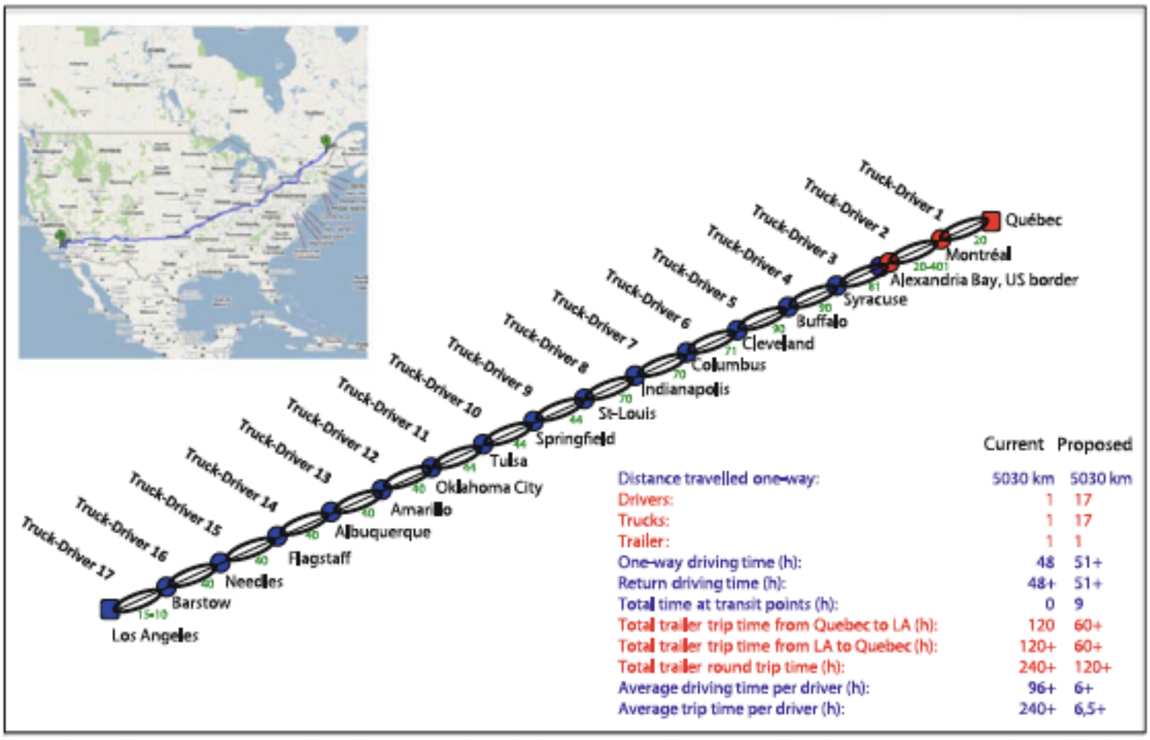

Figure 38: Contrasting current point-to-point transport and Physical Internet enabled distributed transport (Montreuil, 2011, p. 7)

Furthermore, employing these concepts towards transportation within the Norwegian aquaculture industry could potentially make a significant contribution in reducing the transportation time considerably. This could be illustrated by applying it to the previously mentioned example by Hovi et al. (2014A) concerning trailer freight from Trondheim to Paris. Using existing transportation systems the trip would take approximately 46 hours using trailer transport only. This also includes statutory rest periods. The transportation industry in the EEA is regulated by legislations in terms of loading capacity, statutory rest periods etc. With regards to the trip from Trondheim – Paris, the driver can according to the regulations only drive for 4,5 hours before having to take a 45 minute break. Additionally, the driver is obliged to take an 11-hour coherent break each day. This leads to the total driving time being 4,5 + (0,75) + 4,5 + (11) + 4,5 + (0,75) + 4,5 + (11) + 4,5 = 46 hours, with the statutory resting periods marked with (). Making the total effective driving time is 22,5 hours.

As the above example illustrates, the implementation of the PI could potentially reduce the total transportation time by as much as 23,5 hours (46 hours – 22,5 hours). However, this does not account for the added terminal time relating to loading and change of truck/driver at each hub. In the example portrayed by Montreuil (2011), they calculated this to be approximately 30 minutes (9 hours/17 transit points). Thus, in order to eliminate the statutory rest periods, it need to be roughly 10 (46 hours/4,5 = 10,22) transit points along the way between Trondheim and Paris. Consequently this would reduce the total transportation time by as much as 18,5 hours, leading to a total transportation time of 27,5 hours. This would correspond to a roughly 40 percent reduction in transportation time.

4.3.5 Concluding remarks

As the transportation and traceability requirements within the Norwegian aquaculture continues to grow, the need for an effective and reliable transportation system increases. Moreover, the examples presented above suggests that being able to implement and utilize concepts from the PI, can potentially make a significant impact on the way goods are handled, stored and transported in the Norwegian aquaculture industry. Resulting in benefits relating to increased storage and space utilization, reduced transportation time, reduced terminal time, reduced CO2 emissions etc. There are also significant benefits in terms of reduced terminal and transportation costs. However, this will be discussed in the next paragraphs.

