Master's degree thesis

LOG950 Logistics

The impact on warehouse processes in a retail supply chain by implementing improved RFID technology

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Molde, May 2019

Guro Iveland

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Abstract

In order to deal with the pressure from more demanding customers the supply chain must become smarter. Today, the retail industry is suffering from a high number of mis deliveries, and the focus has been towards streamlining operations in order to build more robust processes. This means that a supply chain should include new technology into their operations. Our research will mainly focus on how improved RFID technology can influence the warehouse operations at XXL's central warehouse. Further, it seeks to identify how RFID can impact the economic assessments. To supplement this research problem, a research question was formulated:
How may improved RFID technology applied in warehouses have an impact on economic assessments and warehouse processes for the retail industry?

The research problem focuses on understanding the nature of the problem, seeking to find possible cost, and time savings that are not previously research to any large extent. A mixture of qualitative and quantitative research strategy is therefore applied in conjunction with a case study design to support the research problem and to gather relevant data. Interviews and observations have been conducted as well as related calculations. Theory has been studied and RFID technology is described as the main theoretical concept in this thesis. Other theoretical concepts included are supply chain, information sharing and warehouse.

Potential improvements were revealed in the existing processes of XXL, and it was found issues concerning a high number of errors and the associated cost. By implementing RFID technology our investigation show that XXL have possible time and cost savings. Further, customer satisfaction can increase by reducing errors in the delivery process. Hence the supply chain can overall be more efficient. Some challenges revealed to RFID implementation was reading limitations of product containing metal and liquid, price and infrastructure.

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List of Abbreviations and Acronyms

AVS – Automated Validation Station

EAN - European Article Number

ERP – Enterprise resource planning

FTE – Full-time equivalent

H&M – Hennes & Mauritz

IFF – Friend-or-Fie

IOIS – Inter-organizational information system

IS – Information systems

KPI – Key performance indicator

LS – Lyngsoe Systems

NRL – Naval research laboratory

OCR – Optical character recognition

OMS - Order management system

RFID – Radio frequency identification technology

ROI - Return of investment

SC – Supply chain

SCM – Supply chain management

TMS - Transport management system

WMS – Warehouse management system

XXL – XXL Sport and Outdoor

1.0 Introduction

This thesis is carried out as a case study that is based on a pilot project with the Danish software company Lyngsoe Systems (LS) and the Norwegian company Consignor. Consignor provides programming services and one of their customers are the Nordic sport company XXL Sport and Outdoor (XXL). The pilot project has evolved to become a product called Automated Validation Station (AVS) that Lyngsoe Systems will launch in May this year. The thesis will mainly deal with the central warehouse of XXL in Jessheim outside of Oslo.

This chapter will provide the background for the research and introduce the study. The rest of this chapter is organized as follows; section 1.1 provides the background of the study. Section 1.2 provides an overview of the research, explaining the objectives, research method and conduction of the study. Section 1.3 presents an overview of the chapters to follow.

1.1 Background

The e-commerce market in Norway has exploded massively in recent years and from 2017 to 2018 an estimated increase of 17 percent was predicted. More and more people are shopping online because it is perceived as cheaper and better, time-saving and the consumer gets a better overview of the goods (PostNord 2018; Dibs Payment Service 2018). To deal with the pressure from more demanding customers the supply chains must become smarter, meaning include new technology to create a more robust supply chain (Butners 2010). Major international e-tailers like Amazon and Alibaba have invested greatly in new technology and services in recent time, and it is seen as important that other operators follow in order to maintain as a competitor and an interesting partner (Åkesen 2017). Currently, there has been a growing interest in product visibility which has led to greater awareness among scientists and industries. Based on this, numerous of technologies and software programs have been developed in order to contribute to more product visibility. (Musa, Gunasekaran and Yusuf 2014)

Butners (2010) study find that there are five key challenges in supply chain management; cost containment, visibility, risk, customer intimacy and globalization. A technology that may deal with these challenges, and that have received interesting attention in recent years is radio frequency identification (RFID) (O'Bannion and McMurtrey 2018). RFID has been around for decades, and the use of RFID solutions are constantly evolving where one example of this is the AVS. Further, RFID is referred to as a technology that offers many benefits, from cost reduction to improved shipment errors, accuracy and visibility in the overall supply chain. Still, the implementation of the technology has been somewhat limited. RFID technology has been too expensive among retailers, but the price has decreased considerably since the first retailers adopted the technology. Further, an obstacle discussed in previous literature is the difficulty of calculate the profitability of RFID adoption (Shin and Eksioglu 2014). However, many researchers describe the effect of RFID in a descriptive way without connecting numbers into their arguments.
There are identified a gap in the literature towards empirical investigation into numbers of the effect of RFID. As for this thesis, we will exam the effect of improved technology and conduct related calculations.

In a warehouse the logistic processes like picking, packing and sending products are usually based on manual procedures by the warehouse employees. The order fulfilment process relay on the employees to pick up the right item from the inventory, verify customer order and make sure that the correct content is on the right pallets and loaded onto the right transportation mode. (Richards 2014) In order to achieve an outstanding logistics performance and to eliminate errors that may occur due to human mistakes, a pilot project between LS, Consignor and XXL was signed. XXL has since the spring of 2018 tested the AVS at their central warehouse.

1.2 Research objectives

The purpose of this thesis is to investigate the effect of an RFID technology solution. It is identified a gap in the literature regarding empirical research of improved RFID technology. The literature points out the benefits with RFID but there are no relegations towards calculations of these effects. Due to this it calls for further investigation. Our thesis will use a case study approach, more specific, investigate the processes at XXL's central warehouse.

This include how RFID can create a more cost efficient and visible supply chain. Further, detect if the implementation of the AVS can improve the handling processes, meaning handling, sortation and packing of goods at the warehouse.

Based on this the following research question was formulated:
How may improved RFID technology applied in warehouses have an impact on economic assessments and warehouse processes for the retail industry?

With this in mind, we want to highlight what is going efficient and why, as well as focus on the improvements caused by implementing RFID technology. We want to investigate how much time XXL is using on the logistics operation today, as manual labour and the cost for doing so. It will also be conduct calculations of how much time spent on the scanning process before and after the RFID implementation in order to compare the numbers. Further, we will investigate how many errors that are happening in the shipment preparation and the cost for correcting these errors. We will also investigate how RFID technology can affect the supply chain, and if this can have an impact on the information flow.

1.3 Structure of the thesis

The paper is organized as follows. First, we present the *Theoretical Framework*, which present a general overview of the literature within RFID technologies, information systems and warehouses in a supply chain. The *Case Description* is introduced in Section 3.0. In section 4.0, our approach and methodology used for the data collection are introduced, followed by the variables used in our calculations. Section 5.0 reviews our *Findings* which is discussed in section 6.0 *Discussion.* In section 7.0 a conclusion of the thesis is conducted, followed by limitations and suggested further studies.

2.0 Theoretical Framework

The theoretical framework will carry out previous research, studies and cases completed in conjuring of applying Radio Frequency Identification (RFID) technology. The development of RFID is presented, the price trend and similar competing technologies are described. Further, the benefits and challenges associated with RFID technology and how it is used in supply chain management are presented, followed by a section defining concepts and terminologies used in the study. Relevant concepts such as supply chain, information sharing, and warehouse are presented.

2.1 Automatic identification systems

To understand how RFID technologies is assembled, we have reviewed the history of the most common type of automatic identification systems. Finkenzeller (2010) present in his book *RFID Handbook* an overview of the most important automatic identification systems procedures: barcode system, optical character recognition, biometric procedures and smart cards. An overview is presented in figure 4.

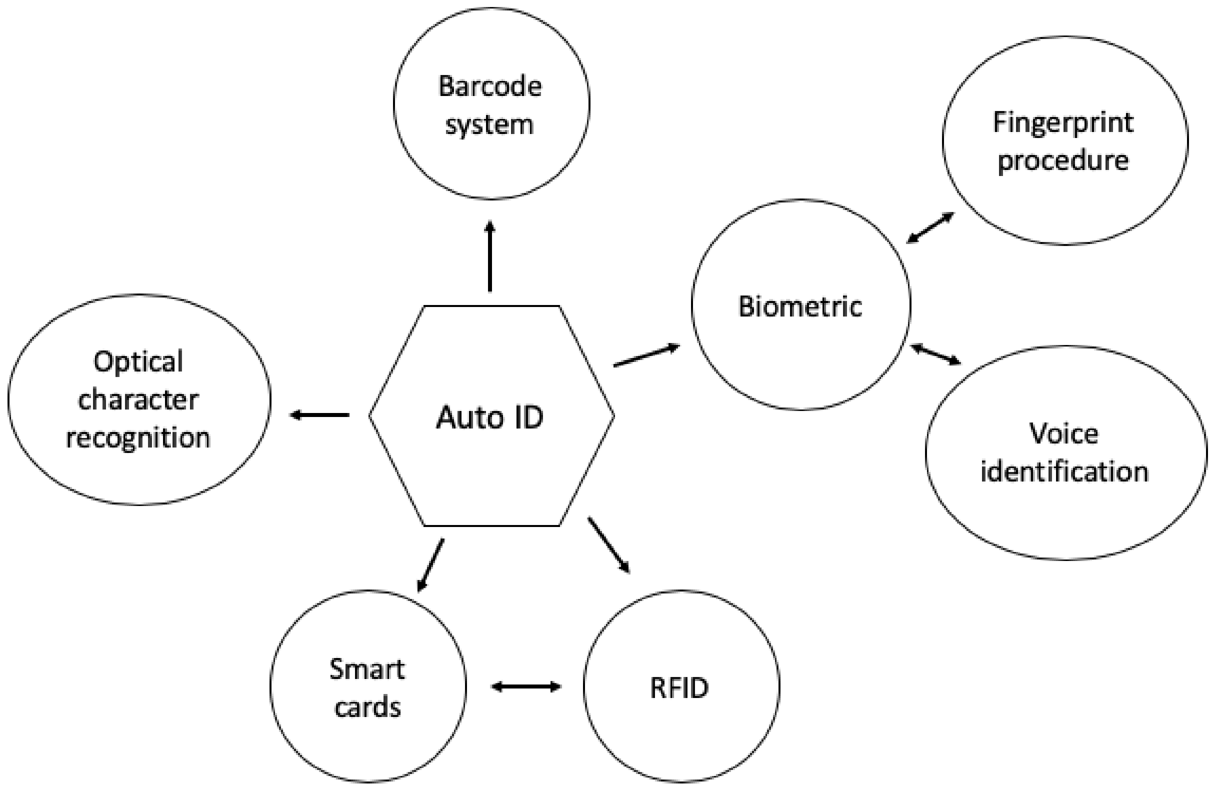

Figure 1 - Overview of the most important auto-ID procedures (Finkenzeller 2010)

Barcode systems

A barcode can be defined as a binary code consisting of vertical bars and gaps of varying and parallel widths that represent letters, numbers and other symbols (Richards 2014; Finkenzeller 2010). The barcode symbols are read by electronical scanning using a laser or a camera-based system. The purpose of barcodes is to encode information from product numbers, serial numbers and batch numbers to recognize and track products in a supply chain. (GS1a 2019) Currently, there is no universal barcode, but the most common and standard barcode today include EAN 8, EAN 13 and Code 128 as illustrated in figure 2 below (Richards 2014; Finkenzeller 2010; Jones and Chung 2008).

Figure 2 - Most common barcode types (Prusty 2015)

In recent times the barcode has evolved to include two-dimensional (2D) barcodes, more known as QR codes. A QR code is a square or rectangle that contain small, individual dots and can store a greater amount of information within a much smaller space than normal barcodes. (GS1b 2019; Richards 2014) Two common 2D barcodes are QR code and DataMatrix code and are shown below in figure 3.

Figure 3 - 2D Barcodes (GS1b 2019)

One of the mentioned obstacles with barcodes is that barcode needs a line-of-sight in order to be read. Meaning that the barcode needs to be visible for the scanner to read.
The possibility to be damaged by for example faded in sunlight, destroyed by the rain or torn apart, are further mentioned as disadvantages (Richards 2014). The barcodes are comparable to RFID tags in the way that both operate with labels that are scanned and further connected to a software system (Finkenzeller 2010).

Smart cards

A smart card is an "electronic data storage system" with a size of a regular credit card (Finkenzeller 2010). One obtains information from the smart card using a reader which makes an electric connection. The most common smart cards are the memory card and the microprocessor card. One of the benefits of smart cards is that the information stored on it is well protected from manipulation, while one of the disadvantages is the vulnerability of dirt and wear over time. (Finkenzeller 2010)

Optical character recognition

Optical character recognition (OCR) is a method which a computer system reads characters on paper and converts them to digitally stored text. OCR can convert images to a file that can be read and understood by a computer. This allows scanned documents to be compared to a database of characters and words, where the device automatic recognizes (Finkenzeller 2010).

Biometric procedures

Biometric procedures are an identification system that use individual physical characteristics like fingerprints, face recognition, voice or retina (iris) to identify people (Finkenzeller 2010).

Features of automatic identification systems

Table 1 highlights some of the advantages and disadvantages between the different identification systems and RFID technology and present a close link between contact-based smart cards and RFID systems (Finkenzeller 2010).

Table 1 - A comparison of automatic identification systems (Finkenzeller 2010)

Systems Parameters	Barcode	OCR	Biometry	Smart Card	RFID Systems
Typical data quantity (bytes)	1-100	1-100	-	16-64 k	16-64 k
Data density	Low	Low	High	Very high	Very high
Machine readability	Good	Good	Expensive	Good	Good
Readability by people	Limited	Simple	Difficult	Impossible	Impossible
Influence of dirt/damp	Very high	Very high	-	Possible (contacts)	No influence
Influence of (optical) covering	Total failure	Total failure	Possible	-	No influence
Influence of direction and position	Low	Low	-	Unidirectional	No influence
Degradation/wear	Limited	Limited	-	Contacts	No influence
Purchase cost/reading electronics	Very low	Medium	Very high	Low	Medium
Operating costs	Low	Low	None	Medium	None
Unauthorized copying/modification	Slight	Slight	Impossible	Impossible	Impossible
Reading speed (including handling of data carrier)	Low 4 s	Low 3 s	Very low > 5-10 s	Low 4 s	Very fast 0,5 s
Maximum distance between data carrier and reader	0-50 cm	< 1cm scanner	Direct contact	Direct contact	0-5 m, microwave

2.1.1 A brief history of RFID technology

In order to get a better understanding of the development of RFID technology, it was conducted a search in historical events. The development of RFID started early in the 1880's by first getting an understanding of how to use electromagnetic energy. The U.S. Naval Research Laboratory (NRL) invented a RFID-like technology called the Identification Friend-or-Foe (IFF) system in 1937. (Bhuptani and Moradpour 2005) The IFF system was the first active RFID system, and in early 1940's the British Air Force adopted the IFF system to help identify allies or enemies.

By using the IFF system, every British aircraft was equipped with a transmitter. When the transmitter picked up waves from a radar station at the ground it was sent signals back to the transmitter who identified the aircraft as allies. The theory of RFID was later presented in a paper by Harry Stockman in 1948. In 1973, the first RFID patents was received and in the 1980s companies started to implement RFID technology, for transportation, personnel and animals. (Finkenzeller 2010) A brief overview of important events is presented below in table 2.

Table 2 - A brief history of RFID technology (Jung and Lee 2015; Jones and Chung 2008; Statista 2019)

Date	*Event*
1880s	Fundamental understanding of electromagnetic energy
1886	The idea of using Radio Frequency to reflect waves from objects was started from Frederick Hertz's experiment
1897	The radio was invented
1930-1940	American navy research laboratories developed a system known as IFF (Identify Friend or Foe)
1940-1950	The first application of RFID consisted of identifying allied or enemy aircraft during World War 2 through the use of IFF system
1948	Harry Stockman presented the theory behind RFID
1973	Mario W. Cardullo received the first patent for an active RFID tag. Charles Walton received the same year patent for a passive transponder, a radio-operated door lock.
1980-1990	Many US and European companies started to manufacture RFID tags
1999	An Auto-ID center was established at Massachusetts Institute of Technology (MIT)
2003	The Auto-ID center for MIT became EPC global, an organization whose objective it to promote the use and adoption of RFID technology
2005	Wal-Mart launched an RFID pilot
2016	On average, an RFID tag costs 7-15-dollar cents
2020	The RFID market is expected to grow to 24,5 billion USD

Around 1999, two professors at MIT, David Brock and Sanjay Sarma, came up with the idea of tracking low-cost RFID tags through the supply chain. The idea was to use a microchip to store information that would be accessible over the internet, which enabled the idea of visibility. From 1999 to 2003 the Auto-ID Center at MIT obtained acceptance of the passive RFID tag, and retailers like Wal-Mart, Tesco and Target initiated plans to implement RFID technology. (Jones and Chung 2008) Since then, RFID technology have come a long way, and the RFID market is expected to grow to 24,5 billion dollars (Statista 2019).

As presented above, the technology has been known for a long time, but it is only in the last decade that commercial operators have adopted RFID. In our literature review, we understood that the reason for this was due to the price of RFID technology. In the next sub-chapter, we therefore look at the price development.

RFID price development

In recent years the unit price of RFID tags has steadily decreased in cost. Figure 4 illustrate the price decline of RFID tags from 2005 to 2015, where the cost for one tag was approximately $0,20 in 2014 (Sower et al. 2012). According to Jones and Chung (2008), the price decline is due to increased scales of production.

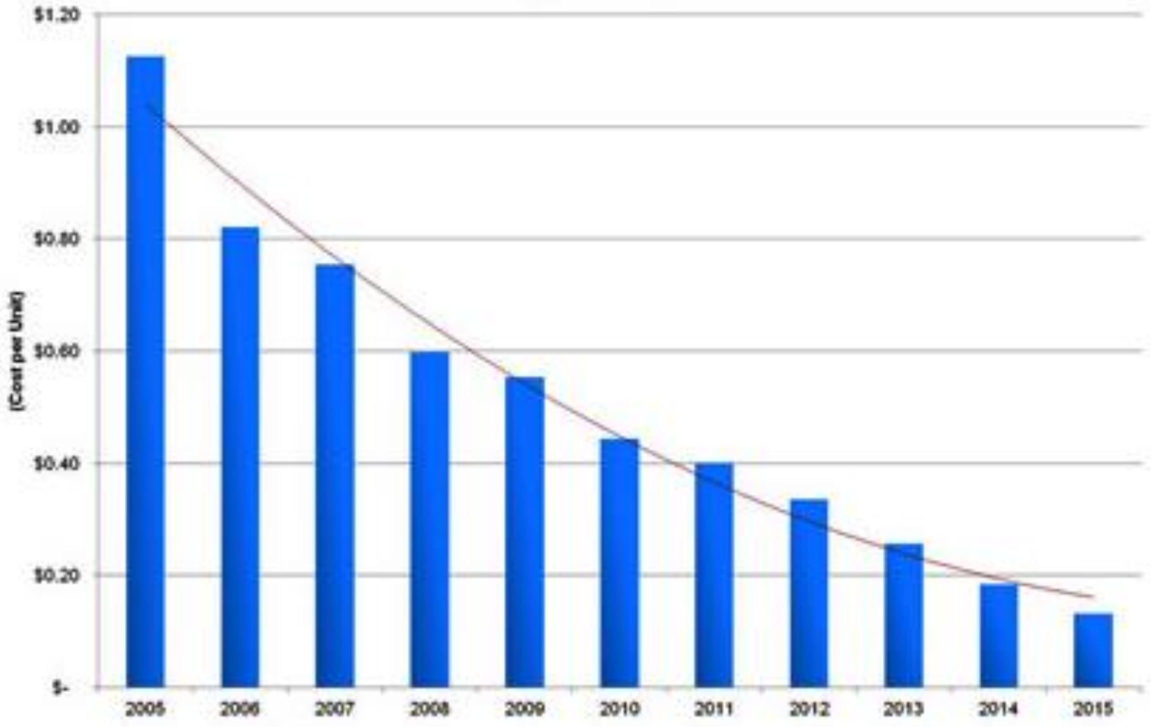

Figure 4 - Global average factory selling prices for RFID tags from 2005 to 2015 (Sower et al. 2012)

Some industry analysts suspected that if the cost of an individual RFID tag dropped to $0.05, more companies would consider implementing (Jones and Chung 2008). Currently, the significant price difference compared to other automated identification technologies has made companies to hold back (Richards 2014). Richards (2014) also states that the cost of an operating RFID system varies, depending on the application, size of installation, frequencies and quantities of tags purchased. Further he explains that the cost will be reduced by increasing the number of purchased tags.

The cost of implementing an RFID system can be divided into three categories; hardware, software and services, which is illustrated in table 3 (Ustundag 2013).

Table 3 - A classification of RFID investment costs (Banks et al. 2007 and Ustundag 2013)

Cost category	Cost items
Hardware	Tags, Readers, Antennas, Cabling and connections
Software	Middleware, Database System, Interface System, Other Software
Services	Implementation, Test, Training, Maintenance and support costs

According to Richards (2014), the cost of a RFID reader in 2014 was between €350 to €1750, while Ray (2018) states that a RFID reader may cost from $1000 to $3000, depending on whether it is a passive or active RFID system. Furthermore, Richard (2014) highlights that a passive RFID tag costs from approximately $0,07 to $0,16. According to Ray (2018), an active RFID tag costs from $5 to $15 each which is 100 times more expensive than passive tags. This indicate that a passive tag is priced around $0,05 and $0,15 in 2018. Additional costs of middleware can be found in Appendix 2. System upgrades and RF network must also be expected in this cost. (Richards 2014)

2.2 Radio frequency identification

Radio frequency identification (RFID) is a technology that was developed for more than a decade ago, but in recent years have gained high attention from supply chain industries and academics (Perret 2014).