4.4 Price

We have defined price as the last important factor. The price is highly dependent on both micro- and macro economical conditions (e.g. supply/demand and exchange rates). However, our main focus will be to analyse how operational improvements in the supply chain affects the final price customers must pay for Norwegian fish. More precisely, we will address how traceability and transportation influences the price for the customer.

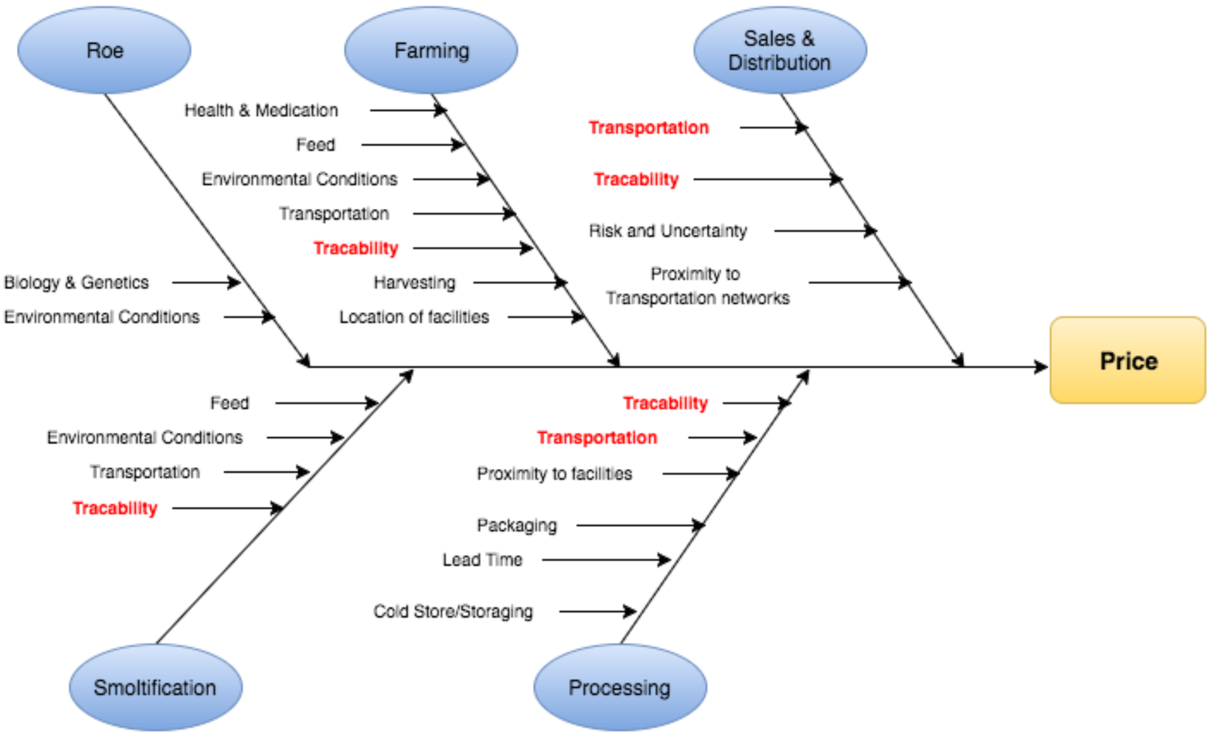

Figure 39: Cause–effect diagram, factors influencing price

4.4.1 Traceability

As referred to previously in this thesis, traceability can potentially reap significant benefits for the aquaculture industry. Traceability systems "find benefits in improved supply chain management, inventory control, access to contracts and markets by having stronger product assurances, more targeted recalls and hence lower costs to recall, and other cost savings incurred during a foodborne illness outbreak" (Mejia et al., 2010, p. 161). Moreover, we have also found evidence that traceability contributes to improved customer confidence. However, implementing these traceability systems includes additional costs for the respective company. Mejia et al. (2010) explain that these costs can be categorized into two main groups:

- Fixed costs (these are one-time costs associated with purchase and installation of the traceability system)
- Variable costs (maintenance and operating costs of the traceability system)

Furthermore, Asioli et al. (2014) supports that implementing electronic traceability systems are capital intensive. Modern traceability systems involve a transition for many companies that alters existing methods and processes. Asioli et al. (2014) have divided costs of traceability into five categories. These are pictured in table 20.

CATEGORY	IMPLEMENTATION	OPERATION/MAINTENANCE
Time and effort (of workforce, administration and management)	Information search/processing Change management Test runs/interruptions	Slow down/interruption of operations Additional reporting/mock recalls
Equipment and software	New purchases/installation	Upgrades and service contracts
Training	Extensive, comprehensive	Ongoing, for new staff
External consultants	For system choice/design Comply new hygiene, labeling legislation (veterinary)	For specific challenges Upgrades hygiene labeling legislation
Materials	Switch to new materials "system"	Labels/Packaging
Certifications and audits	Internal audits/certification	Repeat audits/certification

Table 20: Categories of traceability costs (Asioli et al., 2014, p. 11)

Moreover, research conducted by the Institute of Food Technologists (IFT), displays cost estimates for product tracing solutions. "IFT conducted a series of in-depth discussions with food companies to understand their product tracing efforts" " (Mejia et al., 2010, p. 163). They retrieved information from 58 food companies throughout 7 different sectors. The results are displayed in table 21 below.

Traceability solution category/description	Items included in technology cost	Available price estimates	Comments
Component of temperature monitoring			
Uses RFID-based temperature monitors: Tied to cold chain management; Used for perishables	- RFID tags - Tag readers - Software for data management & storage - Infrastructure to load & retrieve information	- $10 to 23.50/tag - $400/reader (GPS enabled) - Variable costs for data management & storage (provider may handle data for client at a fee)	- Tags can be used multiple times and for multiple uses - Tag prices decrease with quantity purchased - Providers offer service packages with reduced fee, that is, various combinations of number of tags and readers software, and storage time
Unique traceability medium			
Uses unique medium such as bar code accompanied by a software system	- Unique ID registration, for example, bar code with 16- or 24-digit number - Labels – preprinted or printed on site - Scanner - Software for data storage	- $5 to $10/ID - 1 to 2 cents/label - $100 to $500/scanner (could be even more according to producers/ processors)	- Cost of labels decreases with quantity purchased
Information transfer platform (software as a service)			
Offers software services for data capture and storage. Most software are compatible with existing data systems and can accommodate data from any source	- Software purchase - Set-up fee - Hardware, for example, computers - Data management and storage service	- Average service fee is $6000 to 25000/year	- Cost is dependent on o size of the enterprise o number of facilities o number of trading partners involved - Fees for smaller companies may be as low as $3600/year - Large companies with many facilities as high as $1000000/year including hardware

Table 21: Cost estimates for product tracing solutions (Mejia et al., 2010, p. 166)

The information obtained from their research provides a rough estimate of traceability costs. Moreover, the study was conducted in 2010, which implies that technology related to traceability most likely has become more "common". This in turn suggests that costs associated with traceability have declined. Next, as pictured in table 21, the cost of traceability systems varies (from $3600/year to $1000000/year) depending on size of enterprise, number of facilities, and complexity of the supply chain (in terms of integrated suppliers). This information supports that electronic traceability systems are capital intensive. Furthermore, the additional costs of traceability will affect the final price of aquaculture products. In turn, it is the customers that ultimately must pay for the additional cost of traceability.

Despite additional costs, we have previously found that customers are willing to pay more to ensure the quality and safety of fresh food (cf. quality analysis). Moreover, the survey from China indicates that customers are willing to pay a 6% price premium for traceable products. Additionally, Choe et al. (2008) conducted a survey in Korea of price premium and buying behavior with respect to traceability. Their results are displayed in table 22.

Price premium	Percent	Purchase Intention (Int1)	Percent
0	8.79	Very low	1.64
1–5% more	39.56	Low	6.13
6–10% more	35.38	Medium	30.67
11–15% more	13.85	High	47.85
16% and over	2.42	Very high	13.71

Table 22: Amount of price premium and purchase intention by consumers (Choe et al., 2008, p. 10)

The survey from Korea indicates that there is a willingness to pay for traceable products. Only 8,79% of the participants in the survey was reluctant to pay a price premium. On the other hand, 74,94% were willing to pay a price premium between 1-10%. This is coincident with the results obtained from China. Additionally, the purchase intention increased as a result of traceability. Table 22 displays that 92,23% of the participants in the survey (from medium – very high) chose to buy more as a result of traceability. "These results confirmed that the food traceability system serves to boost consumer confidence by reducing the perceived uncertainty of food. Consumers intended to both pay more and buy more food with the traceability system" (Choe et al., 2008, p. 9).

4.4.2 Transportation:

Relating to transportation, we have as previously mentioned that trailer-based transportation is currently the dominating transportation alternative within the Norwegian aquaculture industry. Moreover, fresh fish constitutes roughly 94 percent of the total export. This increases requirements relating to responsiveness, regularity, and flexibility of deliveries, which in turn acts inflationary on the end price for the customer.

Furthermore, there are potentially huge cost savings relating to the implementation of the PI. The PI aims at implementing an open and interconnected logistics web. It enables significant improvements relating to e.g. reduced traveling distance, less "empty travels", reduced storage costs, improved load utilization, improved return freight distribution, reduced terminal time, and reduced transportation costs. Additionally, both the MODULUSHCA project (Landschuetzer et al., 2015), as well as the Carrefour and Casino simulation (Hakimi et al.,

2012) supported this. The MODULUSHCA project showed a reduction of up to 60 % of chain level costs, with roughly 32 percent of the savings coming from better utilisation of transportation and handling. (Huschebeck, 2014) Moreover, the Carrefour and Casino (Hakimi et al., 2012) simulation reported a 32 percent improvement in overall cost savings, along with a reduced travel distance of approximately 20 percent. Additionally, the simulation showed a 60 percent reduction in green house gas emissions. This is also an important point, since the Norwegian aquaculture industry has for a long struggled with a bad reputation in terms of not taking their environmental responsibility. Thus, being able to reduce their "carbon footprint" could potentially improve their reputation, ultimately leading to increased sales.