RFID technology could be defined as a wireless automatic identification technology with the function to “identify, track and trace items automatically” (Asif and Mandviwalla 2005). A complete RFID system consists of three components;

- A RFID tag (also called transponder), that consist of a semi conductive data memory chip, an antenna, and sometimes a battery.
- A reader (or an interrogator) which creates an electromagnetic signal that transmit and receive the content of the RF tag through one or more antennas.
- A host, often a computer system, that runs the database or software program and communicate with the reader by translating the content into data.

The idea behind the technology is to attach a radio transmitter to a physical object in order to track it in the supply chain while communicating with a reader, such as consumer goods. The RFID tag consist of an antenna which emits signals to a reader where the data is received. The software carries out the RFID hardware and the enterprise applications, as illustrated in Figure 5. This means that any item with an RFID tag, within the reach of a reader, is automatically identified and registered without requiring manual handling (Chao, Yang and Jen 2007). (Domdouzis, Kumar and Anumba 2007; Sarac, Absi and Dauzère-Pérès 2010; Violino 2005; Richards 2014).

Figure 5 - Data transfer between RF tag, antenna and the reader (EPC-RFID info 2019)

RFID tag

The data is integrated into RFID tag, where the tag transfer the data to the reader when the tag is within the readers range. A RFID tag comes in all sorts of shapes and sizes, but the tags can be categorized into two standard RFID tags; passive and active tags. (Jones and Chung 2008) Finkenzeller (2010) and Richards (2014) further describes the features of passive tags, where the passive tag has no power source, limited data memory and limited read range. The passive tags receive energy from the electromagnetic field that the reader provides. If the tag is out of the reader's range it will not be capable of communicating, as the tag have no power supply. Due to this it has a very limited read range. Since the passive tags do not have any own power source, the design is usually simpler, the cost lower and the lifetime unlimited. (Jones and Chung 2008)

In contrast to passive tags, the active tags supply their own power source (battery or a solar cell) and therefore have an additional range. Active tags have a larger data memory and longer read rate, as well as the capability to read and write. Thus, information can be added or overwritten by the reader. The active tag can also update the status of the item carried. (Finkenzeller 2010, Richards 2014) Still, the battery must be replaced after five and ten years, depending on the number of times the tag is activated (Richards 2014). Due to the battery, the active tag is both larger and more expensive compared to the passive tag (Jones and Chung 2008). The features of passive and active tags are listed in table 4.

Table 4 - RFID tag comparison (Schuster, Stuart and Brock 2007; Jones and Chung 2008)

	Passive tags	**Active tags**
Power source	External Electromagnetic antenna field	On-board Battery
Reading range	3 to 7 meters	< 30
Size	Smaller	Larger
Data storage	2kb (Read only)	<32kb (Read and write)
Cost	Low (0,07 to 1,10$)	High (5 to 100$)
Frequency	Low	High
Accuracy	Low	High

The layout of a RFID tag can vary depending on the user purpose. In the figure below various RFID tags are presented.

Figure 6 - Passive and active RF tags (Lyngsoe Systems 2019)

Reader and frequencies

The reader administers the flow of data between the RFID tag and the host computer. Thus, the reader can add or remove information to the tag, as well as suppling power to passive tags. Typically, the reader interacts with the software system through a wireless connection. In order to convey the data, the tags need to be within the readers electromagnetic field. (Bhuptani and Moradpour 2005) The range of the electromagnetic field can vary from a few millimetres to above 15 meters. This depends on the given frequency, which is the number of repetitions of a complete wave within one second. (Finkenzeller 2010) The full range of the frequencies is attached in Appendix 1.

The frequency can differ from low to high, the higher the frequency, the faster the tag can transmit the data and from a longer distant (Curtin, Kauffman and Riggins 2007). Although, speed is not the only consideration regarding the choice of an RFID solution, surroundings may also play an important role. The reading range can be restrained as there are limitations that can disturb (Finkenzeller 2010). For example, other radio service producing devices, such as radio, television, or mobile phones can interfere the frequency.

It is especially important to ensure that RFID systems do not interfere with signals that are used by the police and other security services. To prevent such interferes, licensing regulations have clarified protected zones. Products containing metal or liquid, like cans of soda can also disturb the frequency due to reflections. Higher frequency implies smaller antenna, tag size and a broader range, but also more regulated and restricted use in addition to higher cost. (Finkenzeller 2010; Bhuptani and Moradpour 2005) However, the frequency regulations vary from country to country and not all frequencies are available for global use. Richards (2014) states that this may be a problem from a supply chain perspective.

The different range of frequencies can be divided into four types and are listed in table 5; low frequency, high frequency, ultra-high frequency and microwave frequency. Nevertheless, RFID tags are primarily operating in high frequency or ultra-high frequency, where the use rely on the required range and the materials present in the system. It should also be mentioned that the reader and the tags must operate in the same frequency in order to work (Jones and Chung 2008).

Table 5 - Most common RFID frequency ranges (Finkenzeller 2010; Bhuptani and Moradpour 2005)

Type of Frequency	Frequency	Key Characteristics	Typical Application
Low Frequency (LF)	Less than 135kHz/ 13.56 MHz	• Lowest transfer data • Read rate measured in inches • Best around metal and liquid	• Animal identification • Industrial automation • Access control
High Frequency (HF)	13.56MHz	• Longer read range than LF (1 meter) • Lower tag costs than LF • Poor performance around metal • Common worldwide standards	• Payment cards • Various item level tracking applications (books, luggage, garments etc.) • Smart shelf • People identification
Ultra-High Frequency (UHF)	433MHz and 868 MHz (Europe) to	• Longer read range than HF (3 meter) • Potential to offer lowest cost tags	• Inventory control • Warehouse management

	915 MHz (USA)	• Issues related to regional regulations • Susceptible to interference from liquid and metal	• Asset tracking
Microwave Frequency	2.45GHz (Europe) 5.8GHz (USA)	• Range of 3 meter with passive tags, 15 meters with active tags • Fast data transfer rates • Common in active modes • Read range is similar to UHF • Poor performance around liquid and metal • Need a backup battery to supply enough power for the operation of the transponder	• Access control • Electronic toll collection • Industrial automation

2.2.1 Advantages with RFID

There have been an abundant of academic papers examine possible benefits of RFID in supply chains. RFID can improve transaction and shipment errors, delivery errors and the traceability of products (Rekik 2006; Lee and Özalp 2007; Chow et al. 2006; Tajima 2007). Bankes et al. (2007) mention cost reduction, increased revenue, process improvement and service quality as some of the advantages with RFID.

Furthermore, it is mentioned several times in the literature that efficiency and accuracy in the overall supply chain has been achieved with RFID technology, (Agarwal 2001; Langer et al. 2007; McFarlane et al. 2003; Ustundag and Tanyas 2009; Yoo, Hong and Kim 2009; Sarac, Absi and Dauzère-Pérès 2010; Bhuptani and Moradpour 2005) as well as visibility and security level (Ustundag and Tanyas 2009). Yoo, Hong and Kim (2009) acknowledge that RFID technologies delivers information with 100% precision. According to Regattieri, Gamberi and Manzini (2007), RFID technology can streamline both work and material flow as well as reducing the number of physical handling and manual errors. The technology provides decreased lead time, shrinkage and reading time for each tagged pallet or item, overall, an advancement of inventory management (Wilding and Delgado 2004). Inventory visibility can be improved with automated information system and can reduce safety stock and the bullwhip effect (Bottani and Rizzi 2008).

Sarac, Absi and Dauzère-Pérès (2010) consider that RFID will improve the supply chain performance as the inventory will be more available, the cost of employment reduced, the inventory levels and improved coordination.

Leung, Cheng and Hennesy (2007) divides the benefits of RFID technology in three categories; revenue, operating margin and capital efficiency. Figure 7 illustrated the benefits of implementing RFID.

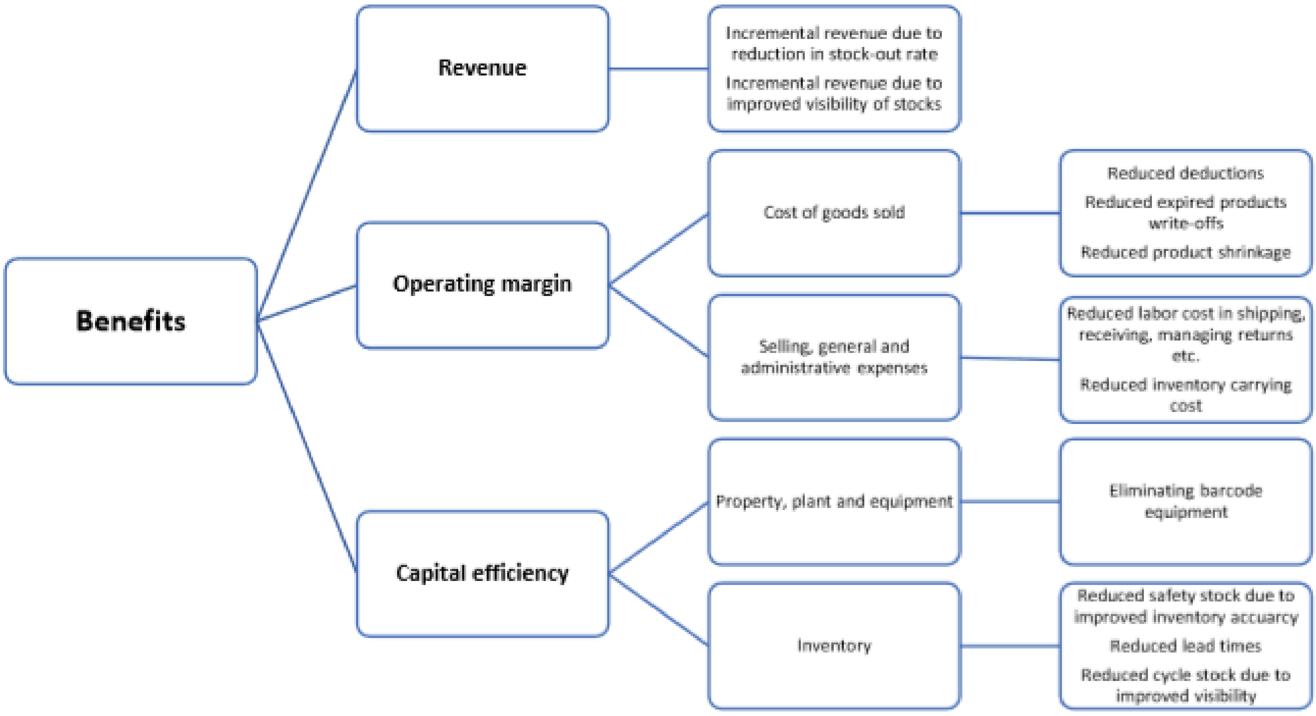

Figure 7 - RFID benefits (Leung, Cheng and Hennesy 2007)

The main advantages with RFID technology can be summarized as; improved traceability and visibility of products which can lead to increased efficiency of processes. The information will be more accurate, and the facilitation of management will be through real-time information. It is also pointed out that manual handling can be reduced as well as reduction of inventory losses, shipment errors and delivery errors.

2.2.2 Limitations with RFID

Despite the encouraging application from RFID in supply chain management there are some challenges in the hampered to adaption of RFID. Products with metal or liquid content or the environment around can disturb the RFID technology signals and influence the reading performance. This indicates that RFID does not necessarily fit all industries.

The industry related to RFID and the solutions are not jet fully developed, and due to this there are still some challenges associated with RFID technology. The main problems with RFID applications can be divided into the following challenges; "technology, standard, patent, cost, infrastructure, return on investment (ROI) and barcode to RFID migration". (Wu et al. 2006) Even though RFID technology has many benefits, the technology is still some limited since it fails to register all type of goods. Another identified barrier is that there is no international standard of using RFID, meaning that the permitted frequency on the readers are lower in Europa compared to the United States. This makes it difficult to get a fully RFID integrated global supply chain. (Richards 2014) Sarac, Absi and Dauzère-Pérès (2010) further mention that RFID is more expensive compared to other similar solutions that has the same function. It is also seen as difficult to calculate the benefits received from RFID implementation. Hence, this can be a reason why companies hesitate to implement RFID.

The main disadvantages identified with RFID technology was regarding high prices, lack of infrastructure, absence of international standards and that the signals can be disturbed (Wu et al. 2006; Sarac, Absi and Dauzère-Pérès 2010; and Banks et al. 2007). Further Richards (2014) addresses issues regarding dead areas in the warehouse where signals are weak. Tags that can be damaged by liquids, static discharges and magnetic surges are also some limitations. Intermitted data capture, with the possibility of some tags not being read and reading issues when close to proximity to liquids and metal are also mentioned as disadvantages (Richards 2014).

An overview of the advantages and limitations regarding RFID implementations are assembled in table 6 below.

Table 6 - Overview of RFID advantages and limitations (own table)

Advantages	**Limitations**
Reduction in cost of employment	High investment costs
Reduction in safety stock	Cost of tags (higher tag price compared to other technologies)
Decreased lead time	Need new infrastructure
Reduced bullwhip effect	Lack of international standards
Reduced number of physical handling	Signals can be disturbed, disturbance from items of liquids and metal
Better visibility overall in processes	Dead areas were signals are weak
Traceability of products	
Reliable and accurate reading	
Efficient, multiple tags can be read simultaneously	
New information can be overwritten	

2.3 Supply chain

A supply chain (SC) can be defined as several activities conducted through a chain of companies that are collaboration in order to add value for a product or service for the end customer. This encompass all activities from raw material to the end customer receives the product and recycling. (Harrison, van Hoek and Skipworth 2014) Mangan, Lalwani and Butcher (2012), defines a SC as a network of organizations that are connected by upstream and downstream activities. Through the various processes and activities, value is created as products or services for the end customer.

According to Gamboa, Rego, and Glover (2005), a SC can be described as a network of facilities and distribution operations. These operations include the procurement of raw materials, transformation of raw material to finished product and final distribution of these products to the end customer. A typical classic SC is illustrated in figure 8 where the involved actors is supplier, producer, dealer, wholesaler and customer. As for this master thesis the focus will be towards the wholesaler function. The figure also illustrates the different types flow of which in this case is physical, information and financial.

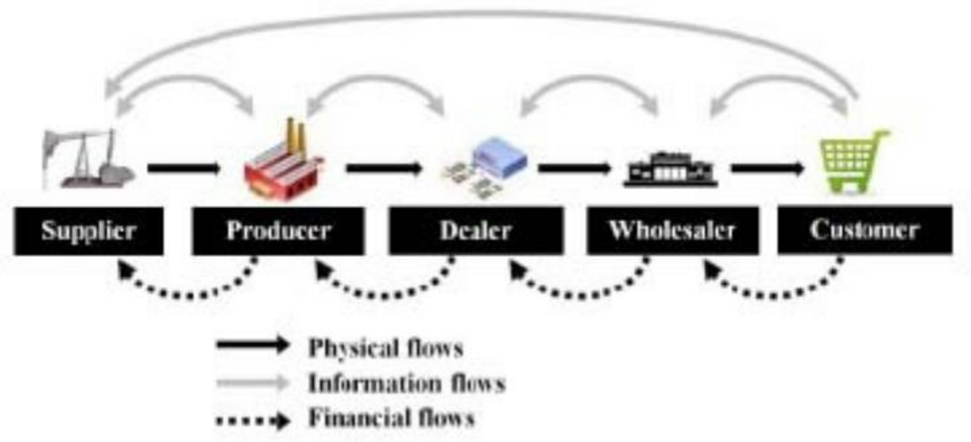

Figure 8 - An example of a classic supply chain (Deroussi 2016)

Today's SC are constant under development and are becoming more complex as there are many involved parties. There is often multiple ownership involved in the SC which can lead to challenges regarding coordinating. As a result of the constant change, managers need to rethink their approaches in relation to cooperation in order to keep up with the development (Lotfi et al. 2013). This highlight the importance of information flow between the involved parties in the SC in order to accomplish effective processes. Better information flow can be achieved with improved technology meaning that the entire SC will gain better accuracy and visibility throughout the chain. For a SC to be able to work efficiently the business processes are dependent on information from all the core parties. This indicate that there will be a high level of dissemination of information between the associated parties which is essential for the supply chain management (Closs, Swink and Nair 2005).

As there are multiple ownership involved in a SC it can occur lack of coordination if the different stages. Companies with different intentions can get in conflicts with each other because information is not shared properly. If information is incomplete or not shared properly it might be contorted as it proceeds through the SC (Chopra 2016). In order to conduct business processes, information from the involved parties in the SC is required. All the parties in the SC need to communicate all important information that can affect the SC in order to achieve maximum surplus (Chopra 2016).

Supply chain management

Supply chain management (SCM) is a broad concept that cover a comprehensive range of disciplines. The definition of SC can be unclear since there are numeral different definitions of the term SCM. In order to be able to fit future needs the term continues to develop as the global SC keeps expanding (Lemay et al. 2017). However, there are similarities with the different definitions of SCM and a common description is the attention towards integration of business processes through the SC. In order to accomplish effective processes, the information flow between the involved parties is important (Helgheim, Jæger and Saeed 2011) important.

Christopher (2016) characterizes SCM as the ability to transport and deliver customer value according to expectations in order to decrease cost for the SC. The term customer value is composed of four factors; quality, service, cost and time. This means that the SCM should provide the service and quality that the customer expects in order to cover their requirements at the right cost and time. The SCM encompass to the management of all upstream and downstream activities which allude to all activities from raw material to finished products to end customer. The correlation between upstream and downstream activities is important in order to achieve a more favourable outcome for all parties in the chain. (Christopher 2016)

2.4 Information sharing in supply chain

Communication is essential in order to transmit relevant information to all involved parties in the SC. Information sharing gives the opportunity for SC to convey significant information for systems, people or organizations. An example is that companies are allowed to take advantage of definite market demand or get a real time perspective of processes. (Lotfi et al. 2013)

Information sharing

Information sharing means allocate useful information for different components such as systems, people or organizational (Sun and Yen 2005). Information sharing could also be expressed as “knowledge sharing” or “information integration” (Lotfi et al. 2013). Example of different information types that could be shared throughout the SC is information regarding logistics, business, strategic and tactical.

Information types could be categorized into more specific information such as inventory information, sales data, sales forecasting, order information, product ability, new products and other information. (Lotfi et al. 2013)

In order to improve the outcome of information sharing, organizations should base their approach on four main questions. The first is to question what to share and who to share the information with, then how and when to share the information. Depending on the quality of the answers one can avert redundancy, decrease sharing cost and enhance response (Sun and Yen 2005). As stated by Sun and Yen (2005), a SC has two primary principles. The first primary target is to stable and balance demand and supply and the second to enhance efficiency and responsiveness, as Lotfi et al. (2013) also relate to in information sharing. In an information sharing SC there are applied a network of information sharing agents that collect, comprehend and satisfy the required information. Further, Lotfi et al. (2013) presents an overview of advantages gained by information sharing in table 7.

Table 7 - Advantages with information sharing (Lotfi et al. 2013)

No.	**Benefits**
1.	*Inventory reduction and efficient inventory management*
2.	*Cost reduction*
3.	*Increasing visibility (significant reduction of uncertainties)*
4.	*Significant reduction or complete elimination of bullwhip effect*
5.	*Improved resource utilization*
6.	*Increased productivity, Organizational efficiency and improved services*
7.	*Building and strengthening social bonds*
8.	*Early problem detection*
9.	*Quick response*
10.	*Reduced cycle time from order to delivery*
11.	*Better tracing and tracking*
12.	*Earlier time to market*
13.	*Expanded network*
14.	*Optimized capacity utilization*

Through information sharing all the involved parts in the SC can stay connected. This involves the processes from end customer through the entire chain, to the manufactures that produce the product or service.

By connecting the SC one can achieve better visibility as well as increased tracing and tracking which are some of the benefits that Lofti et al. (2013) highlights. Also, by having visibility throughout the entire SC, problems can be detected early in the process and the businesses can better allocate resource utilization (Lotfi et al. 2013).

SC have become more and more complex as there are many involved parties (Butner 2010). It can be multiple ownership involved in the different stages of the SC which can lead to challenges regarding coordinating. A common outcome of lack of SC coordination is known as the bullwhip effect. The bullwhip effect can be referred to as how the information gets distorted as it is communicated through the SC. According to Wang and Disney (2016), the bullwhip effect can be referred to as the impact demand has on long-term customers where it creates high frequency swings in the production part for the suppliers in the opposite end of the SC (Wang and Disney 2016). Since each part of the SC estimate individual demand, the bullwhip effect disrupts the information flow in the chain. General causes of the bullwhip effect arise as an outcome of long lead time, time delays, insufficient communication or variety feedback between the different parties in the SC. (Lee, Padmanabhan and Whang 2004) Using RFID, the information sharing will be improved, and the bullwhip effect can easier be removed or controlled which can increase the SC performance (Chen et al. 2000; Sarac, Absi and Dauzère-Pérès 2010; Lee, Padmanabhan and Whang 2004; Simchi-Levi, Kaminsky and Simchi-Levi 2000.). This is one of the stated benefits in table 7.