Moreover, with 94 percent of the about 1,39 million tonnes of seafood exported in 2014 consisting of fresh fish, it is within these 1,31 million tonnes (1,39 million tonnes x 94 %) that the largest potential for improvement lies. Further, of these 1,31 million tonnes approximately 1,06 million (1,31 million tonnes x 81 %) million tonnes are transported using road based transportation. Hence, this is a vital segment in terms of making a significant impact on the transportation within the industry. As table 17 presents, road based transportation has a transportation cost ranging between 1-3 NOK/kg. By assuming an average transportation cost of 2 NOK/kg, we find that the total transportation cost for this segment accounts to roughly 2,11 billion NOK (1,06 million tonnes x 2 NOK/kg). Consequently, applying the results found in the Carrefour and Casino simulation, this would lead to a cost reduction of approximately 675 million NOK (2,11 billion NOK x (1-0,32) = 1,435 billion NOK → reduction of 675 million NOK).

Furthermore, being able to reduce the terminal time through more efficient on –and off loading would further increase the utilization of intermodal transportation. Taking the example from Hovi et al. (2014A), an intermodal transportation solution made up by railroad transportation from Trondheim – Oslo followed by trailer transport from Oslo – Paris, would only take one hour more than a direct trailer-based transport solution directly from Trondheim – Paris. Thus, being able to improve the handling time through a more efficient on- and offloading, can reduce the handling and terminal costs associated with this type of intermodal transport. Making this a viable transportation option for the industry. This could also represent a big efficiency improvement, as railroad-based transport has a much larger cargo capacity than road-based transport. Consequently, enabling an increase in the amount of distributed products, and potentially lowering the transportation costs through a reduced amount of shipments.

As presented in the simulation experiment conducted by Montreuil (2011), utilizing the ability of the mobility web by employing several drivers instead of one could make significant contributions to reduce traveling time, and consequently reduce transportation costs. Furthermore, in the experiment the company were able to reduce the traveling by 50 percent on a trip from Quebec to Los Angeles. Subsequently, this would also lead to a significant reduction in wage costs for companies, as drivers wont have to be compensated for long trips.

Moreover, as presented earlier, applying this to the experiment depicted in Hovi et al. (2014A), would make the total transportation time from Trondheim – Paris last 27,5 hours. Thus, reducing the total transportation time by as much as 18,5 hours, or roughly 40 percent. As table 18 shows, the trip before the implementation of the PI had an estimated cost framework of 40 703 NOK. This corresponds to a transportation cost of roughly 1,63 NOK/kg (40 703NOK/25 000kg). Taking into account that an estimated loading capacity of a fully loaded semi-trailer is approximately 25 tonnes. (Innovasjon Norge, 2005, innovasjonnorge.no) Furthermore, the results from the Carrefour and Casino simulation, suggested a 32 percent improvement in overall cost savings. Hence, the trip in a π –enabled open mobility web would have a total cost framework of 27 678 NOK (40 703 x (1 – 0,32)). Additionally, this would correspond to a transportation cost of roughly 1,11 NOK/kg (27 678 NOK/25 000kg).

4.4.3 Concluding remarks

In conclusion, the implementation of electronic traceability systems requires capital and resources. The implementation results in increased costs for the respective company. Hence, the price of the final product increases to cover these costs. Ultimately, it is the consumers that have to pay a price premium for the additional costs of traceability. However, our results indicate that most customers accept a price premium for traceability. In addition, the purchase intention increases. "Consequently, both producers and merchants of food products would benefit from the increased sales and prices" (Choe et al., 2008, p. 9-10). Moreover, also the implementation of concept from the PI would require capital and resources. However, as the simulations from the MODULUSHCA-project (Landschuetzer et al., 2015) and Carrefour &

Casino (Hakimi et al., 2012) shows, this implementation could lead to a significant cost and time reduction within the industry. Thus, in an industry with a current total transportation cost of roughly 3,86 billion NOK (Appendix), being able to reduce this by 30 or so percent, would make a significant contribution in terms of improving the profitability of the industry. Additionally, it would represent a big improvement in terms of handling and distribution of goods, relating to improved flexibility, reliability, and responsiveness of deliveries, which has become increasingly important due to the shift in the customer base.

4.5 Summary of findings

Traceability and the PI are interconnected aspects of transportation and logistics, and influence the final quality of the product, the lead-time from processing to the customer, and lastly the price. Traceability as a feature of IoT is an integral part of the PI. However, the PI is a vision not yet finalized. Nevertheless, electronic traceability systems and aspects of the PI alone, have the potential to improve supply chains in the Norwegian aquaculture industry significantly. We will now address the most important findings to "connect the dots" and provide a comprehensive picture on how traceability and PI can benefit supply chains for companies operating in the Norwegian aquaculture industry.