Marshall and Bly (2004) states that information sharing establishes and embrace relations and social ties among the information sharers and receivers. However, information sharing within the SC can encounter to several challenges. Among these challenges are problems regarding confidentially of the shared information, trust issues regarding different intentions that conflicts with each other, reliability and costs related to information technology. Other barriers that are mentioned are anti-trust regulations, preciseness of the shared information and the ability to utilize the shared information in the most effective way. One of the main obstructions with information sharing is associated with information privacy. In order to overcome these obstructions, there should be developed a trusted network for individual information sharing of this sensitive information (Razavi and Iverson 2006).

Inter-organizational information systems (IOIS)

Inter-organizational information systems (IOIS) are electronic connections with information or resources that is shared between two or more trading partners. IOIS can phase out the manual information transfer and improve the integration of business transactions. (Humphreys, Lai and Sculli 2001; Madlberger 2009; Barrett and Konsynski 1982; Hadaya and Cassivi 2007; Johnston and Vitale 1988). Angulo, Nachtmann and Waller (2004) argue that IOIS have the attribute to generate closer relationship and more solid coordination between collaborative companies. Further it is stated that vendor-managed inventory depends on generally sharing of information between the trading partners.

IOIS have been used to assist the process of information sharing between trading partners within the SC, (Rai, Patnayakuni and Seth 2006; Saeed, Malhotra and Grover 2005) and is relevant to gain a "timeliness, accuracy, adequacy, completeness, and credibility of information exchange" between the trading partners to achieve SC productivity (Mohr, Jakki and Nevin 1990 and Mohr, Jakki and Sohi 1995). IOIS decrease vulnerability through an improved online service, uncomplicated order process and faster response to customers questions (Humphreys, Lai and Sculli 2001).

Enterprise resource planning

An enterprise resource planning (ERP) is a computer-based system that allows companies to link all involved parties in the SC so that everyone operates with the same data. Thus, by using an ERP system business processes get supported and automated through integrated functions in the organization and allows data sharing across the organization. By using an ERP system every part of the SC has the opportunity to operate with the same data and key performance indicators (KPI). This means that access to information is shared both internal and external to every company vertically in the SC (Sadrzadehrafiei et al. 2013).

In relation to traceability, implementation of an ERP system can be evaluated as one of the most efficient ways. This is because of the integration between modules, data storing and retrieving processes and management and analysis functionalities are connected through standard functionalities of stand-alone applications (Rizzi and Zamboni 1999).

The focus on optimized processes in order to achieve higher efficiency was driven by the technological evolution. Through the technological evolution it was achievable for computers to conduct and resolve more complex problems in order to achieve more efficient manners. During the last decade ERP-systems have expanded and there have been established fully integrated systems (Al-Mashari, Al-Mudimigh and Zairi 2003). RFID technology can also be integrated to an overall ERP system such as warehouse management system and transportation management system, which will be elaborated below.

Warehouse management system

By introducing software technology in a warehouse, companies can improve their operations by achieving better allocation of resources as well as becoming more productive. The customer is becoming more demanding which highlights the importance of the capability to enhance online visibility, and constant receive replies and accurate data. This can be achieved by using a warehouse management system (WMS) (Richards 2014). WMS is an information system (IS) were data of warehouse operations are collected in order to solve different problems that may occur in a warehouse (Poon et al 2009). As Richards (2014) states in his book *Warehouse Management*, technology can improve the productivity, lower the costs and gain a higher customer satisfaction and utilization. Further Richards (2014) explains that a WMS can be adopted with an ERP system that can help backing the current leading technological in a warehouse such as RFID.

Transportation management system

Transportation Management System can be shortened to TMS and aim to contribute to an effective transportation of supply in order to decrease the cost and time. Thus, the purpose of TMS is to assist the transportation logistic so that the transport could be completed in the best possible way and move the aspired goods to the right destination. To achieve this, RFID can contribute to the validation of dispatched goods. TMS functions as a connection between the order management system (OMS) and the warehouse of the businesses. The considerable processes in relation to procurement and shipping or transportation are being carried out by the TMS. (Chalotra and Kumar 2016)
TMS is a part of the SCM where the focus is to conduct an effective operation management of transportation.

By using an effective transportation system, one could seek the most optimal solutions in relation to the best route or mode for the shipment. Subsequently the best provider is chosen, generation of electronic load tendering is conducted in order to be able to track the transportation. Thus, with RFID one can track the shipment as well as support the settlement process further.

Efficiency

When everything corresponds to the plan and the relations between the attempt and the return is high, one can referrer to the concept efficiency. Characteristics with an efficient business is the capability to be efficient in activities, as well as adapt their purposes and goals according to the surroundings. Effectiveness in an organization can be described as the capabilities an organization has to fulfil their ambitions and goals. These fulfilments are achieved with specified resources and means without compromising on the organization's resources (Song and Panayides 2015). There have been challenges associated to efficiency in a SC because of the complexity of many involved parties. However, Song and Panayides (2015) point out that the use of information and communication system is an important part of achieving an efficient SC. Through the IS every part of the SC has the possibility to have access to the same information. By implementing RFID as a part of the warehouse processes one can achieve a more efficient SC by simplifying processes.

2.5 The role of RFID in supply chain management

The concept of RFID is found relevant for our research because this technology provides services in order to identify products, more efficient communication and real information regarding time perspective. The trackability and visibility of products could also enhance through the whole SC. Further, this can lead to more reliable and valid processes as the operational procedures (such as tracking, shipping, counting etc.) could be conducted more rapidly with more accurate information. RFID technology could also contribute to conduct activities at a better way in relation to security and authentication, safety, convenience and process efficiency. (Bhuptani and Moradpour 2005)

According to Jones and Chung (2008), RFID technology is a comprehensive and complex technology that is continuously under development when it comes to applications. RFID technology can contribute to several benefits in the SC. Perret (2014) states that by applying RFID systems, the warehouse process might be conducted more efficient since the flow of information could be improved as well as reducing waste. This also encompasses the trackability of products which includes a huge number of tags, and each of these tags is fulfilling very concrete needs (Perret 2014). Ali and Haseeb (2018) found that RFID sustain a remarkable and positive effect on the performance of the SC. By using RFID technology, the SC can expand the traceability and visibility for both processes and products. Thus, the SC can achieve better efficiency and more rapidity processes.
Sarac, Absi and Dauzère-Pérès (2010) highlight that information sharing, and preciseness could be improved through real-time information.

According to Shin and Eksioglu (2014) has there been a slow development of RFID technology implementation since 2008. One reason for this is the uncertainty around the return of investment (ROI). There has also been a lack of business cases revealing the possible profitability or efficiency of such implementation. Although it is argued that RFID technology can change the SC to have even more efficient systems, there is still skepticism. There have been raised questions whether RFID technology is just an upgraded version of barcodes, with a higher investment- and current cost in addition to limited improvement in benefits. (Collins et al. 2010; Shin and Eksioglu 2014) Further, RFID is considered as risky by many small and medium retailers, while large retailers have the potential to benefit from the economy of scale (Lee and Lee 2010 and Shin and Eksioglu 2014). Shin and Eksioglu (2014) found that companies with RFID technology have better cost- and sales efficiency. Nonetheless, they found no connection that RFID also contribute to profitability and employee efficiency.

Sarac, Absi and Dauzère-Pérès (2010) and Banks et al. (2007) mention that after larger companies like Wal-Mart, Mark and Spencer, Tesco and Gillette implemented RFID, there were seen some progress in industries (healthcare, transportation, warehousing and retailing). Nonetheless, RFID technologies are still limited due to various technical and financial barriers. Further, Musa and Dabo (2016) mention that there are numerous of potential for the utilization of RFID technology. The use of RFID is expected to expand in the future despite the technical and costly challenges (Musa and Dabo 2016).

Today, several companies have raised their attention towards RFID. Among others, Zara and Hennes & Mauritz (H&M) have implemented RFID technology to deal with inventory issues (Grill-Goodman 2018).

2.6 Warehouse in the supply chain

A warehouse can be defined as a short-term place to store inventory as a part of the SC. Thus, a warehouse should be a temporary place where goods are obtained until it is going to be dispatched as quickly, effectively and efficient as possible. Richards (2014) identify typically warehouse processes as "receiving of goods, put-away goods, sorting, order picking, packing, sorting and dispatching, stock counting, value adding services and other activities". Figure 9 illustrate the different warehouse processes and the associated warehouse costs to the given activity. As the warehouse processes involves several work processes and equipment, will these processes particularly be vulnerable to errors. Groose, Glock and Neumann (2015) identify the order picking process as one of the warehouse processes that requires most labour as well as being the most time-consuming process in the SC. The order picking process can be referred to as the process of retrieving goods from the shelves in the storage accordingly to a certain customer demand (Groose, Glock and Neumann 2015). As seen from figure 9, Richards (2014) identify the order picking process followed by sorting and dispatching and packing as the warehouse activities that accounts for the biggest costs in the warehouse.

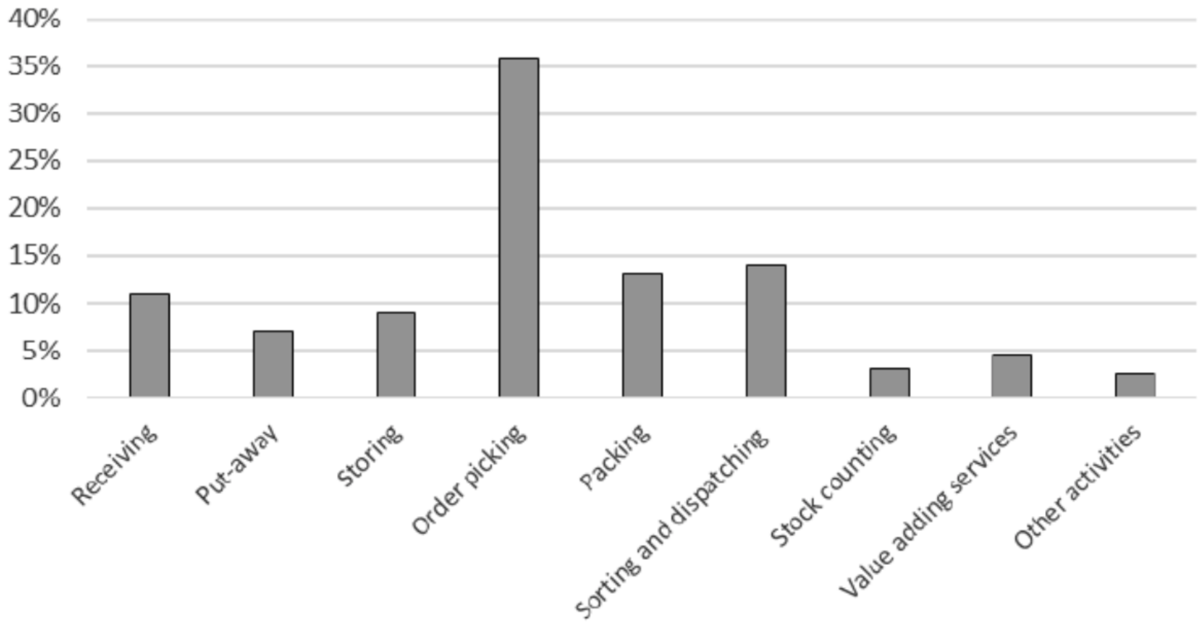

Figure 9 - Warehouse activities as a percentage of warehouse costs (Richards 2014)

A reason why these costs are the highest could be that warehouses are still based on manual handling. Thus, the warehouse is therefore dependent on human availability or productivity in order to conduct the process in a warehouse. Further this will influence the warehouse performance and costs (Battini et al. 2015).

Technology in the warehouse

Warehouses today can be affected by the e-commerce phenomenon whereas they need to adjust the logistics systems. Also, the warehouse needs to adapt the functions in order to meet the new demands caused by the growth of e-commerce (Richards 2014). Further, retailers and warehouses are being affected by the rapidly growth in the industry and need to continuous search for new or improved solutions that will increase the efficiency and productivity of the warehouse processes. This especially referrers to the order picking process in a warehouse. (Dujmešić, Bajor and Rožić 2018). However, Škerlič and Muha (2017) mentioned that there is no assurance that the implementation of technology itself will remove all errors without considering all the warehouse processes.

Due to the high use of labour and time spent it is important for the warehouse to invest into some attempt of reducing the associated cost and to shorting the cycle time. In the recent years, technology has continuously grown, and more and more companies are becoming aware of the increasingly benefits and potential of process optimization of implementing technology into the warehouse processes (Dujmešić, Bajor and Rožić 2018). RFID is one of the technologies that have been given more attention in recent years and have been proven to be a reliable technology (Yoo, Hong and Kim 2009). As mentioned, are many warehouses still based on manual handling, but by introducing RFID technology into the warehouse processes can the number of physical handling be reduced. RFID technology have several benefits whereas some of them is the possibility to improve the traceability and visibility of products as well as increase the efficiency of processes (Wu et al. 2006). According to Stock and Lambert (2001) and Richards (2014), the use of improved technology solutions can contribute to better utilization of space in the warehouse, improved control as well as the feasibility to coordinate product flow in order to evade bottlenecks. It is also highlighted that modern technology can provide increased productivity and savings both energy and manpower.

It is determined that the use of modern technology solutions in a warehouse can lead to less mistakes. Škerlič and Muha (2017) claims that those who were against the use of modern technology in the warehouse processes acknowledge the given benefits for the system and user capabilities. However, automation of processes makes it more complex as there are higher demand for a more rapidly, powerful and accurate system. There has also been arisen critic to the adaption of new technology towards existing work processes which demand extra training. Hazards can be that the automation brings new vulnerabilities that did not exist before. (Škerlič and Muha 2017) As an outcome of developing technology the extent between technology and the human factor has increased. The aim is to adjust and suite products, systems and technology as well as their surroundings accordingly to human capabilities (Song and Panayides 2015).

2.7 Errors

According to Reason (1990) are there three common types of human errors; mistakes, lapses and slips. The mistakes and lapses mostly occur in the organization and planning processes, while the operational slips mainly appear in the execution process.

The errors making process can be divided into two different cases be whereas individual errors and shared errors. Individual errors are conducted alone by one individual while shared errors are done by some or all of the participants. Further, errors can then be sub divided into two categories; independent errors and dependent errors. Characteristics with independent errors is that it transpires when the individual have all accessible information correct. However, dependent errors occur when some of the information is improper, missing or erroneous. (Sasou and Reason 1999)

In cases with expansion in errors, the cost will increase as a result of it. Mis delivery is one type of error and Richards (2014) identify some elements involved in the cases of mis deliveries;

- Cost in relation to labour meaning the extra handling of the goods by checking the item on its return
- Cost related to replacement of the item as well as caring out repacking and delivery
- Potential reduction is sales of the product shipped by a mistake

As for this thesis, errors will be used in cases *when something occur that was not according to the plan*. Example of errors in a warehouse can be when packages are placed on the wrong pallet/cage or when packages are delivered to the wrong address. In cases of mis delivery of items, the item needs to be returned to its right location. This process is known as reverse logistics. Reverse logistics can be referred to as the handling of a product or item that is going to be returned. Processes involved in the return can be restoration, reuse, renovation, and recycling. The cost associated with reverse logistics can be difficult to calculate because it is normally a part of other processes within a company's logistics infrastructure (Lambert, Riopel and Abdul-Kader 2011).

Added value

Value can be referred to as something that is generated through interaction among the members of a value network consisting of resources, the company as well as the end customer (Leon 2017). Added value can be characterized as an improvement in a company, meaning that a special feature is added in order to increase the value of a company or for a product or service. Value can be created when the benefits of decision making transcend the cost. These costs include the direct cost of investment and the cost of capital. The benefits can be retrieved either in near or distant future. (Larrabee 2013. Several warehouses have proposed value adding services that can be implemented into their process areas. Typical there are a third-party logistics company that supply this service. Some of the value-added processes that are highlighted are; *pricing, (re)labeling, (re)packing, reconfiguration etc.* (Richards 2014). One example of a value adding service can be RFID technology, which can provide the warehouses with added value, meaning improvements in the warehouse processes. RFID technology can also provide better quality and service for the end customer which can lead to higher customer satisfaction.

Economic value

Economic value can be described as the advantages gained by a goods or service. Economic evolution can be referred to as a correlation that aims to examination the different options in consideration to both cost and consequences.
This can be utilized to determine and evaluate cost and diverse outcome of different interventions with the aim to verify which will give the highest profit (Drummond 2005).

3.0 Case Description

In this part of the master thesis the framework of the case will be described and explained, in addition to a presentation of the involved parties. Data for this case study regarding the automated verification system has been given by Lyngsoe Systems and XXL through email, brochure, and white papers as well as through Skype conversations and observations on site.

3.1 Presentation of the Companies

We will start by briefly explain the involved companies Lyngsoe Systems and Consignor, before focusing on the central warehouse of XXL.

Lyngsoe systems

Lyngsoe Systems (LS) is a Danish software company that works to develop user-friendly solutions within RFID technology. LS operates in different industries such as healthcare, airports and airlines, library, and postal and logistics. In this case study the focus will be towards the postal and logistics industry. The company provides logistics solutions through the customer SC, where the companies get a realistic time perspective on the processes. LS have established IT decisions within energy, environment, marine and industry. To be able to monitor and collect all kinds of data, they have used sensors or codes that have been translated into Cloud-based apps that further transmit the data to machines which in turn enable mobile real-time responses. LS have been in the logistics and RFID industry for many years.

Consignor

Consignor is a global company that provide services that support delivery processes. They provide programming services where the focus is towards delivery management software. The software provided by Consignor aim to handle all the shipping and delivery processes for customers. Also, to provide customers with an integrated and complete delivery solution that will develop in parallel with their strategies. Thus, the software binds the warehouse and the customers together. Consignor provides different customers, all from small online stores to larger multinational companies.

Regardless of which ERP system, WMS or online store the customer uses the software can be integrated towards the customers systems. By doing this integration the customer can decide the best carrier or transportation mode that fit their shipments. (Consignor 2019a)

XXL sport and outdoor

XXL is a sports equipment chain that was established in 2000. Today, XXL is the largest sports chain in the Nordic region with 36 warehouses in Norway and additional department stores in Sweden, Finland and Austria. The vision to XXL Sport is to have a concept that is different from others where the target is to reach out to sport enthusiasts, fitness teams and outdoor persons. XXL also aims to be an eldorado for everyone that is interested in sports, exercise and outdoor activities. XXL is a multi-brand store with a board range of well-known brands under the same roof. (XXL 2019)

The collaboration between Lyngsoe Systems, Consignor and XXL

XXL already had a partnership with Consignor before the involvement of LS. The logistics manager of XXL was introduced for LS and a collaboration for the pilot project was then concluded between the parties. Consignor is installed in the warehouse and the stores of XXL, where their function is to print labels, create shipments, send notification to customers and track shipments for XXL.

Material flow and information flow

The flow of material and information is illustrated in the figure below and can be explained as followed; first XXL receives an order from a customer or one of their stores. XXL then will receive an order in their ERP system and order a carrier for transportation. Further, the RFID labels are printed via Consignor and then placed on the items. The RFID labelled packages will then be sorted after destination and scanned in whole pallets or cages with the RFID antenna. Status of the package will be updated after the scanning where LS will validate the destination for the packages as well as control the content. After the validation, will LS provide XXL with the result of the scanning (Consignor 2019b). Figure 10 gives an overview of the material, - and information flow between the involved parties.

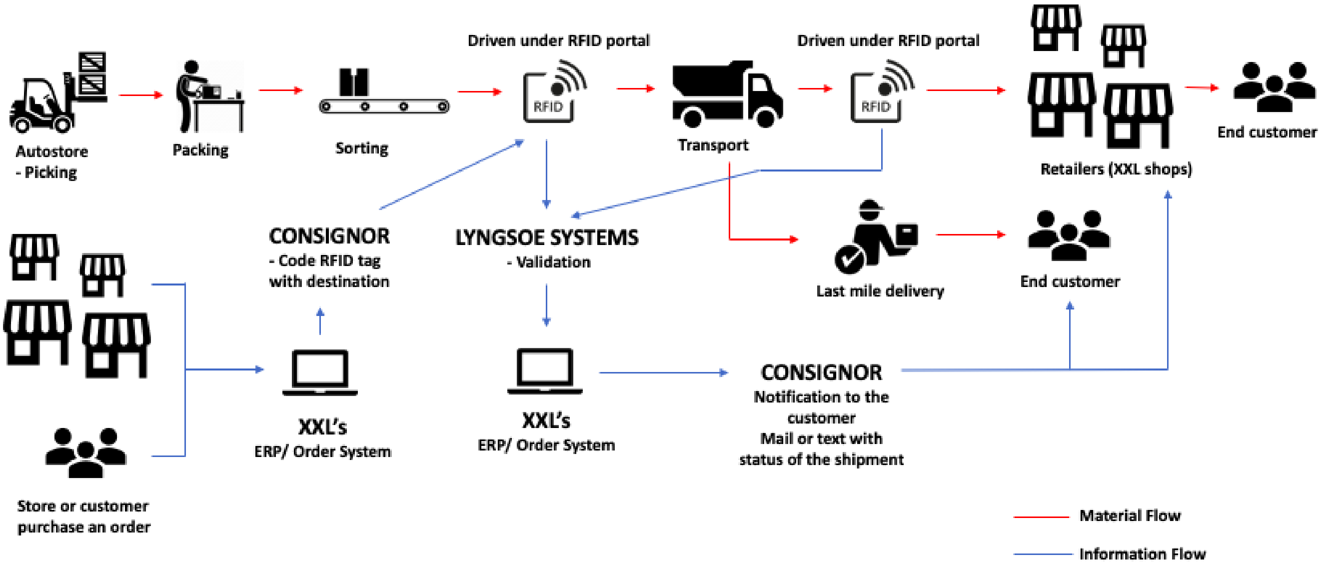

Figure 10 - Material- and information flow (Own figure)

3.2 Background for the AVS

The background for the pilot project is based on how improved RFD technology can influence warehouse processes. Errors often occur in the preparing process for shipments which has led to several mis deliveries. The order fulfilment processes are usually conducted with manual handling where the processes relay on humans to collect the right items from the inventory, and that the right items are loaded on the right transportation mode.