There has over the last few decades been a significant shift in the customer base for aquaculture products, from traditional fishmongers towards large retail chains. This development has led to increased requirements from customers in terms of documentation, regularity and flexibility in deliveries, as well as responsiveness. In turn, this has created challenges for actors operating in the Norwegian aquaculture industry, as the need for reliable information both up- and downstream in the supply chain has increased. Traceability and the PI can be a solution to these challenges. Moreover, our cause-effect diagrams displays that traceability and transportation is common denominators in terms of quality, time, and price.

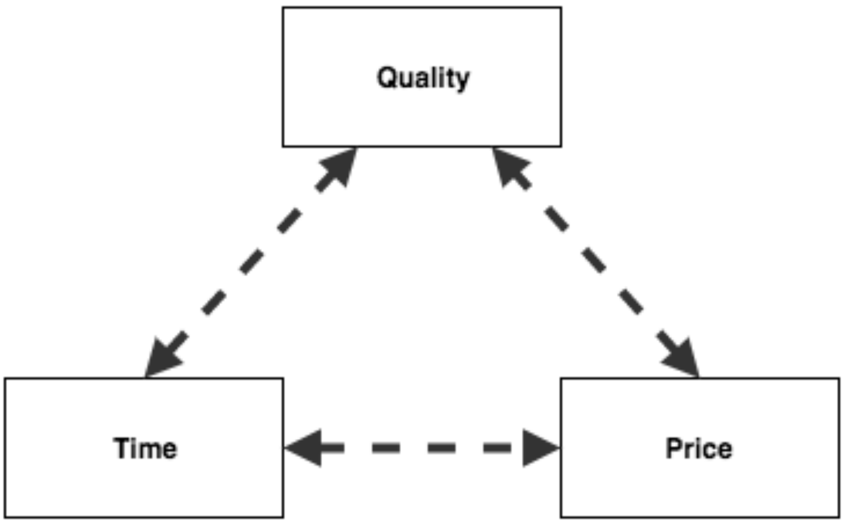

Figure 40: Relationship between Quality, Time, and Price.

Figure 40 displays that the three defined factors are interconnected and affects each other. First, quality is dependent upon time and price. As shown in table 14, the volume and timing of deliveries, are important customer demands within the aquaculture industry. Reductions in transportation time, along with a more responsive and flexible transportation system will increase the perceived quality through the eyes of the customer. This can be achieved through the PI. As the analysis presents, lead-time during transportation will be reduced as a result of more efficient logistics solutions through the PI. This was displayed by results gathered from the MODULUSHCA-project, the Carrefour and Casino simulation, along with the PI enabled transportation experiment presented in Montreuil (2011).

In addition, traceability will ensure the quality of the product by providing transparency and real-time information, as well as enabling more efficient production processes that reduces the "manufacturing" lead-time. This has been demonstrated by the research of Parreño-Marchante et al. (2013). From table 15, one can read that efficiency, flexibility, and responsiveness increase significantly as a result of electronic traceability. Transparency in the supply chain allows customers to ensure the quality of the product through monitoring (RFID, WSN, and GPS). Operations and processes are streamlined and conducted in a more efficient manner, and the responsiveness increases due to real-time tracking of products. Thus, traceability address important aspects of production and distribution, and has the potential to support companies in the Norwegian aquaculture industry to deliver products of high quality when they are needed.

Further, time is a pivotal factor influencing both quality and price. As depicted in both the MODULUSHCA-project and the Carrefour and Casino simulation, utilizing concepts from the PI reduced transportation cost significantly. This was ensured by reduced terminal time, more efficient distribution routes, and increased space utilization leading to less empty travels. Moreover, traceability affects the transportation time indirectly by enabling a more efficient distribution through universal interconnectivity (e.g. RFID and GPS). Further, it is fair to assume that reduced transportation time-and costs could lead to either reduced price for the customer, or increased profit for aquaculture companies.

Lastly, price is a product of quality and time. Price is defined as one of the main customer demands by Tveterås & Kvaløy (2004). Additionally, coarse granularity with respect to traceability suggests lower operating costs. Thus, reducing the final price for the customer. Finer granularity on the other hand, implies higher costs associated with investments in equipment as well as expenses relating to operational activities. This is confirmed by Mejia et al. (2010), and pictured in table 21. They explain that costs of traceability depend on the size of the company, the amount of facilities, and number of suppliers in the supply chain. Further, they have estimated the price of RFID tags- and readers, software required, set-up costs, training etc. Thus, implementing traceability on a finer granularity level implies a need for more material and equipment (RFID tags, readers, labels etc.), which in turn results in higher operational costs. Hence, increasing the final price for the customer. However, as discovered in the analysis, customers are willing to pay a price premium for traceability. This is confirmed by several sources; Parreño-Marchante et al. (2013), Olafsdottir et al. (2010), and Choe et al. (2008). The WTP differs between the different studies, but ranges between 0-10 % of the original price. Additionally, Choe et al. (2008) found that the purchase intention increased as a result of traceability. This underline the importance and impact traceability has for the final customer with respect to perceived quality. Moreover, as mentioned above findings in the analysis indicates that utilizing the PI can reap substantial rewards with respect to reduced transportation costs. In turn, lower transportation costs implies reduced price for the final customer.