LS has developed the AVS which based on RFID technology. This solution is now a pilot product where XXL Norway is testing and using this solution as a part of their business processes. This pilot project has led to further development of the AVS which is going into the market in the end of May 2019. Now they have a working prototype that will be used in the implementing part of the solution as it illustrates all workflows, functions, features, actions, warnings and bottom that they want to have in the final product. Since the spring of 2018, XXL have used RFID labels on small packages when sending items to the customers from the central warehouse in Oslo (Consignor 2019b).

3.2.1 The AVS

The AVS is a standardized solution used for validating and tracking of goods and shipments in order to get a real time perspective during the logistics processes. Thus, it is a system for validation shipments that are going out from the warehouse and received at the store. The AVS is based on RFID technology, and the solution can be integrated towards the platform to the provider of the customer's delivery management system. Integration can be conducted regardless if it is a separated delivery management software platform or if it is a part of the WMS. The individual customer has different needs so the customer can decide for themselves which features that they want to implement. The aim with the product is to decrease the number of errors and the cost related to the manual handling labour in the warehouse as well increase the visibility into the SC.

In order for LS to perform validations they need information regarding the shipment, which is delivered from the management solution provider, Consignor. The solution will automate the following shipment processes and preparation

- Validate that the shipment is going to the same destination
- Registration of the arrival shipment in the store
- Documentation of the consignment handover to the distributor/carrier

As a part of the development process of the AVS, LS has involved XXL because LS believed that the customers have a better understanding of what they need. The product integration is in a way tailored to XXL's needs and specification, but the interface can also be used towards other customers.

3.2.2 Workflows

The root of the AVS is based of four different workflows that support various processes. The different workflows support separate areas depending on what the employee desire to validate. The four workflows of the AVS are as followed

- Destination validation
- Content validation
- Load validation
- Arrival validation

Figure 11 illustrate the four different workflows of the AVS and their tasks.

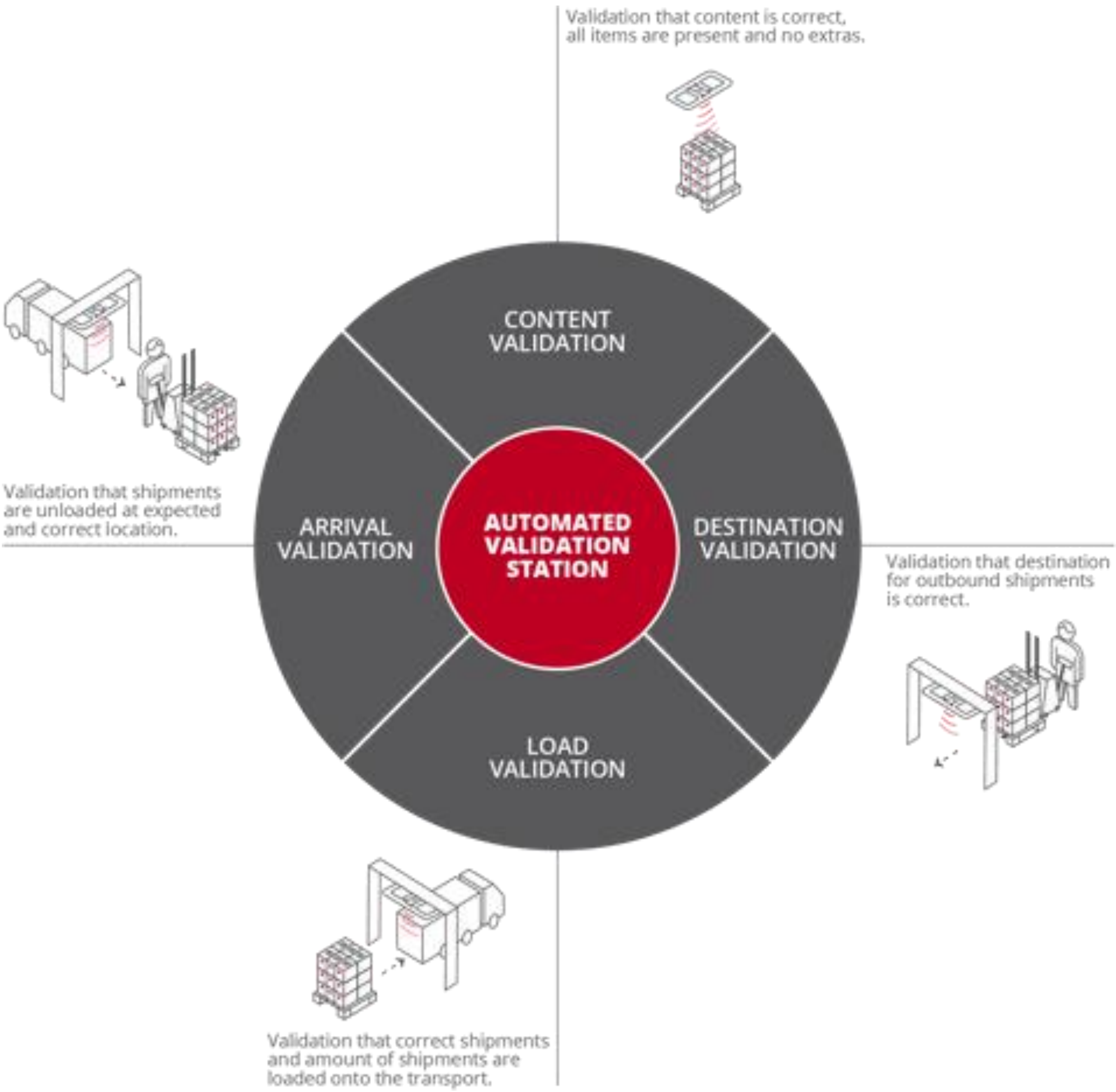

Figure 11 - The four workflows (Lyngsoe Systems 2019b)

Destination validation concerns the outbound logistics activities and are supposed to ensure that the shipment is correct. Requirement for this workflow is that the pallets are packed and ready for the shipment. In order to do the validations, the employee will put the pallet under the reader which will read and validate the tags and indicate the destination for the tags that is read. XXL is using this workflow in their warehouse processes. The reading is live, meaning that is reads and scan all the time.

Content validation count the items under the RFID portal to make sure that it is the right content and that all items are read. Here the employee can create shipment manifests based on a bunch of packages. This can be done by placing the pallet under the scanner, create a manifest by a name of choice and then start to scan. Under this workflow the employee can remove tags from the manifest if some items were read by a mistake.

Load validation ensure that the right pallets are loaded onto the correct transportation mode or route. This workflow also validate that the right amount of shipment is loaded. In this workflow the employee has the opportunity to entering a manifest if they know the ID, or one can select an existing list received from the back end. If the wrong pallet is loaded onto the transportation mode the employee will get a warning, and the screen will show a red colour which indicates that something is wrong. In this case the employee can either remove it from the load meaning that is was wrong by a mistake or add it to the manifest

Arrival validation ensures that the right packages was delivered to the right store. It validates the unloaded shipments that have reached the store, and all the items are presented. This workflow is something that XXL want to implement, and they already have this in some of the stores. When XXL have the reader in the shop the reader will read everything that goes under it. LS then send the readings towards Consignor.

There are no significant differences behind the different workflows, but it is divided to make it simple for the user to choose the workflow for the specific situation.
The AVS solution is divided into four different workflows. XXL are mainly using destination validation and arrival validation in their processes.

3.2.3 The AVS processes

The processes of the AVS is divided into seven different steps, where step 1 to 6 is about the warehouse processes and step 7 is about the physically store, which is an optional choice depending on which features the customer wants to implement. In figure 7, the different stages of the warehouse processes are illustrated.

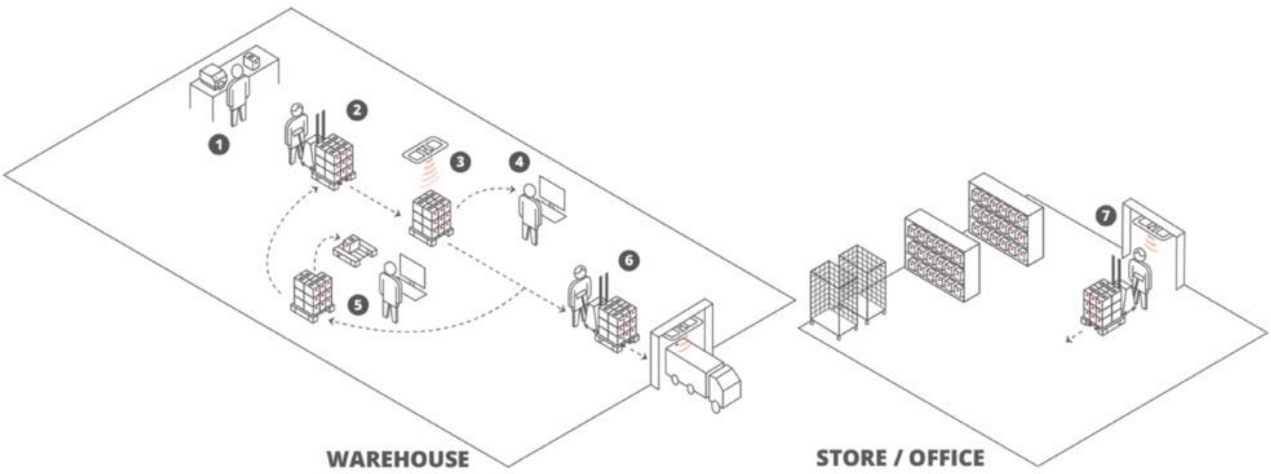

Figure 12 - AVS processes (Lyngsoe Systems 2019b)

Step 1: In the first step of the process Consignor codes a RFID label with the needed information. This information includes destination and label ID which is associated in Consignors backend. When the RFID tags have been correctly coded the label is printed and applied on each item.

Step 2: In step 2 the packages are being sorted after destination, and the employee stacks the RFID labelled items in a cage or on a pallet.

Step 3: Here the pallet or cage with the RFID tagged items are placed under the RFID portal. The portal will read all the RFID marked items. The portal is constantly reading and actively scanning.

Step 4: In this step the validation of the content in the cage or on the pallet are conducted. The validation process starts when the employee presses the bottom “start scanning” in the app. The content is validated based on data from Consignor and is validated towards destination. The system then analyses the tags by comparing the package ID and destination information in order to acknowledge if all the packages are going to the same destination. The scanning and validation process take approximately 10 seconds. If the scanning and validation process is ok then the employee can continue to step 6, but if it has occurred an error then the employee need to go to step 5.

Step 5: This step is only necessary in the case of errors. Errors occur if the content do not match the shipping manifest caused by misplacing of packages.

The app will highlight which items that are going to be removed or added, and it auto refreshes so it will show the actual status of items under the portal. In cases of error or failure the cage or pallet must re-wrapped and errors can be corrected.

Step 6: When the content matches the shipment and destination information the scanning is ok. When the employee presses the bottom “scan complete” then it will appear a summary of the completed scanning on the application screen. The employee then closes the scanning and move the shipment to the load area. Status information regarding the scanning is then sent to Consignor for tracking and tracing purposes. The packages are shipped or transferred from the warehouse to the transportation mode.

Step 7: Step 7 is regarding the physically store and is optional in the AVS. In this step the RFID portal will automatically register the arrival of the packages at the store. This information is sent to Consignor which uses this information to automatically notify the end customer. If the destination encoded into the labels are in line with the actual destination, then the arrival registration is done.

(Lyngsoe Systems 2019b)

However, in cases were the encoded RFID labels have another destination the arrival registration is incorrect.

3.3 Portal Reader Test

From April 3rd to 4th 2019 LS performed a reader test on the portal reader placed at XXL to investigate the read performance. A total of 27 tests were carried out with various number of packages. The tests were performed with different configurations on the reading equipment and different user scenarios. The power setting in the portal reader also varied from 75%, 85% and 100%, but most of the tests had 100% power. The portal reader was mounted and hanging 265 centimetres above the floor. The reader started to scan and the pallet/roll cage with boxes or bags was moved to under the reader.
The test varied with four different setups:

- Boxes in cages: 5 tests (Test 1, 2, 3, 4 and 5)
- Bags in cages: 18 tests (Test 6 to 23)
- Boxes on pallet and cages: 3 tests (Test 24, 25 and 26)
- Boxes on pallet and cage and bags in cage: 1 test (Test 27)

Some of the objects tested are illustrated in the figure below.

Figure 13 - Test objects (From Appendix 3: XXL reading at gates test report)

The reading equipment were set up against a channel, either “2” or “1, 2, 3, 4”. The channel refers to configuration of the RFID reading equipment. This was done to investigate if there were any interference from other devices around that could also send out wireless signals, such as Wi-Fi and mobile phones. The population estimate was set to 200 or 450. Population estimate is a parameter that can be set and is related to a term in the RFID world called “session”. The parameter tells the RFID tags to stop sending out signals for a period of time before it again responds to the signal from an RFID reader. This can be helpful when reading a larger volume of tags, since the reader might not be able to register all RFID tags at the same time.

Test 10 to 22 were performed without clearing the buffer, meaning that the tests was started with a reading session and the pallet or cage were moved back and forth while reading. A test with 2 runs is pushed two times below the portal, a test with 3 runs is pushed three times below the portal.

It is not 2 or 3 separate reading sessions, but one long session to investigate if the reader will register tags that were not read in the previous runs. These numbers are highlighted in table 8. An overview of the tests is presented in table 8 below. The full test report can be found in Appendix 3.

Table 8 - An overview of XXL reading at gates test report

Test	Description	Tags	Power	Population Estimate	Channel	ROUND										Avgerage Read
						1	2	3	4	5	6	7	8	9	10	Performance
	Boxes in cage															
1	Roll cage driven under portal	61	100 %	200	2	61	61	61	61	61	61	61	61	61	61	100,00 %
2	Roll cage driven under portal	46	100 %	200	2	46	46	46	46	46						100,00 %
3	Roll cage driven under portal	46	85 %	200	2	46	46	46	46							100,00 %
4	Roll cage driven under portal	61	85 %	200	2	61	61	61	61							100,00 %
5	Roll cage driven under portal	107	85 %	200	2	107	107	107	107	107						100,00 %
	Bags in cage															
6	Roll cage driven under portal	160	75 %	200	2	158	157	156	158	157						98,25 %
7	Roll cage driven under portal	160	85 %	200	2	158	157	155	158	158						98,25 %
8	Roll cage driven under portal	160	100 %	200	2	158	158	156	158	158						98,50 %
9	Roll cage driven under portal	160	100 %	200	2	158	159	159	159	159						99,25 %
10	Roll cage driven under portal - without clearing the buffer	410	100 %	200	2	392	401	**402**								98,05 %
11	Roll cage driven under portal - without clearing the buffer	410	100 %	200	2	371	401	**407**								99,27 %
12	Roll cage driven under portal - without clearing the buffer	410	100 %	200	2	394	404	**404**								98,54 %
13	Roll cage driven under portal - without clearing the buffer	410	100 %	200	2	406	**407**									99,27 %
14	Roll cage driven under portal - without clearing the buffer	410	100 %	200	2	406	**407**									99,27 %
15	Roll cage driven under portal - without clearing the buffer	410	100 %	200	2	406	**406**									99,02 %
16	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	417	**418**									99,52 %
17	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	417	**417**									99,29 %
18	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	415	**416**									99,05 %
19	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	413	**416**									99,05 %
20	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	411	**416**									99,05 %
21	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	413	**417**									99,29 %
22	Roll cage driven under portal - without clearing the buffer	420	100 %	450	1, 2, 3, 4	417	**417**									99,29 %
23	Roll cage driven under portal	420	100 %	450	1, 2, 3, 4	417	417	417								99,29 %
	Boxes on pallet and cage															
24	Pallet driven under portal	100	100 %	200	2	99	98	99	98	99						98,60 %
25	Roll cage driven under portal	50	100 %	200	2	50	50	50	50	50						100,00 %
26	Roll cage and pallet driven under portal	150	100 %	200	2	148	148	149	148							98,83 %
	Boxes on pallet and cage and bags in cage															
27	Roll cage and pallet driven under portal	310	100 %	200	2	307	301	305								98,17 %

The test revealed that when it was a high volume of tags to be read, the time in the reading field was a critical parameter. Although it is not exactly recorded how long the items were under the reader. Nevertheless, it is logical to believe that the longer the pallet is under the reader, the higher the reading rate.

For boxes in cages the total average read rate was 100%. For bags in cages the total average read rate was 98,97%. For boxes on pallets and in cages the total average read rate was 99,14%. For boxes on pallet/in cage and bags in cage the total average read performance was 98,17%. See table 9 for an overview of the average read rate performance.

Table 9 - Average read rate performance

Description	Average Read Rate Performance
Boxes in cage	100 %
Bags in cage	98,97 %
Boxes on pallet and cage	99,14 %
Boxes on pallet and cage, and bags in cage	98,17 %
Total Average Read Rate Performance	99,07 %

The average read rate of all the tests together was 99,07%, which is a very good result. The read rate performance was only affected of the aluminium foil from some chocolate bars and a bag with metal foil.

4.0 Research Methodology

Methodology is an approach used to collect empirical data in order to solve problems and find new knowledge (Jacobsen 2015). Methodology comes from Greek and the original meaning behind it can be referred to as “the way to the goal” (Ulleberg 2002). The chosen method depends on what goal the researcher wants to achieve. The methodology is described according to the choices the researcher does during the processes as well as the methods impact on the result (Holme and Solvang 1996). As stated by Hellevik (2002) can methods be described as a way to move forward in order to resolve problems as well as convey new knowledge. Eriksson and Kovalainen (2008) bring forth an overview over the demanding procedures of conducting research and define method as “how we came to know the world”. Thus, methodology can be explained as tools and methods used in order to describe a problem and expand the understanding of our world.

In this chapter, different aspects of method used in order to conduct this thesis will be presented and explained. The research- strategy and design will be explained followed by a description of the research method. Further, the data collection methods will be explained before describing the variables used to calculate the findings. Our research will mainly focus on how RFID tracking can influence the warehouse processes in a retail SC.

4.1 Research strategy

According to Bryman and Bell (2011) is research strategy an overall approach to perform research. The literature divided methodology into two main strategies; qualitative and quantitative research.

It is stated by Bryman and Bell (2011) that quantitative research manly emphasizes around the quantification of data gathering, and that the strategy objectives focuses mainly on examine theory. The quantitative research approach is based on statistical and numerical data, in other words, data that are expressed in terms of numbers or can be measured is characterized as quantitative data (Grønmo 2016). This type of method is used to cover large quantities of data that simply can be illustrated in tables and figures.

In contrast, Bryman and Bell (2011) describe qualitative research as a strategy that aims to accentuate the world where the objectives are mainly towards the generation of theory. There are no explicit or clear definition for qualitative methodology but there are some precise differences from quantitative method. Qualitative methods can be recognized by being studied in a limited environment. (Jacobsen 2015)

Qualitative method is used for generating knowledge that examines the meaning of events and experiences for those who experience them, and how these options can be interpreted or understood by others. Thus, the objective with qualitative method is trying to comprehend around social processes and how they can influence the pattern of action, learning, thinking etc. (Krumsvik 2014). Also, Krumsvik (2014) highlight that qualitative method is used in order to accomplish an overall understanding of the human experience. Eriksson and Kovalainen (2008), states that the objectives of qualitative strategies is concerned about comprehending around the problem, while the quantitative strategy attempt to clarify and test through statistical analysis.

It has occurred critics towards both strategies whereas researcher following the qualitative method expresses that the general science model is not a suited approach for studying the social world. Regarding the qualitative strategy the criticism has been towards the problems of generalization, lack of clearness and to some critiques are the research to subjective. (Bryman and Bell 2011)

4.2 Research design

Research design is a comprehensive plan that bring forth an overview of how to conduct a research design (Selnes 1999). Bryman and Bell (2011) describe a research design as “framework for the collection and analysis of data”. In order to achieve suitable results, it is expedient to design and identify goals as early as possible in the process. When conducting research, it should be accordingly to suitable methods so that the research problem can be answered properly. To do this, the first principle is to find a research design that is suitable for the given study. As stated by Gripsrud (2004) will research design consist of the explanation of how to conduct the analysis processes and how they should be prepared and carried out in order to answer the research question.

Yin (2009) states that the choice of research design should in large parts relay on the research questions. Bryman and Bell (2011) acknowledge four different fields of social research design; cross-sectional design, longitudinal design, comparative design and case study design.

Case study research

The term case study can be referred to as an empirical study where there are use multiple sources and there are no clear distinguish between the context and the phenomenon (Yin 1994; Bukve 2016). Yin (2009) states that case studies are best suited when the aim is to answer research questions of "how" and "why". According to Andersen (1997) case studies go in-depth where the study require involvement of one or a few studies. In other words, case studies are one or a few studies where the terminology express that the substance is to be immersed (Andersen 1997). Thus, case studies can be described as a research strategy that is applied in several areas, with no clear standard consensus on what refers (Andersen 1997). Bryman and Bell (2011) referrers to case studies as an "detailed and intensive analysis of a single case".

The principle and tendency among all types of a case studies can be described as the attempt to enlighten a decision or a set of decisions. Justify why decisions were taken, how they were implemented and what was the result of these decisions (Schramm 1971). Like other research methods, case studies also intend to investigate an empirical topic by following appropriate guidelines. Yin and Darnella (2007) highlight characteristics with a case study as an empirical method of exploring a contemporary phenomenon in-depth in relation to a real-world setting when the margins between the phenomenon and the situation might not be so obvious. In such a case study it is assumed that an understanding of the situation likely will involve important contextual settings that is relevant in relation to the case. (Yin and Darnella 2007).

Concern have been raised regarding case studies as researchers see it as a less desirable research method. According to Yin (2018) one of the biggest concerns regarding case studies is because case study researchers have been inaccurate by not following systematic approaches, thus not been rigorous enough. There has also been questioned how one can generalize from one single case study (Yin 2018). As there has been scepticism to case studies we need to take this into account when conduction our case study.

4.3 Research method

According to Bryman and Bell (2014), a research method can be referred to as an approach for collecting data. When the researcher has decided which type of research design to use it is necessary to select what type of research method to use in order to gather required data. Stated by Yin (2009), robust case studies will relay in several sources of evidence and highlight six different sources; direct observations, interviews, archival records, documents, and participant-observation and physical artefacts. As for this thesis the research methods that will be used is direct observations, interviews and documents provided by the involved parties. Due to this we will not elaborate regarding the other mentioned research methods.

Direct observations

The conducting of case studies should be done in a real-time setting. To get a real-time setting on the case, it should be done direct observations. Observations can be done in several forms, from formal to less formal observations. Formal observations can be characterized as observations of meetings, factory work etc., while less formal observations can be done through fieldwork and observations of interviews. Also, by observing the working environment the researcher might get indications of the organization culture which can led to a better understanding of the case study.

Organizational documents

Organizational documents are found within most organizations and can be particular important for the business and management researcher. Some documents such as annual reports, press releases etc. are normally public for everyone, but there are some other documents that are not available for the public eye. These documents can be; organizational charts, internal and external correspondence etc. The researcher can gain a great information from some of the listed documents. In addition, these can be beneficial in order to gain a better understanding of the company to build a description of the company. (Bryman and Bell 2011) However, the researcher should consider the accuracy by the organizational documents because the possibility for lack of objective.

Interview

Interviews can provide the researcher with a large amount of useful data, and there are several forms of interview design to choose from. According to Yin (2009), interviews for case studies are often more fluid and guided conversations instead of structured questions. Nevertheless, it is important to ask questions that will provide the needed information and simultaneous are sensible and clear for the interviewee (Yin 2009).

In a semi-structured interview, the main themes are predominantly in advance, but the order of the questions can be changed during the interviews. By doing this, the interviewer has the opportunity to obey to the interviewee's story as well as getting the needed information. This makes the interview more flexible, so it allows the questions to be linked to the interviewee's premises. Semi-structured interview also give room for topics that was not planned in advance. (Jacobsen 2015)

4.4 Data collection method

Primary data can be referred to as data that are collected for the first time and is in its original character (Kothari 2004). There are multiple ways of collecting primary data where the most used methods are based on observation, interviews, questionnaires, schedules etc. (Dhawan 2010).

Secondary data can be defined as data that have already been collected by someone else. The data have already been processed and passed through statistical processes (Kothari 2004). There can be different aims behind the use of secondary data which means that it might not be suitable for other studies than the original. Gathering secondary data is normally a quicker and more effective way compared to primary data. However, it is difficult to distant from the weaknesses that might appear when collecting this type of data, since the data have been collected by someone else and one cannot be sure if there were any mistakes during the process. There are some possibilities that the data can have been manipulated or reorganized in order to get the desired result or that the researcher has influenced the data.

4.5 Data collection

In this chapter the data collection phase is described and the choice of research strategy, research design, research method for this thesis is presented. To collect data for our research, both primary and secondary was applied in order to get the most updated and latest information available within the field. Both forms of data were found relevant because there might be a limited scope on relevant sources.

Primary data was the information retrieved directly from LS, Consignor and XXL as well as facts from the employees. Secondary data has mainly been collected and evaluated through textbooks, journals and scientific articles from different databases. Database research most frequently used was through the libraries databases. The literature was mainly collected from journals regarding SCM, warehouse management, inventory management, IS and RFID.

This study aims to analyse how implementing of RFID tracking can impact the economic assessment in a retailer's SC and how the warehouse processes can be influenced. A specific warehouse was chosen, which means that it was done in a limited environment. This thesis was built around understanding and explanations of the circumstances today, and interpretation of why and how the RFID technology may add economic value.

Choice of research strategy

According to Yin (1994) it is suitable to use several sources of evidence in order to strengthen the validity of the research. Due to this, this thesis will rely on research from multiple sources in order to answer the research questions adequate. As for this thesis, the focus will be towards trying to understand the nature of the problem and identify areas of development. The set of data analysis regarding numbers and calculation for this thesis contains of quantitative data. The qualitative data was primary used for background information, but the mainly focus have been towards the quantitative aspects.

Choice of research design

The desire behind the study is to obtain a deeper understanding of the single case, even though there are several business units involved. The objectives emphasis to view the problems in a certain company in order to achieve a deeper understanding of the given issues. According to Yin (2009), case studies are best suited when the questions to be answered are regarding how and why, which matches the nature of this research. The focus for the research is also towards real-word events that are considered in natural environments.

This master thesis will use a descriptive research design since this is best fitted to the background of the master thesis, where the purpose is to investigate into how RFID technology can impact the economic assessments. The purpose behind choosing this type of research occurs from the need to observe and describe the circumstances of different actors involved (XXL, Consignor and LS) in the SC, before and after the implementation of the RFID tracing, as a part of the AVS project and the effects of such application.

Choice of research method

The main source of evidence applied for this master thesis was through observations, organizational documents and interviews for background information. To begin with, we started to read organizational documents as well as having Skype conversations with LS and Consignor. This was done to get a better insight and overview of the product, the AVS as well as the objective and goals behind the product development.

During the research period, we got the opportunity to visit LS's office accommodations in Aars as well as XXL's central warehouse in Jessheim. By these visits we were provided a unique opportunity to observe the companies and its culture. The value of this could allude to the additional understanding we could gain during less formal circumstances where people talked freely. These types of observation might influence the way we perceived problems in the organization and as a result of this the discussion and conclusion.

Organizational documents provided by the involved parties does also have a significant part of this thesis. The majority of organizational document used were provided by LS regarding the product development as well as an overview of the involved cost associated to the investment. These documents were an important source of information. Public documents found available through the websites were also frequently used.

The intention with the interviews was to uncover different aspects within the organization and to comprehend around what was done in the warehouse processes. For the business case the interviews were conducted with eight LS employees in different roles. The interviews that was conducted was in-depth interviews with the aim to get a better understanding of how the product development has influenced the SC as well as collecting numbers regarding errors, revenue and profit margin. Further, the interview was structured as a semi-structured interview, giving the interviewee's the opportunity to talk freely, and not being bounded by pre formulated questions. The interview guide is presented in Appendix 2. After conduction the interviews, a decision was made to transcribe the interview word by word to ensure that we got all the necessary information. Given that the interviews are informal and open discussed, some parts of the interview are more relevant than others.

4.6 Variables

Throughout the data collection phase, we had some issues concerning the collection of specific numbers associated with the AVS, because the product is still in its implementation phase. Since the final product is not going launch before May, it was too early to get the performance data and the effects of the RFID implementation in their warehouse processes. The assembled research data is gathered from existing and previous analysis and reports from the AVS pilot project. Assumptions have been based on secondary data in order to fill the gap of missing information. All variables collected for this thesis are given by LS, unless something else is specified.

Cost per employee

According to Statistics Norway (2019) a full-time equivalent (FTE) corresponds to 1950 including holidays and 1750 hours a year exclusive holiday. In our calculations FTE will be based on 1750 hours.

Average cost per employee for XXL are given to 250 NOK per hour. This cost is based on gross income and include social security costs and pension cost. It does not include welfare costs such as courses, subsidized canteens and gifts for employees, Christmas parties or other social gatherings.

$$\textit{Total cost per employee} = 1750 \times 250\ NOK$$

The total cost per employee is calculated in the formula above and is calculated to be 437 500 NOK per year.

Freight cost associated with mis deliveries

Cost associated with mis deliveries include the indirect cost per shipment and the direct cost per shipment. The indirect cost per shipment/packages was given to be 271 NOK, while the freight cost per shipment/packages was given to be 79 NOK. Calculation for total cost per mis delivered shipment are illustrated below.

$$\textit{Total cost per mis delivered shipment} = \textit{Indirect cost pr. shipment} + \textit{Freight cost}$$

Table 10 - Cost of mis delivered shipment

Indirect cost pr. Shipment/package	271 NOK
Freight cost pr. Shipment/package	79 NOK
Total cost per mis delivered shipments	**350 NOK**

Number of mis delivered packages and associated cost

Number of packages for all calculations will be referred to as RFID labelled packages and do not include packages without RFID labels. It was assumed that one month is 4 weeks, where the warehouse operates 6 days a week (Sunday to Friday) Thus, a month in this master thesis will be referred to as 24 days. The amount of errors per month are given at a rate that varies from 0,4% to 0,5% and it will therefore be given calculations of both cases. Total amount of mis deliveries per month depends on the number of packages sent as well as the error rate.

There are not given any accurate data on how many RFID labelled packages that is sent daily from the warehouse. However, it emerged during the interviews that it can vary from 800-2000 packages daily. Due to the huge variation, a decision was made to calculate best and worst scenarios with intervals of 250 packages starting from 750 and ending at 2250. Thus, the focus will be towards 2000 packages as this is the highest number of packages they send each day. We will also include the lowest and highest number of packages sent in order to compare the differences. Further, the calculations are mainly based on monthly and yearly number of packages.

By calculating different outlines, we were able to compare the costs with the number of packages sent, in addition to get a better insight into how much is spent on correcting these mis deliveries. In order to calculate the number of packages sent each month, number of mis deliveries per month and cost of mis deliveries per month we have used the following formulas;

$$\boldsymbol{Number\ of\ packages\ sent\ each\ month} = Number\ of\ packages\ sent\ each\ day \times Number\ of\ days\ in\ a\ month$$

$$\boldsymbol{Number\ of\ mis\ deliveries\ per\ month} = Number\ of\ packages\ sent\ each\ month \times Error\ percent$$

$$\boldsymbol{Cost\ of\ mis\ deliveries\ per\ month} = Number\ of\ mis\ deliveries\ per\ month \times total\ cost\ per\ mis\ delivered\ shipment$$

Table 11 present an overview of number of mis delivered packages and associated cost per month. The table is divided into two different scenarios whereas the error percent is respectively 0,4% and 0,5%.

Table 11 - Cost of errors per month

Number of packages sent		**Errors of 0,4%**		**Errors of 0,5%**	
Each day	Per month	Number of mis deliveries per month	Cost of mis deliveries per month	Number of mis deliveries per month	Cost of mis deliveries per month
750	**18 000**	72	25 200 NOK	90	31 500 NOK
1 000	**24 000**	96	33 600 NOK	120	42 000 NOK
1 250	**30 000**	120	42 000 NOK	150	52 500 NOK
1 500	**36 000**	144	50 400 NOK	180	63 000 NOK
1 750	**42 000**	168	58 800 NOK	210	73 500 NOK
2 000	**48 000**	192	67 200 NOK	240	84 000 NOK
2 250	**54 000**	216	75 600 NOK	270	94 000 NOK

The same principles apply for mis deliveries per year as in the case of mis deliveries sent per month. In order to calculate on a yearly basis, number of packages needs to be multiplied with 12 to get the number into years. The rest of the calculations are the same as for one month.

$$\text{Number of packages sent each year} = \text{Number of packages sent per month} \times 12 \text{ months}$$

Number of mis sending per year are illustrated in table 12 below. The table is divided into two different scenarios whereas the error percent is respectively 0,4% and 0,5%.

Table 12 - Cost of errors per year

Number of packages sent		**Errors of 0,4%**		**Errors of 0,5%**	
Each day	Per year	Number of mis deliveries per year	Cost of mis deliveries per year	Number of mis deliveries per year	Cost of mis deliveries per year
750	**216 000**	864	302 400 NOK	1 080	378 000 NOK
1 000	**288 000**	1 152	403 200 NOK	1 440	504 000 NOK
1 250	**360 000**	1 440	504 000 NOK	1 800	630 000 NOK
1 500	**432 000**	1 728	604 800 NOK	2 160	756 000 NOK
1 750	**504 000**	2 016	705 600 NOK	2 520	882 000 NOK
2 000	**576 000**	2 304	806 400 NOK	2 880	1 008 000 NOK
2 250	**648 000**	2 592	907 200 NOK	3 240	1 134 000 NOK

Possible time savings on the scanning process

The average time an employee spent on manual scanning was estimated to 60 seconds before the RFID implementation. After automating this process, the scanning process is estimated to 10 seconds. The calculations are based on 48 000 packages sent per month and in order to investigate the outcome of further improvements to the scanning process. It was also included calculations of 7 and 5 seconds.

In the formula below, X represent the time used on scanning before the RFID implementation which in this case is 60 seconds. Y represent the time used on the scanning after the RFID implementation which in this case is 10-, 7- and 5 seconds. 3 600 represent seconds in one hour.

$$\textit{Time spent on scanning before RFID} = \frac{(X \textit{ second } \times 48000 \textit{ packages})}{3600} \times 12$$

$$\textit{Time spent on scanning after RFID} = \frac{(Y \textit{ second } \times 48000 \textit{ packages})}{3600} \times 12$$

$$\begin{aligned} &\textit{Total time saved} \\ &\qquad = \textit{Time spent on scanning before RFID} \\ &\qquad - \textit{Time spent on scaanning after RFID} \end{aligned}$$

Table 13 illustrate the time rate that was used on the scanning process before and after the implementation of RFID. The table show the calculations respectively to 60-, 10-, 7- and 5 seconds.

Table 13 - Time used before and after RFID implementation

Before RFID	
Time rate per year 60 seconds	9 600 hours
After RFID	
Time rate per year 10 seconds	1 600 hours
Time rate per year 7 seconds	1 120 hours
Time rate per year 5 seconds	800 hours

Possible scanning cost

The cost associated with the scanning process per month and year was calculated according to 60-, 10-, 7- and 5 seconds.

$$\textbf{Hours used on scanning per month} = \frac{(Scanning\ time \times Number\ of\ packages)}{3600}$$

$$\textbf{Hours used on scanning per year} = Hours\ used\ on\ scanning\ per\ month\ \times\ 12$$

$$\textbf{FTE} = \frac{Hours\ used\ on\ scanning\ per\ year}{1750}$$

$$\textbf{Scanning cost} = FTE \times total\ cost\ per\ employee$$

The scanning cost per year for each package interval is calculated in the table 14 below. The table is divided respectively to 60, -10, -7, - and 5 seconds. It also illustrates the cost of scanning with the associated FTE.

Table 14 - Scanning cost per year

SCANNING COST							
60 SECONDS		10 SECONDS		7 SECONDS		5 SECONDS	
FTE	COST	FTE	COST	FTE	COST	FTE	COST
2,06	900 000,00	0,34	NOK 150 000	0,24	NOK 105 000	0,17	NOK 75 000
2,74	1 200 000,00	0,46	NOK 200 000	0,32	NOK 140 000	0,23	NOK 100 000
3,43	1 500 000,00	0,57	NOK 250 000	0,40	NOK 175 000	0,29	NOK 125 000
4,11	1 800 000,00	0,69	NOK 300 000	0,48	NOK 210 000	0,34	NOK 150 000
4,80	2 100 000,00	0,80	NOK 350 000	0,56	NOK 245 000	0,40	NOK 175 000
5,49	2 400 000,00	0,91	NOK 400 000	0,64	NOK 280 000	0,46	NOK 200 000
6,17	2 700 000,00	1,03	NOK 450 000	0,72	NOK 315 000	0,51	NOK 225 000

Cost related to implementation

The original numbers for the investment cost were given in DKK so in order to make the numbers more transparent, we converted all costs into NOK with a currency of 1,3 DKK. The RFID tag price was given to be around 0,689 Norwegian Kroners (NOK). In these calculations, VAT and taxes was not included. Some modules in the software is optional, but we only included the solutions that XXL has adopted.

In table 15 the investment costs are calculated. Barcode prices are not included in our calculation because this cost is already an ongoing cost. The total price for RFID tags per month will be 33 072 NOK (given that they order 48 000 tags). Annually, this will be 396 864 NOK. These are running costs and the RFID tags will not be returned and reused. The one-time costs of the RFID investment are divided into reader, software and professional services. Purchasing of the RFID reader costs 31 070 NOK and XXL have one reader at the warehouse. Today, they have in total 12 readers, one in the warehouse and 11 around the different XXL stores. In these calculations, will only the cost of one reader be calculated. The tablet costs 7 280 NOK which is used for controlling the validation. Gantry is the stand that the RFID reader is mounted to and costs 11 050 NOK. The total costs related to one reader will then be 49 400 NOK. The software itself costs 50 050 NOK to build up, and the validation framework costs 18 850 NOK. XXL has two out of four modules and pay 2 275 NOK for each module. The total software costs will then be 73 450 NOK. It costs 29 055 NOK for the installation and running in the first day (an extra day will be 18 401 NOK). In total, the investment cost for one investment will be 151 905 NOK.

Apart from the one-time investment costs, there is a monthly recurring sum of 11 375 NOK in software maintenance, helpdesk and monitoring, which corresponds to an annual cost of 136 500 NOK. In addition, the RFID tags costs 33 072 NOK per month and 396 864 NOK annually. Sum recurring costs will then be 44 447 NOK per month and 533 364 NOK annually as illustrated in table 15.

Table 15 - Investment costs by implementing RFID in one warehouse

Investment Costs	**in NOK**			
Reader				
RFID reader	NOK	31 070		
Number of readers		1		
Tablet	NOK	7 280		
Gantry	NOK	11 050		
Sum Reader	NOK	49 400		
Software				
Set up cost	NOK	50 050		
Validation framework	NOK	18 850		
Module - Destination validation per portal	NOK	2 275		
Module - Arrival validation per portal	NOK	2 275		
Sum Software	NOK	73 450		
Professional Services				
Installation and running in	NOK	29 055		
Sum Professional Services	NOK	29 055		
Sum Total Investment Costs	**NOK**	**151 905**		
Recurring Costs				
Service Packages / Recurring costs	**Per month**		**Per year**	
Helpdesk, software maintenance and monitoring	NOK	11 375	NOK	136 500
Sum Service Packages	NOK	11 375	NOK	136 500
Tags	**Per month**		**Per year**	
RFID tag price	NOK	0,689	NOK	0,689
Number of tags per month		48 000		576 000
Sum tag price per month	NOK	33 072	NOK	396 864
Sum Recurring Costs	**NOK**	**44 447**	**NOK**	**533 364**

4.7 Quality evaluations

In order for the results to be believable and useable it is important that the content is of sufficiently high quality. Hence, the thesis must have some substance and therefore the terms validity and reliability will be critical evaluated as the basis for the quality evaluations. (Bryman and Bell 2011)

To ensure validity in this thesis, we have used prolonged engagement and observations. We were given the opportunity to visit the office accommodations for both LS and XXL. By doing this we were given a unique opportunity to observe the organizations and get insight based on conversations with the employees. Further, it was arranged regular Skype meetings with our contact person where ideas and thoughts were shared to make sure that our understanding are aligned. Additionally, several articles from approved journals have been used to ensure reliability. A research database was created and maintained throughout the work on this thesis. The database included research proposal, raw data, theory and literature.

5.0 Finding

This chapter will focus on presenting the findings from our research. It is investigated into how much time XXL use on the logistics operations today, as manual labour and the related cost of doing so. Further, it is identified possible times savings XXL can achieve by implementing RFID technology. It was conducted calculations based on how much time XXL used on the scanning process before and after the RFID implementation in order to compare these numbers.

5.1 RFID related cost in the case of XXL

The related cost in the case of XXL are mainly divided into cost of mis deliveries and time consumes before and after RFID implementation. Cost associated with possible savings per year will also be elaborated.

5.1.1 Cost of mis deliveries

During our study we found that the main reason for mis delivered shipments is due to human mistakes in stage 2 of the warehouse process. This process relay on the employees to stable, pack and scan the pallets. In this stage it may occur errors because packages are misplaced. In order to calculate the total cost per mis delivery one need to look at the cost associated to a shipment shown in table 10.