5.0 Validity and Reliability:

Maxwell (2005) defines validity as a "way to refer to the correctness or credibility of a description, conclusion, explanation, interpretation, or other sort of account" (Maxwell, 2005, p. 106). Moreover, validity is treated differently between quantitative and qualitative studies. "Quantitative and experimental researchers generally attempt to design, in advance, controls that will deal with both anticipated and unanticipated threats to validity" (Maxwell, 2005, p. 107). "Qualitative researchers, on the other hand, rarely have the benefit of previously planned comparisons, sampling strategies, or statistical manipulations that "control for" plausible threats, and must try to rule out most validity threats after the research has begun, using evidence collected during the research itself to make these "alternative hypotheses" implausible" (Maxwell, 2005, p. 107). Moreover, Golafshani (2003) explain that reliability relates to the quality of the research. In short, "reliability and validity are conceptualized as trustworthiness, rigor and quality in qualitative paradigm" (Golafshani, 2003, p. 604). As a final remark, "reliability is a consequence of the validity in a study" (Golafshani, 2003, p. 602). This implies that reliability and validity is interconnected in explaining the quality and trustworthiness of the study.

5.1 Validity and reliability of sources

The thesis mainly consists of secondary sources. It is therefore imperative to pay attention to validity threats of these sources in terms of quality, dependability, transferability and trustworthiness. We have throughout this thesis used various sources in the analysis to shed light over relevant aspects of traceability and transportation. First, regarding the analysis of traceability, a frequently used source is the article of Parreño-Marchante et al. (2013). This article is mainly used to explain how traceability operations in the aquaculture industry takes place. Moreover, it is important to note that the research provided by Parreño-Marchante et al. (2013) was conducted in aquaculture companies in Slovenia and Spain. Thus, some of the supply chain operations described by Parreño-Marchante et al. (2013) may differ from the practises in the Norwegian aquaculture industry. However, it is reasonable to assume that the described traceability operations functions somewhat similarly regardless of fish are farmed in Slovenia/Spain vs. Norway. Hence, we consider the implementation and operation of electronic traceability systems described by Parreño-Marchante et al. (2013) transferable to companies in the Norwegian aquaculture industry.

Next, another important aspect regarding trustworthiness and credibility of sources are the implications of electronic traceability systems. The article by Parreño-Marchante et al. (2013) is the main source in terms of concrete improvements as a result of electronic traceability. Their article provides actual figures (KPIs) of efficiency improvements. However, they are the only source that points out improvements in terms of actual numbers, and one should therefore be careful to conclude that these numbers are representative for all other companies operating in the industry. Additionally, these numbers are as previously mentioned obtained from aquaculture companies located in Europe. Thus, the numbers provided by Parreño-Marchante et al. (2013) cannot be used to conclude the benefits of electronic traceability, but they indicate potential benefits for the industry. We did not come by any other sources that could confirm traceability improvements by actual figures. Nevertheless, when preparing for the analysis, we could read from various other sources that electronic traceability has a positive effect on supply chains with respect to efficiency. Moreover, Nordlaks confirms that electronic traceability solutions had a positive effect on improving both quality and streamlined operations. Thus, it is fair to believe that our sources are valid, and that they indicate possible benefits for the aquaculture industry in Norway. In addition, the article provided by Parreño-Marchante et al. (2013) is a paper in "Journal of Food Engineering", which in turn increases the validity.

WTP for traceability is another important aspect of this thesis. We have throughout the thesis used several sources to ensure the reliability and validity of this feature. Among these sources are Parreño-Marchante et al. (2013), Olafsdottir et al. (2010), and Choe et al. (2008). However, the studies of WTP were conducted in countries (China, Korea, and Slovenia) that not are main export markets for Norwegian salmon or other aquaculture products. Thus, one cannot conclude that the findings are representative for customers in markets where Norwegian aquaculture products are sold. However, Parreño-Marchante et al. (2013) conducted the WTP study in one European country (Slovenia). Moreover, the main export markets for Norwegian aquaculture companies are European countries such as Poland, France and Denmark. Hence, the results acquired from Parreño-Marchante et al. (2013) indicates that one can expect similar buying behaviour in the main export countries for Norwegian farmed fish in Europe. Lastly, the fact that all sources confirm that the customers accept a price premium for traceability strengthens the reliability and the validity in the analysis with respect to WTP.