Cost of mis deliveries per month

From table 10 one can see that the total cost per mis sending shipment is 350 NOK. Given that the number of packages sent per month is 48 000, the number of mis deliveries corresponds to around 192 and 240 depending on which error percent used. The full range of interval calculations are illustrated in table 11.

Figure 14 illustrate the calculations based on mis deliveries and cost per month that was presented in table 11. By comparing the three different scenarios of 10-, 7- and 5 seconds towards the error percentages, the result show differences of 6 300 NOK (18 000) 16 800 NOK (48 000) and 18 900 NOK (54 000). This indicates that one can save significantly costs by eliminating the mis delivery cost by just 0,1%.

For each interval, the cost of mis deliveries per month increases with 8 400 NOK with a 0,4% error rate and 10 500 NOK with errors of 0,5%. This means that the difference between the error rates increases by 2 100 NOK as the number of packages sent increase.

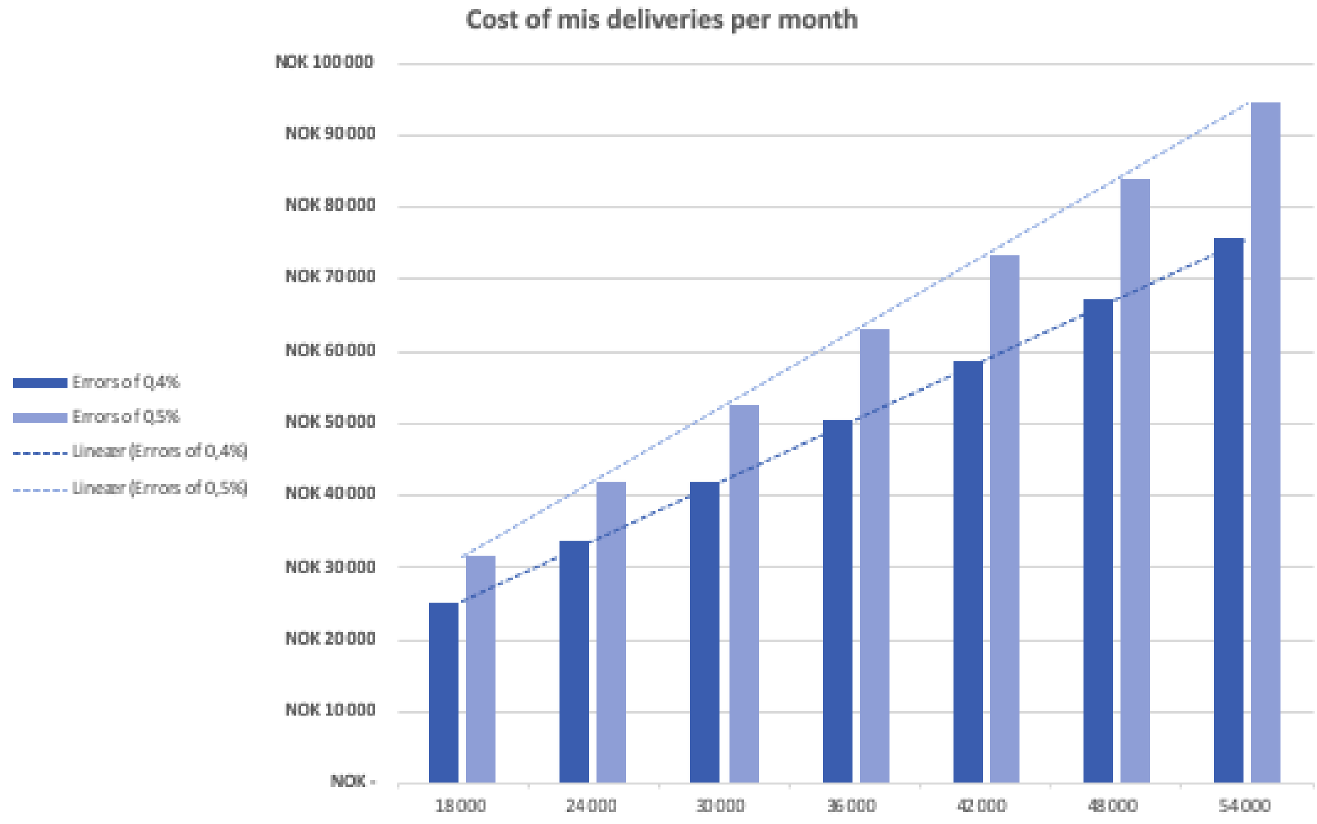

Figure 14 - Cost of mis deliveries per month

Cost of mis deliveries per year

Figure 15 illustrates number of mis deliveries and associated costs for one year. A monthly shipment of 18 000 packages corresponds to an annual shipment of 216 000 packages. With a 0,4% error rate this gives a mis delivery of 864 packages, and with a 0,5% error rate a mis delivery of 1 080 packages. The cost for XXL will then be 302 400 NOK a year (errors of 0,4%) and 378 000 NOK a year (errors of 0,5%). This makes a difference of 75 600 NOK. The calculations are presented in table 12.

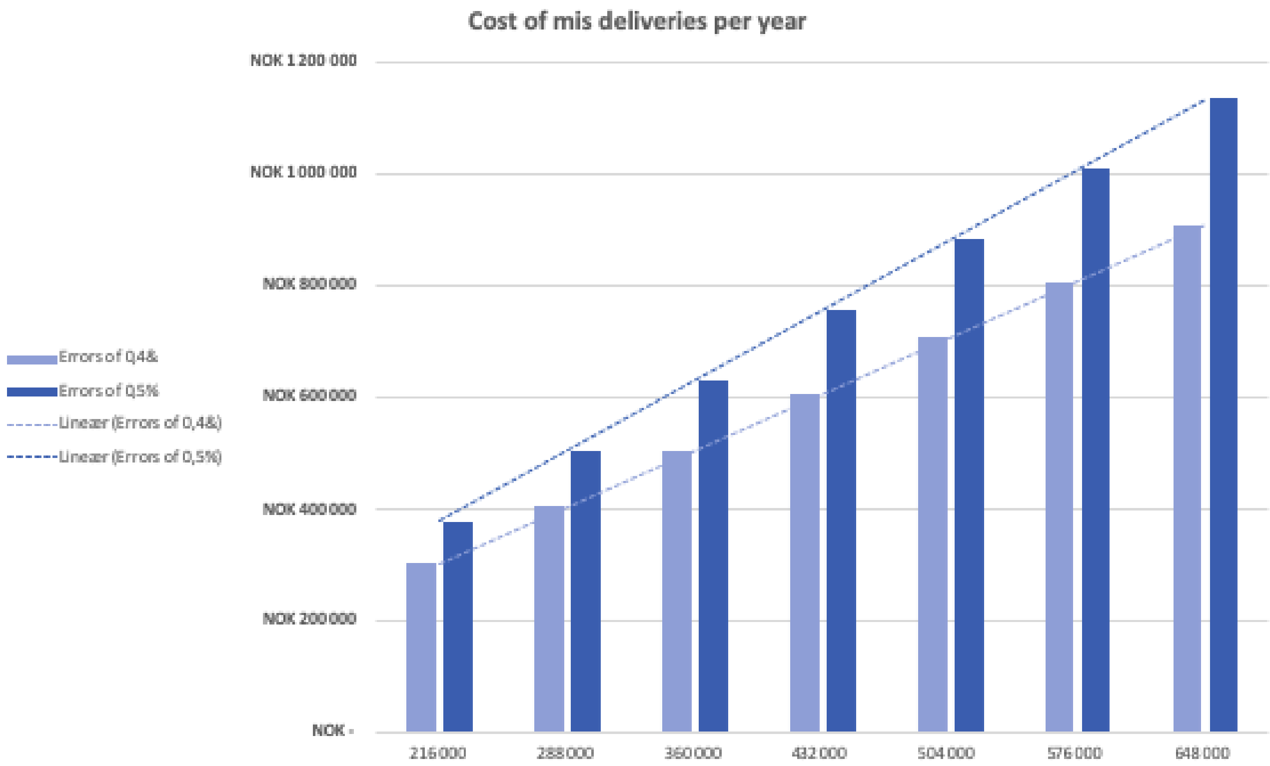

Figure 15 - Cost of mis deliveries per year

A yearly shipment of 576 000 packages gives a mis delivery of 2 304 (0,4%) and 2 880 (0,5%). The cost is then calculated to be 806 400 NOK and 1 008 000 NOK, a difference of 201 600 NOK between the error percentage.

With a yearly shipment of 648 000 packages the mis deliveries are estimated to be 2 592 packages with a 0,4% error rate, and 3 240 packages with a 0,5% error rate. This will cost XXL 907 200 NOK a year (0,4%) or 1 134 000 NOK a year (0,5%). With a 0,1% difference in error rate the gap varies with 224 800 NOK.

For each interval, the yearly cost of mis deliveries increases with 100 800 NOK with a 0,4% error rate and 126 000 NOK with errors of 0,5%. This means that the difference between the error rates increases by 25 000 NOK as the number of packages sent increase.

After the implementation of the RFID application it was found that the number of mis delivered shipment have been reduced to almost zero. By using the AVS in stage 2 and 3 of the warehouses processes the employee get a message regarding the scanning. The scanning will either indicate that everything is ok, or if there are some errors.

Due to the AVS the employee can correct potential errors before the shipment is sent to the wrong location. By having this opportunity XXL can correct errors early in the process and before the shipment leaves the warehouse, which again will reduce the number of mis deliveries. Before the implementation of the AVS, XXL found it difficult to detect errors before it was too late, and the shipment was already sent to the wrong location.

Given that it is sent 2 000 packages a day, XXL have the possibility to save up to 1 008 000 NOK each year by reducing the number of mis deliveries to zero. These numbers indicate that by removing manual handling in stage 2 and 3 of the processes this will cause reduced mis deliveries of shipment.

5.1.2 Time consumed before and after RFID implementation

The average time an employee spent on the manual scanning process before RFID implementation was estimated to 60 seconds. After the RFID implementation the scanning process have been automated which means that it is not conducted manually anymore. By automate this process XXL have estimated that they can save 50 seconds per scanning. This means that an employee now uses 10 seconds per scanning, which is equivalent to 1 600 hours a year. Which means that they saved 8 000 hours by automating the scanning process, as illustrated in table 16. By reducing the scanning process from 9 600 to 8 000 the manual handling of shipments can be reduced by approximately 83 %.

Table 16 - Time spent on scanning shipments before and after RFID implementation

	Before RFID	After RFID		
Time per scanning (seconds)	60	10	7	5
Time per year (hours)	9 600	1 600	1 120	800
Time saved per year (hours)		**8 000**	**8 480**	**8 800**

If the employee was able to reduce the scanning time even more, respectively to 7- and 5 seconds the hours saved per year can expand. As one can see from table 16, XXL used 9 600 hours a year on the scanning process, but if they were able to decrease this time, they could save 8 480 (7 seconds) or 8 800 (5 seconds). In percentage, XXL have the opportunity to remove the manual handling of goods with approximately 88% (7 seconds) and 92% (5 seconds).

Possible cost savings associated with the scanning process

By saving 50 seconds on the scanning process XXL will be able to save a lot of time. Table 17 illustrate the possible cost savings XXL can gain by reducing the scanning process respectively down to 10-, 7- or 5 seconds. The calculations are done in order to find the possible FTE that XXL can save, as well as the associated cost for that given FTE. As illustrated in table 17, XXL can save up to 4,57 FTE with a 10 second scanning and approximately 2 000 000 NOK, given a number of 576 000 packages each year. These calculations give an indication of how much XXL can save by implementing RFID technology.

It appears from our interviews that RFID is most beneficial in larger quantity. This matches our calculations in table 17, where one can see that XXL can save more cost regardless of how many packages they send. If XXL were able to get the scanning process down to 7- or 5 seconds per shipment, they could save more time and costs. By reducing the scanning process with 53 or 55 seconds, approximately 2 120 000 and 2 200 000 NOK can be saved yearly with 576 000 packages yearly.

Table 17 - Possible cost saving with 10-, 7- and 5 seconds

POSSIBLE COST SAVINGS PER YEAR						
Packages per year	10 SECONDS		7 SECONDS		5 SECONDS	
	FTE	COST	FTE	COST	FTE	COST
216 000	1,71	750 000,00	1,82	795 000,00	1,89	825 000,00
288 000	2,29	1 000 000,00	2,42	1 060 000,00	2,51	1 100 000,00
360 000	2,86	1 250 000,00	3,03	1 325 000,00	3,14	1 375 000,00
432 000	3,43	1 500 000,00	3,63	1 590 000,00	3,77	1 650 000,00
504 000	4,00	1 750 000,00	4,24	1 855 000,00	4,40	1 925 000,00
576 000	4,57	2 000 000,00	4,85	2 120 000,00	5,03	2 200 000,00
648 000	5,14	2 250 000,00	5,45	2 385 000,00	5,66	2 475 000,00

If XXL were only able to send 216 000 packages per year, they could still save up to 750 000 NOK (10 seconds), 795 000 NOK (7 seconds) or 825 000 NOK (5 seconds) per year. Comparing the numbers from 10-, 7- and 5 seconds, we found that for each interval the FTE increases by up to 0,6.

This means that by halving the scanning process to 5 seconds, XXL has the possibility to save 0,6 FTE per interval as the number of packages increases. This corresponds to a saving of 262 500 NOK. For a scan of 7 seconds, the savings can be up to 175 000 NOK.

With 576 000 packages per year, XXL can save up to 5 FTE. If the scanning process reduces to 5 seconds this can give the possibility to save additional 200 000 NOK compared to a scanning process of 10 seconds. If XXL were to send 648 000 packages a year, the possible savings associated to FTE can respectively be 5,14 (10 seconds), 5,45 (7 seconds) and 5,66 (5 seconds). This corresponds to costs going from 2 250 000 to 2 475 000 NOK.

Illustrated in figure 16 one can see the different cost associated with the scanning processes according to 10-, 7- and 5 seconds. Horizontal, the figure shows the different package intervals. Vertically, in the figure show the potential cost that XXL can save if the scanning process is respectively 10-, 7- or 5 seconds. The linear function shows the ratio between number of packages sent and how the cost develops for each interval. The number of packages will vary while the other variables are constant.

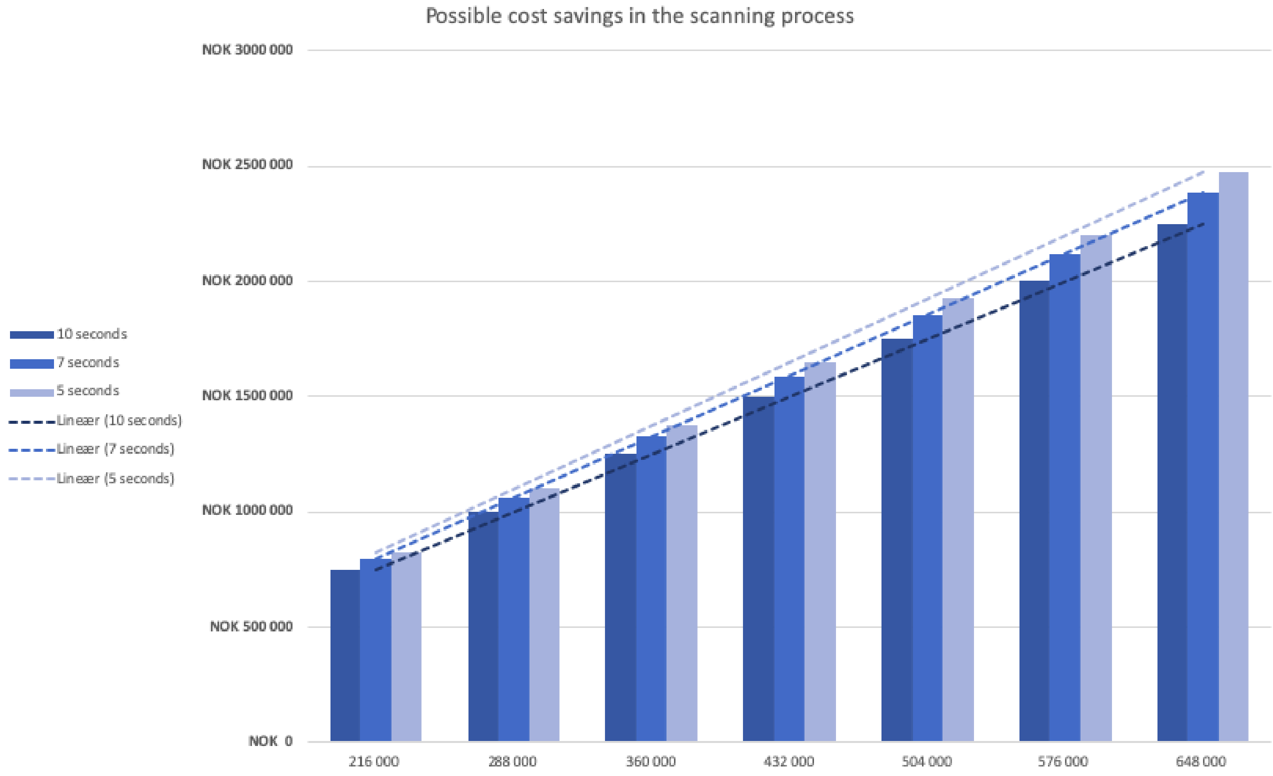

Figure 16 - Illustration of cost associated to scanning process of 10-, 7- and 5 seconds

In the first interval, one can see that the difference between 10 and 5 seconds is 75 000 (825 000 minus 750 000), and in the second interval the difference is 100 000. This indicates that each interval increases with 25 000 by going from 10 to 5 seconds. Meaning that XXL have the possibility to save 75 000 NOK plus 25 000 per interval if they manage to halve the scanning process. If it is not possible to halve the scanning time, 7 seconds may be obtainable. Then XXL can save 45 000 NOK in the first interval and 60 000 NOK in the second, thus interval increases with 15 000 NOK.

6.0 Discussion

In this section it will be discussed around our findings towards the research question and relevant theory. From the interviews conducted it was found that the main problem for the warehouse processes at XXL occurred in stage 2 and 3. In these stages the employee stable and pack the pallets. Meaning that before the RFID implementation the employee had to scan each item individually and then stack and prepare the shipments for dispatch. There was no quality control that the packages stabled was actually the right packages for the given destination. This led to many mis deliveries which cost money, time and effort. This chapter looks at the economic assessment, processes, customer satisfaction, technical limitations, barriers for implementation, and success criteria's.

This discussion constitutes the answer to the research question below:
How may improved RFID technology applied in warehouses have an impact on economic assessments and warehouse processes for the retail industry?

Economic assessment

During our research it was found that XXL had problems with high cost associated with mis deliveries and correcting these. The total cost of mis deliveries each month can be difficult to estimate due to various factors that may have an impact on the freight cost. As Sarac, Absi and Dauzére-Pérès (2010) address, the effect of RFID can be difficult to calculate due to the involvement of several processes. It is likely to think that impacted factors could be the distance to the warehouse, size and weight of the shipment and who the customer is. Norway is an elongated country with varied quality and speed limit on the roads, and it is therefore a difference between the delivery times for Kirkenes versus Kristiansand from the central warehouse in Oslo. Hypothetically, if a shipment is sent to Kirkenes by a mistake, the transportation cost will normally increase, and it will take more time to correct an error because of the longer distance to the central warehouse. However, from the XXL case the best and worst scenario of mis deliveries was respectively based on 72 to 270 per month given an interval of 18 000 to 54 000 packages. As calculated, this will give a cost of 25 200 NOK to 94 500 NOK per month for mis sending of shipments. We believe that the cost associated with the mis deliveries is unnecessary high, as the cost can be reduced or even removed by implementing improved RFID technology.

After implementing the AVS the number of mis deliveries a month have decreased to almost zero. The AVS detects errors when the pallets are being scanned, so XXL can repack and fix the pallets with the right shipments, before it is sent out to its destination and customers. In the scenario were the number of mis deliveries has gone down, XXL do not need to use a high fee on correcting errors. This can indicate that by removing these errors XXL have recouped a lot of the investment cost. The investment cost was calculated to be 151 905 NOK which is approximately 62% of the highest cost (94 500 NOK) of mis deliveries. Taking this into account one can see that the AVS is beneficial for XXL because the ROI will be earned in a short period of time.

It also emerges that XXL will be able to reduce the labour cost in manual handling. Showing to the calculations is section 4.6, one can see that XXL potentially can save 8 000 hours on the scanning process per year by reducing the manual handling. This constitute to 4,6 FTEs. According to Sarac, Absi and Dauzère-Pèrès (2010), will the cost of employment be reduced by using RFID. This is in line with our calculations, which show that average labour cost per employee makes a total of 437 500 NOK. By saving 4,6 FTEs XXL can have the possibility to save 2 000 000 NOK a year. This is also consistent with previous research which states that RFID can reduce number of physical handling as well as manual errors (Regattieri, Gamberi and Manzini 2007).

However, XXL will not be able to directly save 2 000 000 NOK unless they denounce employees. The resources and capacity used on the manual scanning process can now be used on other activities. Meaning that they can use the labour alternatively and utilize the available resources in a better way. Also, it is assumed that it is normal to rent temporarily employees in the retail industry as a result of lack of available labour capacity. By using the released capacity and utilize the existing employees alternatively, XXL will be able to reduce the cost given that they previously had activities where they had to rent temporarily employees.

As for this thesis, the calculations only show the possible savings in one warehouse. Thus, do not consider the entire effect of RFID implementation in the entire SC. Meaning that one is not able to see the big savings in relation to the income statement for the whole company.

The percentage in the income statement for one warehouse will not be significant high, but it is likely to believe that it will have a great overall effect if RFID is implemented throughout the SC. Even though, this is only done at one specific warehouse, it is likely to believe that there are many similar warehouses that can relate to our calculations. Due to this we can say that our result can be generalized to other similar warehouses.

As shown in our calculations, RFID applications can have an impact on the economic assessments. By replacing physical handling of the goods with RFID technology, XXL can save scanning time and reduce the number of mis deliveries. The cost related to reverse logistics was high before the implementing of RFID. However, after implementing RFID the number of mis deliveries has gone down to almost zero. This indicates that XXL can save the cost previously used on correcting errors. By saving time XXL can better allocate the available resources and which can imply that the processes are being conducted more efficient. It is likely to believe that this can influence the economic assessment.

Processes

In this section the following will be described; reduction in time used on quality control, reduction in manual handling, and constantly update of inventory in warehouse and store. As found in the interviews, reduction in time used on quality control is one of the advantages mentioned several times. Quality control is defined as the time spent to validate that all packages are on the right pallet or cage and shipped to the right destination. The processes itself have been improved with the AVS. The time was reduced considerable, from 60 seconds to 10 seconds, so this match the answers in the interviews. This constitute to a removal of 83% in manual handling of shipments. Thus, one can assume that the processes is done 83% more efficient with the AVS. Even though the time saved in this case is significant, one can asks the question to why the scanning process is not even lower. An assumption of why the scanning process is not down to 7 or 5 seconds today can be because the portal does not get in contact with all the RFID labels. This can be due to readings problems of products of- or wrapped in metal or liquid. The antenna has as mentioned problems with reading through these types of material.

In order to find the possible time savings on the scanning process it was conducted calculations respectively to 7- and 5 seconds. Our findings show that if XXL were able to use 7 seconds the times savings would correspond to 8 480 hours.

This means that the manual handling of shipments can be removed up to 88%. If the time was halved the savings would be 8 800 hours. This make a total of 92% reduction in manual handling. We can assume that the scanning process can be reduced somewhat more when the final AVS is fully implemented and the employees have more knowledge to the solution. However, we found it unlikely that the scanning process will come to this point in the nearest future since there are still some barriers with the technology.

Reduction in time is also emphasized by Bankes et al. (2007), which states that process improvements are one of the advantages with RFID. Nevertheless, it should be mentioned that by implementing the AVS an extra step is added in the process. Before the RFID implementation, the packages were scanned with a barcode reader while they were put on the pallet. When the pallet was full it was finished and ready for dispatch. Now, all packages must be loaded on the pallet before conduction the scanning. Even though the AVS requires one extra step in the process, we see more benefits of being able to use RFID scanning rather than doing it manually.

However, the employees have been doing the processes manually for a long time and humans tend to follow their habits and do not like interferes with this. As this technology is something new it can lead to sceptics among the employees because they need to let go of the control. Despite that, the AVS is not a very complex solution so XXL do not need to use much time on training of employees. Since the solution is simple and easy to use this can be seen as a value driver for XXL to implement it. If the solution was very complex and XXL had to use much time on training, this could be a barrier to decide not to implement.

Another time-saving advantage mentioned were the constantly update of inventory. By introducing RFID technology, one does not have to physically count the stock as this is registered by the portal. As Richards (2014) explains, the registration is not dependent on line-of-site in order to conduct the scanning process. In this way, stores can get a better all-time overview of the stock, which in turn can be connected to the OMS. It is likely to think that this will create value for XXL because they will always have control of the inventory. Further, one can assume that this also will affect the customer satisfaction as the online store will be automatically update through real time inventory.

If a product is out of stock the delivery time might be longer, which is valuable information for the end customer to know before making an order.

With the AVS, XXL have better predictions for real time updates as they have better visibility into the SC by RFID applications. As long as the RFID tag is registered, XXL will be able to get a real time perspective. By having more available information XXL can get a better overview of the operations in order to allocate the resources in a better way. XXL will then get an insight into actual material flow and are able to identify potential problem areas. Further, be able to improve their planning management and the general operation. However, a disadvantage that allude is that when an error occur the employee only get an alert that something is wrong. The alert does not indicate what is wrong, so they need to locate the error themselves. This process can be time consuming with a high number of packages going through, so one can ask the question if this is profitable. However, we look at this as a significant small disadvantage because the employee will at least get an alert that something is wrong. Hence, the employee has the opportunity to correct this error before sending the shipment. Without the RFID application the employee would probably not discover this error before the shipment was sent to the wrong store, where someone is missing a package, or someone have a package in surplus.

Our findings show that XXL have achieved better visibility, reduced the number of errors as well as time spent in the scanning process after implementing RFID technology. These results are in line with what is stated in the literature (Rekik 2006; Lee and Özalp 2007; Chow et al. 2006; Tajima 2007). It is also stated that the general management of the operation will be streamlined through better resource utilization, better quality control, and time reduction in conduction processes. Hence, as Ali and Haseeb (2018) allude to, it is likely to believe that if the entire SC would implement RFID it could have a positive effect on the SC. In addition, Lofti et al. (2013) point out that the effects could be better visibility and control through the entire chain as well as constant update in the different processes.

In recent years there has been a development in technology which has led to enhancement on efficiency in the warehouse operations. This might indicate that the goods are being sorted and dispatched at a much shorter time, placing even more pressure on logistics performance. As the retail market is under a rapidly development, it can be challenging to keep up with the customers' requirements.

Customer satisfaction

It emerges that XXL will be able to get better visibility throughout the whole SC by using the AVS. XXL used time to scan all packages manually in order to notify the customer that their packages were available for them. This was not often prioritized due to busy hours at the stores. With the AVS, this process is done automatically, and the employee does not need to use time on this job. XXL is able to track and trace the parcel, and by doing this they will get better quality control and more real time estimates on where the given parcel is located right now. With better visibility into the SC, XXL will be able to give the customers more information, which is highlighted by Lofti et al. (2013) as something the customers highly appreciate. The customer can be notified early in the process on where their package is, or if it is delayed etc.

Most likely, the customer expects their package to be delivered within the given time line and be notified early if there are any delays. Implementing of RFID technology can contribute to this, as XXL have the possibility to update the shipment status as the parcel is sent through reading points in the SC. RFID can also reduce errors by automate the processes which can have an impact on the delivery time for the end customer. Appendix 4 illustrate the first time XXL activated automatic notification for customer delivery. Further this illustrates when the customer is notified by SMS and the time the customer picks it up.

Investment costs

According to price, it can have a tendency to impact on whether businesses decide to implement RFID solutions our not. According to the interviewees the price of the RFID tags has been too high for companies to consider implementing. It is estimated that the tag price today is around 0,689 NOK. This indicate that the tag price must be even lower before more companies would consider implementing.

This is consistent with the research of Jones and Chung (2008), which emphases that if the tag priced dropped to $0,05 more companies would consider implementing RFID. With this in mind, we see a trend that the price will probably decrease even more as presented by Sower et al. (2012). It was found in the literature that the cost of RFID tags will be reduced when the number of purchase tags increases (Richards 2014). This indicates that RFID will be more beneficial for companies that send a larger volume of packages. However, this is not considered in our thesis. Still, this can be an argument for why XXL should implement RFID into all their stores, since the number of packages sent today will most likely increase with the development in the retail industry.

There are also challenges regarding customized cost because the RFID system need to be adapted to the certain working surroundings and purposes. Meaning that the RFID applications must be installed in a proper place in the warehouse which might conflict with the infrastructure to other processes. If this is the case, the businesses may need to relocate the warehouse in order to get the RFID application proper installed. It is likely to think that this is an expensive change.

Technical limitations

It is highlighted that the technology is somewhat limited as it has problems with reading through certain types of material. The interviews revealed that the best suited industry segment for RFID adaption is within garments as there are little possibility that the portal will have problems reading through these types of material.

The limitations related to the RFID technology is that the portal has problems by reading through metal and water because the radio waves are being disturbed. Looking at the results from LS read rate test; the read rate performance was only affected of the aluminium foil from some chocolate bars and a bag with metal foil. Other parameters that can influence a good reading rate could be environment, amount of time in the reading zone, general movement etc. Setting the population estimate to a large number for reading a large volume may not always give the best response. The RFID reader was therefore tested with different configurations to see if it occurred any differences. In general, setting a low population estimate can give a faster read, but no necessarily the most accurate. The mentioned limitations with the technology allude to the limitations stated by Richards (2014).

As presented in the portal read test, the average read rate performance ended up at 99,07%, which is a very good result. This do not allude to the research of Yoo, Hong and Kim (2009) which indicate that RFID deliver information with 100% precision. However, the results from the portal read test is a small deviation so we do not consider this as a major difference. With this in mind, we can conclude that RFID deliver a very accurate reading performance.

Infrastructure

Infrastructure at the warehouse can be a barrier for implementing RFID technology. In order to implement RFID technology, the stores and warehouses are dependent on RFID readers and the space for them. The surrounding area must be clean and tidy (not necessarily a disadvantage, but it can mean that it is not for all industries), and other RFID labelled packages must be out of frequency range. A problem that have arose from our case study is that RFID labelled packages nearby the portal was read without purpose. A suggestion to avoid cross readings can be to build insulation walls around the reader. This can impair the radio waves and make sure that only the desired tags are read. However, this might be a cumbersome solution.

Further, to avoid cross readings it is important that the area around the portal is clean. Additionally, it has come to our knowledge that the set-up time for the RFID portal was estimated to 27 hours, meaning that there will be no major disturbances in the warehouse while it is being set up.

Barriers for implementation

In the interviews it was revealed many advantages and just mentioned some disadvantages with the RFID technology. Further, it was questioned why RFID is not used in a bigger extend as there are so many advantages with the technology. The main features mentioned was the price and other qualified solutions, especially compared with barcodes. Barcode do the same job, why use extra resources and time on another technology with mostly the same features? Roberti (2009) conducted a comparison of RFID and barcodes. The barcode is cheaper, and the job will be done but RFID technology will do the job faster. Further, it has been shown that retailers use 75 to 80% less time to complete a store inventory with RFID rather than with barcode (Roberti 2009). Our results show that manual handling can be reduced from 60 to 10 seconds.

To maintain a high inventory accuracy, it costs more to gather the information needed with barcodes than with RFID due to the required labour. The reality today is that many stores conducts store inventory two to four times a year, why not two times a day? It can be assumed that this is because it is expensive to hire people to scan barcodes twice a day. That said, increasing information does not necessarily provide better insight into the business. In order to use the information in the right way, a clear plan of the needed data is suitable to get the best outcome without being overwhelmed by the data collection.

There are many good and similar technologies on the market, some are more familiar and qualified solutions, so the company needs to look into their budget. The company need to consider what they want to achieve and decide based on their needs. It is also difficult to calculate the benefits the business will gain in advanced. This can be one of the reasons why RFID are used to a small extent. Moreover, the companies may like to wait on implementing RFID until it is done more accurate research on the subject. The research conducted today mainly highlights the general benefits a company can gain but do not refer to actual calculations.

Another barrier could be that RFID can interfere with existing procedures. The employees have been doing the same processes manually for a long time and humans tend to follow their habits and do not like interferes with this. To implement the technology and add a new step to the process, can lead to sceptics among the employees because they need to let go of the control.

Hypothetically we can say that if the customer does not have a critical problem that can be resolved by RFID, they attend to wait until the price of the RFID tags drops. Also, wait to the standard of RFID applications are sorted out before making an investment. Here it may be relevant to look at the gains that the business will get out of the RFID implementation.

Success criteria's

We have identified some success criteria that we see as important in order to succeed with such implementation. First, it is believed that the close collaboration between all the involved parties is a success factor. LS has involved XXL in the developing part of the product as XXL can better understand their problems. By doing this, one can better targeting a specific problem and find the best solution together.

One can further assume that by developing a product together, the solution can be customized towards the companies' problems. This can be a huge advantage for XXL. However, if we see this from LS's perspective it can be perceived as a drop back due to the risk of developing a product that is customized towards one specific customer's problem and cannot be generalized to others.

A success criterion can be to have knowledge within the areas of operation, which in this case is logistics and RFID technology. Further, we believe that one success factor is due to the overall understanding of the customer processes. By having a better understanding one can come up with better inputs or solutions into solving different situations. We believe that there has been a close follow up during the entire process, and that this is one of the reasons why this implementing has been a success. In our case study there has been a close collaboration between the involved parties from the beginning of the pilot project.

Additionally, the AVS can be implemented towards every system, and perceived as easy to integrate towards the customers' existing production processes. Since the customer do not need any significant changes in order to implement the AVS, we believe that this also is a reason for success so far. Furthermore, a success criterion can be the option for a trying period. With this option the customer gets the opportunity to test if RFID can be suitable for their processes. Another identified benefit is that the RFID portal has proven to be a trusted technology. As referred, the reading test ended up at 99,07% which indicates that the technology is almost 100% trustable. As the technology has proven to be according to the expectations, it is likely to assume that the customers in generally are willing to implement RFID into all their activities. We see this as a success criterion of why XXL considered to continue the collaborate beyond the pilot project.

Value drivers

After reviewing the results of the interviews, we became aware of a common factor that the interviewees pointed out. Everyone mentioned that the value driver behind investing in RFID solutions is that the manual handling of the processes can be reduced or even removed. This is in line with the findings in the theoretical framework and through our calculations which is further emphasized by Regattieri, Gamberi and Manzini (2007). Automating the processes in stage 2 and 3 will lead to avoidance of the "human effect".

As XXL had problems within this process area, one can assume that this is the main value driver why XXL choose to implement the product.

During the interviews, it was found that XXL now have better control of their SC as they can track and trace the shipments. As a result of this, XXL will gain better visibility through the SC and more precise deliveries. One can assume that many companies decide to invest in new technology as a strategic choice. Thus, the objective behind the decision is not only because of the aspiration for increased profit or improved utilization of the resources, even though this is an important decision making. When companies decide to invest in new technology one can assume it is to be able to offer the customer's something that the competitors do not have. This can strengthen the company's competitive position in the industry.

Complex supply chain

As XXL is a multi-brand company who receives goods from several suppliers, it is natural to assume that they will receive goods that are crossing international borders. This can indicate that the XXL SC is complex. For XXL to get the entire effect of RFID applications in their SC, they are depended on the suppliers to also implement RFID. In the case of international trade, the goods will probably be sent from the supplier by air or sea transportation and then with truck in order to arrive at the warehouse. Meaning that the infrastructure behind the transportation is an important part of the SC. Hypothetically, if every stage in the SC implemented RFID tracking of the goods, (from production till the physically product is picked up by the end customer) the involved parties in the SC could have better product information and insight due to constantly updates on a given item. This could lead to an even more efficient SC. However, this is not the case for XXL since the implementation has only been done in a little degree, meaning only at the XXL facilities. Implementation was done in the warehouse process including two e- commerce categories; mail box packages and pick up at store. The benefits of RFID implementation will vary depending of the degree of implementation, if it is done in one single process, the whole company or in the entire value chain.

One can also assume that a reason for not having fully integrated RFID applications in the whole SC can be due to the different international regulations regarding radio frequency. The strength of the radio waves differs according to the law in the different countries (Richards 2014).

As for now, XXL print and put on the labels at their warehouse. This process could have been avoided if the manufacturer had done this under the production process of the goods. This is the case for companies such as Zara and H&M where RFID are fully integrated. However, Zara and H&M are single brand companies which makes it easier to fully integrate the SC. If brands, such as Nike and Adidas had implemented RFID in the entire SC, the processes could probably have been more efficient. Then XXL can evade printing the label themselves.

By adapting RFID labels early in the SC, it can be easier to track the items and get a real time perspective in the different processes. It is possible to acquire accurate information regarding how the product was made and what it contains. However, there are many elements that must be considered when one chooses to implement RFID, like type of label, supplier, system etc. One may need various types of tags and readers depending on the type of material. In such cases it might be that a given tag does not fit all the products for the different retailers. It can be conceivable that this is a reason for why some suppliers have not implemented the technology. Also, a barrier can be that the management do not have the fully insight into how RFID can create value since it can be difficult to calculate the given profitability in advance with such an implementation.

7.0 Conclusions

In this chapter the conclusion will be presented, followed by recommendations to the company based on the findings. The objective of this thesis was to discuss *how improved RFID technology applied in warehouses can have an impact on the economic assessment and the warehouse processes for the retail industry*.

The factors that are emphasized to have a major impact on the warehouse performance has been identified to be the physical handling of goods. When operating in an industry suffering from a high number of mis deliveries, the focus has been towards streamlining operations in order to build more robust processes. In order to overcome these obstacles a pilot project developed by Lyngsoe System was tested out in the central warehouse of XXL. The pilot project was found to assist XXL in order to obtain a more visible SC flow. Meaning that XXL got an overview of goods from the warehouse to the end customer's mailbox and to the physical XXL stores. It was determined that by implementing RFID technology into the warehouse process 2 and 3, XXL will be able to increase the efficiency, reduce errors as well as decreasing cost associated with manual handling. However, some limitations identified with the technology indicates that it is still some development potential. We firmly believe that new structure and new indications caused by RFID implementation can improve the performance of warehouse processes. Further, that this can have a positively impact on the economic assessment.

We believe that the improved RFID solution with a tailoring towards the ERP systems will increase the visibility throughout the SC. RFID technology may improve helpful to optimize the warehouse processes by removing the manual scanning and reducing the manual handling time with 50 seconds. The RFID has shown accuracy and positive effects on the warehouse operations. Further recommendations for XXL can be to implement RFID technology in more processes at the warehouse and in-store. XXL should also try to collaborate with their suppliers regarding implementing RFID in full scale.

In this thesis it was found that improved RFID technology can have a real effect and are now working in the XXL warehouse in general. It was assumed that warehouses have similar activities such as picking and making sure that the right order is dispatched. This can indicate that the warehouse operations are similar.

Meaning that one can suspect that other warehouses also have obstacles with errors. Even though this research is limited to a specific warehouse, we feel confident that the method used, and the main findings might be applicable to other similar retail warehouses. Due to this, one can assume that the RFID technology will also function in other warehouses, in addition to be a great economic value for retailers.

To conclude, the case study has contributed to accentuate how improved RFID technology can have an impact on the economic assessment, and further the warehouse processes in a retailer's SC. It was proven that RFID technology can lead to more efficient processes and an overall better SC performance.

8.0 Limitations and suggested further studies

This master thesis is limited to investigate on one single case study. The case study was conducted in the retail industry in one specific company, XXL Sport and Outdoor. Further, the result of this research is limited to XXL central warehouse. However, it is most likely that similar warehouses can relate to our calculations. Due to this we can say that our results can be generalized to other similar warehouses.

Further, there are limitations regarding that the AVS is currently a pilot project. We recommend that future research should investigate the solution in full scale in order to better determine the full effect of the improved technology. The technology also has potential improvements regarding cross readings and dead areas in the warehouse, and a study regarding optimal location of the RFID reader can be another direction to explore. Another suggestion for further research is to investigate how RFID can be fully integrated in the case of multi-brands companies. Then, also a discussion about who should be responsible for the RFID tag is necessary.

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10.0 Appendix

10.1Appendix 1: Definitions of key RFID terms and concepts

Definitions of key RFID terms and concepts (adapted from RFID journal) (Curtin, Kauffman and Riggins 2007)

Term	Definition
Active tag	RFID tac with a transmitter to send back information, rather than reflecting back a signal from the reader, as a passive tag does. Most active tags use a battery to transmit a signal to a reader. However, some tags can gather energy from other sources. Active tags can be read from 300 feet (100m) or more, but they're expensive (typically more than US$20 each)
Antenna	The tag antenna is the conductive element that enables the tag to send and receive data. Passive, low- (135kHz) and high frequency (13.56MHz) tags usually have a coiled antenna that couples with the coiled antenna of the reader to form a magnetic field. The RF energy from the reader antenna is "harvested" by the antenna and used to power the microchip.
Compatibility	Two RFID systems are considered compatible if they use the same protocols, frequencies and voltage levels and are able to operate together within the same overall application.
Frequency	The number of repetitions of a complete wave within one second. 1 Hz equals one complete waveform in one second. RFID tags use low, high, ultra-high and microwaves frequencies.
High- frequency	From 3MHz to 30MHz. HF RFID tags typically operate at 13.56 MHz. Can be read from less than 3 feet away and transmit data faster than low-frequency.
Low- frequency	From 30 kHz to 300 kHz. Low-frequency tags typical operate at 125 kHz or 134 kHz. The main disadvantages of low-frequency tags are they have to be read from within three feet and the rate of data transfer is slow. But they are less subject to interference than UHF tags
Middleware	In RFID, software that resides on a server between readers and enterprise applications. Filters data and passes on only useful information to enterprise applications. Used to manage network readers.
RFID	Method of identifying items using radio waves. A reader communicates with a tag, which holds information in a microchip. Chip less tags reflect some of the radio waves beamed at them.
RFID tag	Microchip attached to an antenna that is packages in a way that it can be applied to an object. Tag picks up signals from and sends signals to a reader; contains a unique serial number, buy may have other information (e.g., customer account number). Come in many forms: smart labels with a printed barcode, tag in a carton or embedded in plastic. Can be active, passive or semi-passive.