Much of the information regarding the Norwegian aquaculture industry is largely built on rapports gathered from Statistics Norway (SSB). They are a stately owned organization responsible for the research and elaboration of official statistics in Norway. Especially the rapport concerning the annual preliminary figures within the aquaculture industry (SSB, 2016A, ssb.no), have been vital in providing background information with regards to the scope of the industry. We would consider these sources as “trustworthy”. This due to the fact that SSB is an impartial institution with a vast amount of resources at their disposal, which enables them to carry out extensive research and analysis to obtain the best possible statistical datasets. One potential weakness regarding this information is the fact that it is heavily built around one primary source of information. Nonetheless, we think that the information is trustworthy. SSB is the organization in Norway with the best organizational capabilities, access to information, and statistical data.

The main sources used regarding the PI are Montreuil (2011), Hakimi et al. (2012), Landschuetzer et al. (2015), and Huschebeck (2014). These provide the theoretical groundwork with respects to the PI, along with practical applications and implications of the PI. We consider the validity with regards to the theoretical framework relating to the PI to be good. The information that constitutes the theoretical framework of the PI in the thesis is gathered from sources written by a number of different authors. Further, the articles are to a large degree written by academic researchers across various institutes and universities. This does in our view strengthen the validity and thus the reliability of the information gathered, as academic researchers must uphold a certain standard relating to source reproduction, source criticism etc. Additionally, the fact that it in the Carrefour and Casino has been used actual real world transportation data strengthens the validity and reliability of the thesis. Furthermore, the Carrefour and Casino simulations were conducted in France, which is one of Norway´s largest exporting markets. In our view this further strengthens the practical application of the PI, as well as the validity of the research. Besides, the MODULUSHCA-project is supported and sponsored by the European Union. This in turn increases the validity of the research as it shows that there exists a certain amount of belief in the project from people within the EU.

However, a potential weakness of the theoretical framework is that some of the authors may have an “agenda”. Meaning that they can be seen as somewhat emotionally invested in the PI, leading to them being slightly biased. Taking e.g. Benoit Montreuil, one of the main authors behind much of the theoretical framework for the PI. He is the founder of the PI, and may thus have a personal incentive for seeing the PI succeed. This may in turn consciously or subconsciously affect his academic papers regarding the PI. Furthermore, another potential weakness of the research is that there is a lack of real world data regarding the PI. The PI is still in a development phase, with a planned full-scale implementation by the year 2050. Thus, until now the only data regarding the practical application of the PI is build around simulations, and even though it is by many seen as the solution to “the grand challenge” there is still doubts as to whether it will be realized. This is due to the fact that the realization of the PI is highly dependent on a number of political factors. This in turn weakens the validity and reliability of the thesis, as the lack of real world empirical evidence of the PI causes an amount of uncertainty with regards to its practical application. Although there is not planned a full scale roll-out until the year 2050, some of the main concepts like modular π –containers, along with traceability through RFID-tags are feasible using current technology. We consider this to further add to the validity of the thesis.

Moreover, Tveterås & Kvaløy (2004) along with Josupeit et al. (2001), forms the groundwork of the analysis. These sources are used to portray the general trends in the industry. Meaning trends towards more vertically and horizontally integrated supply chains, as well as a more retail-focused customer base. We consider that the validity and reliability of these sources are good. The FAO is a large independent organization working towards food security, food safety, sustainable production etc. They have large organizations providing numerous academic and statistical publications surrounding the aquaculture industry, and are by many considered as “world standard” within their respective fields. Moreover, Ragnar Tveterås and Ola Kvaløy are respected researchers at the University of Stavanger. Tveterås has in particular participated in numerous publications regarding the Norwegian fishery and aquaculture industry. Although, one potential weakness with these sources are the fact that they are over 10 years old. This may impact the validity of the information as the market may have shifted, and gone in another direction. However, the information gathered is backed up by Asche & Tveterås (2011), which states that in many of Norway´s primary exporting markets about 50-80 percent of the customer base is made up of retail chains. Moreover, the fact that we have found more than one source that supported the general industry trends increases the trustworthiness of the information gathered.

Further, the rapports gathered from Hovi et al. (2014A), and Hanssen et al. (2014) forms a pivotal part of the analysis. They present the most common transportation routes for fresh fish from Norway, the flow of goods, along with the transportation costs associated with different means of transportation. The Norwegian Transport Economic Institute is a profit foundation with a mission of "carry out applied research on issues connected with transport and to promote the application of research results by advising the authorities, the transport industry and the public at large" (Transportøkonomisk Institutt, 2016, toi.no). Moreover, the rapport by Hanssen et al. (2014) is published by the Centre of Innovation and Business (SIB AS) but is a collaboration between SIB AS, the University of Nordland, and Bodø Business School. We consider the validity and reliability of these sources to be good. This is based on the fact that they are all written and published by independent institutions/organizations without a clear agenda.

5.2 Validity and Reliability of method

As previously mentioned in the chapter of methods, this thesis is built upon a mixture of quantitative- and qualitative methods. The data and information are gathered primarily through secondary sources. This implies existing statistics, reports, articles etc. Thus, this is a potential weakness of the thesis. We have not conducted any surveys, interviews, or questionnaires ourselves. Therefore, the validity of the thesis is highly dependent on the trustworthiness of our sources. However, as discussed in the paragraphs above, we consider our sources to be valid, which in turn strengthens the overall validity of the thesis.

Lastly, we would consider out data collection and utilization of the gathered information as good. The collection of data was conducted early in the semester, giving us time to process and sift out relevant and important information. Moreover, we believe that if others using the same methodology had conducted the study again, the conclusions would have yielded similar results. Hence, we consider the thesis to be reliable.

6.0 Conclusion:

The primary research question for this master thesis was:

How can the Norwegian aquaculture industry benefit from utilizing concepts from the Physical Internet and the Internet of Things in their supply chains?

However, in order to answer this inquiry, we first need to address the subordinated proposition:

How can the utilization of concepts from the IoT and the PI with respect to traceability and onshore transportation, help improve quality, time and price within the Norwegian aquaculture industry?

The results from the analysis show that quality, time, and price are interconnected factors. First, traceability is an integral part of this thesis. In terms of quality, traceability enables increased transparency through real-time monitoring- and tracking of products. Further, the analysis revealed that traceability along with flexibility in deliveries was important factors in the customers purchasing decision.

Next, traceability has the potential to improve the efficiency, flexibility and responsiveness in the supply chain. Thus, it indirectly affects time in terms of more streamlined operations in production, processing, and distribution. Moreover, the PI influences time through increased efficiency as a result of more efficient transportation, less empty travels, and reduced terminal time. Consequently, this also relates to quality, as the timing of deliveries is a key factor in customer demand.

Furthermore, the analysis showed that price is among the most important factors influencing customer demand. The implementation of traceability implies increase in costs, as investments in equipment and software is expensive. This essentially leads to an increased price for the final customer. However, results from the analysis suggest that there is a WTP for traceable aquaculture products. Moreover, implementation of the PI can potentially contribute to significant cost reductions relating to transportation. In turn, reducing the final price for the customer.

The thesis suggests that the Norwegian aquaculture industry can benefit from utilizing concepts from the IoT and the PI in their supply chains. This as a result of influencing the three interconnected factors; quality, time, and price. The primary focus in terms of supply chain improvements in the industry has been mainly directed towards upstream activities. However, due to increased focus relating to regularity and flexibility in deliveries, along with food safety, quality, and documentation, the need for innovative transportation- and traceability solutions has become imperative.

Electronic traceability systems enable transparency and efficient communication throughout the supply chain. It provides key information about the products, which in turn facilitates better decision-making. Hence, traceability supports decisions regarding inventory management, logistics management, and forecasting. Further, this improves the relationship between up- and downstream activities in the supply chain. Moreover, traceability ensures the perceived quality of the product, which can improve the reputation and sales for Norwegian aquaculture companies.

Implementing the PI in the Norwegian aquaculture industry could potentially lead to significant reductions in transportation costs- and time. This can be accomplished through utilizing smart modular π-containers, an open and interconnected logistics network, as well as enabling more intermodal transportation. Moreover, through reduced transportation costs, the industry could be able to further strengthen their competitive advantage in terms of proximity to market. The introduction of the PI also has the potential to significantly reduce the amount of greenhouse gas emissions generated by transportation from the Norwegian aquaculture industry. This can in turn improve the reputation and sales for the industry.

As a final remark, we consider traceability and the PI as highly relevant for Norwegian aquaculture companies. The industry is facing increasingly high demands with respect to delivering products of high quality, at the right quantity, when they are needed. Thus, we believe that effectively utilizing concepts from the IoT and the PI has the potential to benefit companies operating in the industry.

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Appendix:

Total scope of transport within the Norwegian aquaculture industry:

Total export x total export of fresh fish

1,39 Million tonnes x 94 % = 1,3066 million tonnes

Total amount in tonnes of fresh fish transported using trailers:

1,3066 million tonnes x 81 % = 1,0584 million tonnes

Total amount in NOK of fresh fish transported using trailers:

1,0584 million tonnes x 2 NOK/kg = 2,116 Billion NOK

Total amount in tonnes of fresh fish transported using airfreight:

1,3066 million tonnes x 0,11 % = 0,144 million tonnes

Total amount in NOK of fresh fish transported using airfreight:

0,144 million tonnes x 11 NOK/kg = 1,584 Billion NOK

Total amount in tonnes of fresh fish transported using ship freight:

1,3066 million tonnes x 8 % = 0,105 million tonnes

Total amount in NOK of fresh fish transported using ship freight:

0,105 million tonnes x 1,5 NOK/kg = 0,158 Billion NOK

Total scope of transport within the Norwegian aquaculture industry = *Total amount of fresh transported using trailers + Total amount of fresh transported using airfreight + Total amount of fresh transported using ship freight* →

2,116 Billion NOK + 1,584 Billion NOK + 0,158 Billion NOK = 3,858 Billion NOK