Reader	A device used to communicate with RFID tags. The reader has one or more antennas, which emit radio waves and receive signals back from the tag. The reader is also called an interrogator.

10.2 Appendix 2: Interview Guide

Explore how RFID has an impact on information systems in supply chains:

- Developing an information sharing supply chain

Information (5-10 min)

- We inform about the background and purpose of this conversation by presenting the consent form. It must be signs before any interview. We ask for permission to record audio. We inform about confidentiality.

The questions asked will vary somewhat from interview to interview based on the position and background of the interview objects, but there are also some questions that are asked to everyone.

Interview 1:

Product

Why did LS develop this product?

- What need did you see in the market?
  - What is the reason that this have not been done earlier?
- Did LS conduct a market analysis? If yes, how?
- Did LS have a specific business/market strategy when you decided to develop the product?

Can you please explain the processes of how the automated verification system work?

- What are the advantages and disadvantages of using this product?
  - Expense? Size? Range? Identification capability?

What did LS want to achieve with this product development?

- Did you set some specific goals?
- If, have you reached any of this?

What do you think is needed in order to succeed in launching a new product?

What do you think make Lyngsoe Systems different from the competitors?

What makes your product unique compared to other products?

- What are new with your solution?

How did you choose the company that were going to test the pilot product?

- Specific criteria?

How do you think this product can affect the supply chain processes in your customer's warehouse regarding time consumed, errors, productivity, effectivity?

- Effect on the information flow?

How can the state of art of RFID solution improve the performance for the customer satisfaction?

What do you think is the value driver for the customers to implement your solution?

- What benefit can they gain?
- How can this influence their supply chain?
- Do you think this can improve the customer satisfaction for the end customer? If yes, could you please explain?

Interview 2:

RIFD

What is new with the RFID tags you used compare to previous RFID tags?

- Do you use active or passive responders, or both? Semi-active?
- If passive, how do you power supply to passive transponders?

From how long range can the RFID antenna receive signals from the RFID label products?

What kind of frequency do you operate with?

What is the operating frequency of your operating tag?

- Ranging from 135 kHz long wave to 5,8 GHz in the micro wave range
- What are the achievable range of the system?
- What are minimum and maximum?

What do you see as the next development in RFID?

- Is it a good time to implement now or better to wait?

How can the new features of RFID create value for the supply chain?

- Can the structure be influenced or changed?
  - With this we mean if you can skip some links / cut out some links in the value chain or if more steps can be added?

Information/data

How has the RFID technology developed over time?

How does RFID integrate with the ERP system?

- Could the system be integrated with every system or are there some limitations?
- Could you describe the use of information system in LS?

- What kind of information system do you use? / Which data systems do you use?

How is the information flow from LS's customers to the software system? Please describe.

- Do you get all the information you need?

Have you experienced that lack of information has been a problem?

- How did you experience it?
- What have been the main reason?
- What were the consequences?

Do you store the information/data you receive?

- What kind of data is desired to get stored, which is not stored today?
- What data / information / key figures are stored today from production, ordering, storage, picking, delivery process, logistics?

Did you conduct some specific analysis in your company regarding the cost and value in information availability?

- Or technical limitations to using increased information availability?

What is the cost of developing the RFID antenna?

- What does an RFID tag cost?
- What is the associated cost of using RFID tag?

Identify the potential errors; what type of errors occurs? How many errors occurs on monthly basis? What are the cost of correcting these errors? Can errors be removed by introducing the automated solution product?

How often does your software system register error at customers on a weekly basis?

  - 0
  - Once a week
  - 2-3 days per week
  - 3-5 days per week
  - More

- How many errors occurs on monthly basis?
- Where in the fulfilment process do they occur?
- What are the cost of correcting errors?

How can errors be reduced or removed by implementing the ASV product?

Interview 3:

Why did LS develop this product?

- What need did you see in the market?
    - What is the reason that this have not been done earlier?
- Did LS conduct a market analysis? If yes, how?
- Did LS have a specific business/market strategy when you decided to develop the product?

Can you please explain the processes of how the automated verification system work?

- What are the advantages and disadvantages of using this product?
    - Expense? Size? Range? Identification capability?

What did LS want to achieve with this product development?

- Did you set some specific goals?
- If, have you reached any of this?

What do you think is needed in order to succeed in launching a new product?

What do you think make Lyngsoe Systems different from the competitors?

What makes your product unique compared to other products?

- What are new with your solution?

What do you see as the next development in RFID?

- Is it a good time to implement now or better to wait?

How can the new features of RFID solutions improve the performance for creating value for customer/supply chain?

How can the new RFID technology influence the supply chain structure in the sports warehouse industry?

What are the new features of your RFID solutions and ASV product?

- How can the new features of RFID create value for the supply chain?
- Can the structure of the supply chain be influenced or changed?
    - With this we mean if you can skip some links / cut out some links in the value chain or if more steps can be added?

How did you choose the company that were going to test the pilot product?

- Specific criteria?

How was the implementation of the solution with the customers?

- Much training, complications, errors?

How do you think this product can affect the supply chain processes in your customers warehouse regarding time consumed, errors, productivity, effectivity?

- Effect on the information flow?

Interview 4 & 5

Why did LS develop this product?

- What need did you see in the market?
  - What is the reason that this have not been done earlier?
- Did LS conduct a market analysis? If yes, how?
- Did LS have a specific business/market strategy when you decided to develop the product?

Can you please explain the processes of how the automated verification system work?

- What are the advantages and disadvantages of using this product?
  - Expense? Size? Range? Identification capability?

What did LS want to achieve with this product development?

- Did you set some specific goals?
- If, have you reached any of this?

What do you think is needed in order to succeed in launching a new product?

What do you think make Lyngsoe Systems different from the competitors?

What makes your product unique compared to other products?

- What are new with your solution?

How did you choose the company that were going to test the pilot product?

- Specific criteria?

How do you think this product can affect the supply chain processes in your customer's warehouse?

- Effect on the information flow?

What is the cost of developing the RFID antenna?

- What does an RFID tag cost?
- What is the associated cost of using RFID tag?

Interview 6 & 7:

Product

Can you please explain the processes of how the automated verification system work?

- What are the advantages and disadvantages of using this product?
  - Expense? Size? Range? Identification capability?

What did LS want to achieve with this product development?

- Did you set some specific goals?
- If, have you reached any of this?

What do you think is needed in order to succeed in launching a new product?

What do you think make Lyngsoe Systems different from the competitors?

What makes your product unique compared to other products?

- What are new with your solution?

How did you choose the company that were going to test the pilot product?

- Specific criteria?

What are the specific value drivers for implementing the automated solution and hereby filling the gap between Warehouse Management Systems and Transport Management Systems?

How can the state of art of RFID solution improve the performance for the customer satisfaction?

What do you think is the value driver for the customers to implement your solution?

- What benefit can they gain?
- Do you think this can improve the customer satisfaction for the end customer? If yes, could you please explain?

How do you think this product can affect the supply chain processes in your customer's warehouse regarding time consumed, errors, productivity, effectivity?

- Effect on the information flow?

RFID

What is new with the RFID tags you use compare to previous RFID tags?

- Do you use active or passive responders, or both? Semi-active?
- If passive, how do you power supply to passive transponders?

From how long range can the RFID antenna receive signals from the RFID label products?

- What kind of frequency do you operate with?
- What is the operating frequency of your operating tag?
  - Ranging from 135 kHz long wave to 5,8 GHz in the micro wave range
  - What are the achievable range of the system?
  - What are minimum and maximum?

What do you see as the next development in RFID?

- Is it a good time to implement now or better to wait?

How can the new RFID technology influence the supply chain structure in the sports warehouse industry?

How can the new features of RFID create value for the supply chain?

- Can the structure be influenced or changed?
  - With this we mean if you can skip some links / cut out some links in the value chain or if more steps can be added?

Cost and price

Did you conduct cost analysis before developing the product?

- How is the cost of developing such product compared to previous?
- Do you know why the cost of using RFID tags decreased?

What is the cost of developing the RFID antenna?

- What does an RFID tag cost?
- What is the associated cost of using RFID tag?

How is the market you are operating in?

- Competition?

What are the most common reasons why companies implement RFID?

Are the customers satisfied with the RFID antenna?

- What kind of feedback have you received?

Is the product easy to use?

- Do one need much training?

Interview 8:

Can you identify potential errors in the fulfilment process?

- Which type of error occurs?
- Where in the fulfilment process do they occur?
- How many errors occurs on monthly basis?

What are the specific value drivers for implementing the automated solution and hereby filling the gap between Warehouse Management Systems and Transport Management Systems?

What are the value drivers behind implementing the RFID solution?

What is the cost of correcting these errors?

- Subsequently what are the benefits of correcting them?

Can errors be removed by implementing RFID technology?

- Which can be removed, and which cannot?

Have the RFID implementation improved the operation?

- Cost efficiency?

How many packages in average are sent from the warehouse pr. month?

- How many packages in average are sent to the wrong address?
- How many packages in average were sent to the wrong address before you started to use the ASV and RFID solution?
- What is the cost of correcting misplaced deliveries?

10.3 Appendix 3: XXL Reading at Gates Test Report

(Provided by Lyngsoe Systems 2019)

XXL Reading at Gates Test Report

XXL Sport & Vilmark, Norway, W14 2019

REVISIONS

Revision no.	Date	Author	Changed pages	Description of change
1	2019-04-06	FVN		Created

CONTENTS

1 INTRODUCTION

The portal reader test was performed at XXL Sport, Jessheim, Norge, on April 3-4th, 2019.

The purpose was to test the read performance of the portal reader on the location with the right tags and packet/bags. The packets/bags were placed on pallets or in roll cages ready for shipment.

Participants:

- Vaidotas Klumbys, XXL
- Flemming Nygaard, Lyngsoe Systems

2 TEST SETUPS

2.1 RTLS Portal reader Setup

The portal reader LS4510 was mounted hanging 265cm above ground.
The reader was started and the pallet/roll cage with packets or bags was driven under the portal.
Workers moving the pallet under the portal are expected to pass the portal in the same pace that they normally to, when they move pallets around e.g. not in a very slow or very fast pace. This is also what is done in the testing, except in the cases where it is explicitly mentioned, that a different scenario was done.
LS Edecs SW was used to measure the read rate on a PC.

Figure 1. Portal reader.

3 TEST RESULTS

3.1 Boxes in cages

3.1.1 Test Results - Reading test 1

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 61 boxes
Test runs: 10

Test	Test setup	Description	Tags	1	2	3	4	5	6	7	8	9	10	AVG %
1	1	Roll cage driven under portal	61pcs.	61	61	61	61	61	61	61	61	61	61	100

Figure 2. Reader test 1

The measured read rate of passive RFID tags is 100%.

3.1.2 Test Results - Reading test 2

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 46 boxes
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	46pcs.	46	46	46	46	46	100

Figure 3. Reader test 2

The measured read rate of passive RFID tags is 100%.

3.1.3 Test Results - Reading test 3

Power setting in reader: 85%.
Population estimate: 200
CH:2
Test items: roll cage with 46 boxes
Test runs: 4

Test	Test setup	Description	Tags	1	2	3	4	AVG %
1	1	Roll cage driven under portal	46pcs.	46	46	46	46	100

Figure 4. Reader test 3

The measured read rate of passive RFID tags is 100%.

3.1.4 Test Results - Reading test 4

Power setting in reader: 85%.
Population estimate: 200
CH:2
Test items: roll cage with 61 boxes
Test runs: 4

Test	Test setup	Description	Tags	1	2	3	4	AVG %
1	1	Roll cage driven under portal	61pcs.	61	61	61	61	100

Figure 5. Reader test 4

The measured read rate of passive RFID tags is 100%.

3.1.5 Test Results - Reading test 5

Power setting in reader: 85%.
Population estimate: 200
CH:2
Test items: 2 roll cages, with 46 boxes and 61 boxes
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	107pcs.	107	107	107	107	107	100

Figure 6. Reader test 5

The measured read rate of passive RFID tags is 100%.

3.1.6 Summary boxes in cages

The measured read rate of the passive RFID tags on boxes in total for all measurements in the 5 tests was 100%. For both 85% and 100% power.

3.2 Bags in cage

3.2.1 Test Results - Reading test 6

Power setting in reader: 75%.
Population estimate: 200
CH:2
Test items: roll cage with 160 bags
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	160pcs.	158	157	156	158	157	98,25

Figure 7. Reader test 6

The measured read rate of passive RFID tags is 98,25%.

3.2.2 Test Results - Reading test 7

Power setting in reader: 85%.
Population estimate: 200
CH:2
Test items: roll cage with 160 bags
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	160pcs.	158	157	155	158	158	98

Figure 8. Reader test 7

The measured read rate of passive RFID tags is 98%.

3.2.3 Test Results - Reading test 8

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 160 bags
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	160pcs.	158	158	156	158	158	98,5

Figure 9. Reader test 8

The measured read rate of passive RFID tags is 98,5%.

3.2.4 Test Results - Reading test 9

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 160 bags
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	160pcs.	158	159	159	159	159	99,25

Figure 10. Reader test 9

The measured read rate of passive RFID tags is 99,25%.

The tags were moved to another cage and the test was preformed again, after that we moved the bags one by one and find the bags that was not read. The root cause was that there was a metal layer on the plastic bag inside the bag.

Figure 11. Bag with metal foil

3.2.5 Test Results - Reading test 10

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 270 bags and 140 test tags
Test runs: 3 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	410pcs.	392	95,6
2	1	Roll cage driven under portal	410pcs.	401	97,8
3	1	Roll cage driven under portal	410pcs.	402	98

Figure 12. Reader test 10

The measured read rate of passive RFID tags is 98%.

3.2.6 Test Results - Reading test 11

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 270 bags and 140 test tags
Test runs: 3 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	410pcs.	371	90,5
2	1	Roll cage driven under portal	410pcs.	401	97,8
3	1	Roll cage driven under portal	410pcs.	407	99,3

Figure 13. Reader test 11

The measured read rate of passive RFID tags is 99,3%.

3.2.7 Test Results - Reading test 12

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 270 bags and 140 test tags
Test runs: 3 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	410pcs.	394	96,1
2	1	Roll cage driven under portal	410pcs.	404	98,6
3	1	Roll cage driven under portal	410pcs.	404	98,6

Figure 14. Reader test 12

The measured read rate of passive RFID tags is 99,6%.

3.2.8 Test Results - Reading test 13

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 270 bags and 140 test tags
Test runs: 2 runs without clearing the buffer and with 5sec stop under portal

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	410pcs.	406	99
2	1	Roll cage driven under portal	410pcs.	407	99,3

Figure 15. Reader test 13
The measured read rate of passive RFID tags is 99,3%.

3.2.9 Test Results - Reading test 14

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 270 bags and 140 test tags
Test runs: 2 runs without clearing the buffer and with 5sec stop under portal

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	410pcs.	406	99
2	1	Roll cage driven under portal	410pcs.	407	99,3

Figure 16. Reader test 14
The measured read rate of passive RFID tags is 99,3%.

3.2.10 Test Results - Reading test 15

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 270 bags and 140 test tags
Test runs: 2 runs without clearing the buffer and with 5sec stop under portal

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	410pcs.	406	99
2	1	Roll cage driven under portal	410pcs.	406	99

Figure 17. Reader test 15
The measured read rate of passive RFID tags is 99%.

3.2.11 Test Results - Reading test 16

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer
CH: 1,2,3,4

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	417	99,3
2	1	Roll cage driven under portal	420pcs.	418	99,5

Figure 18. Reader test 16
The measured read rate of passive RFID tags is 99,5%.

3.2.12 Test Results - Reading test 17

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	417	99,3
2	1	Roll cage driven under portal	420pcs.	417	99,3

Figure 19. Reader test 17
The measured read rate of passive RFID tags is 99,3%.

3.2.13 Test Results - Reading test 18

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	415	98,8
2	1	Roll cage driven under portal	420pcs.	416	99,1

Figure 20. Reader test 18
The measured read rate of passive RFID tags is 99,1%.

3.2.14 Test Results - Reading test 19

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	413	98,3
2	1	Roll cage driven under portal	420pcs.	416	99,1

Figure 21. Reader test 19
The measured read rate of passive RFID tags is 99,1%.

3.2.15 Test Results - Reading test 20

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	411	97,9
2	1	Roll cage driven under portal	420pcs.	416	99,1

Figure 22. Reader test 20
The measured read rate of passive RFID tags is 99,1%.

3.2.16 Test Results - Reading test 21

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	413	98,3
2	1	Roll cage driven under portal	420pcs.	417	99,3

Figure 23. Reader test 21
The measured read rate of passive RFID tags is 99,3%.

3.2.17 Test Results - Reading test 22

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 2 runs without clearing the buffer, with slow speed under portal

Test	Test setup	Description	Tags	1	AVG %
1	1	Roll cage driven under portal	420pcs.	417	99,3
2	1	Roll cage driven under portal	420pcs.	417	99,3

Figure 24. Reader test 22

The measured read rate of passive RFID tags is 99,3%.

3.2.18 Test Results - Reading test 23

Power setting in reader: 100%.
Population estimate: 450
CH: 1,2,3,4
Test items: roll cage with 280 bags and 140 test tags
Test runs: 3, with slow speed under portal

Test	Test setup	Description	Tags	1	2	3	AVG %
1	1	Roll cage driven under portal	420pcs.	417	417	417	99,3

Figure 25. Reader test 23

The measured read rate of passive RFID tags is 99,3%.

3.2.19 Summary bags in cage

This scenario was tested in different conditions e.g. different configurations on reading equipment, and different user scenarios. It is evident that when high volume tags are needed to be read, the amount of time that the pallet is in the reading field, is the critical parameter. By configuring the system for high volume reads, it was seen that the first run below the portal, gives results that are close to the second or third run. The main difference between the different runs is the time which the tags are in the field.

The measured read rate for first run of passive RFID tags on bags in total for all measurements with different conditions: Fast speed under portal 98,7%, with 5sec. stop under portal 99%, Slow speed under portal 99,3%.

3.3 Boxes on pallet and cages

3.3.1 Test Results - Reading test 24

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: pallet with 100 boxes
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	pallet driven under portal	100pcs.	99	98	99	98	99	98,6

Figure 26. Reader test 24
The measured read rate of passive RFID tags is 98,6%.

The root cause with the one tag there not was possible to read was that there were chocolate bars with metal film around inside the box, when the box was move away from the tag on the box beneath the tag was readable.


Figure 27. Box with chocolate bars inside.

Figure 28. Not possible to read while bars on the tag

3.3.2 Test Results - Reading test 25

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 50 boxes
Test runs: 5

Test	Test setup	Description	Tags	1	2	3	4	5	AVG %
1	1	Roll cage driven under portal	50pcs.	50	50	50	50	50	100

Figure 29. Reader test 25
The measured read rate of passive RFID tags is 100%.

3.3.3 Test Results - Reading test 26

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 50 boxes and pallet with 100 boxes
Test runs: 4

Test	Test setup	Description	Tags	1	2	3	4	AVG %
1	1	Roll cage and pallet driven under portal	150pcs.	148	148	149	148	98,8

Figure 30. Reader test 26

The measured read rate of passive RFID tags is 98,8%.

3.3.4 Summary boxes on pallet and cages

The measured read rate of the passive RFID tags on boxes in total for all measurements in the 3 tests was 99.1%.

3.4 Boxes on pallet and cage and bags in cage

3.4.1 Test Results - Reading test 27

Power setting in reader: 100%.
Population estimate: 200
CH:2
Test items: roll cage with 50 boxes, pallet with 100 boxes and cage with 160 bags
Test runs: 3

Test	Test setup	Description	Tags	1	2	3	AVG %
1	1	Roll cage and pallet driven under portal	310pcs.	307	301	305	98,5

Figure 31. Reader test 27

The measured read rate of passive RFID tags is 98,5%.

3.4.2 Summary boxes on pallets and cage and bags in cage

The measured read rate of the passive RFID tags on boxes and bags in total for all measurements in the 3 tests was 98,5%.

4 CONCLUSION

The read rate for boxes is 98,5 to 100%, the read rate is only affected of the metal foil in the packets, so all in all the result is very good.

The read rate for bags in first run with different test conditions, fast speed under portal 98,7%, with 5sec. stop under portal 99%, Slow speed under portal 99,3%. In these tests is there 3 tag that has never been read, possibly caused by metal foil in the bags, so all in all also a very good result.

We have seen in the test that if the time in the field is increased, the read rate will also be increased, if there are many tags at same the time under the portal reader.

5 PICTURES FROM XXL SITE

5.1 Pictures of test items

Figure 32. Cage with 160 bags

Figure 33. Cage with 280 bags and 140 test tags

Figure 34. Cage with 61 boxes

Figure 35. Cage with 46 boxes

Figure 36. Pallet with 100 boxes

Figure 37. Pallet and Cages with total 310pcs. Of tags

5.2 Pictures of AVS area

Figure 38. AVS portal

Figure 39. Packet storage before AVS

5.3 Pictures from ski storage:


Figure 40. Ski storage 1


Figure 41. Ski storage 2

Figure 42. Marking on ski

5.4 Pictures from gates:

Figure 43. Gate from inside

Figure 44. Gate outside

Figure 45. Gate outside

10.4 Appendix 4: Notice period

(Provided by XXL Sport and Outdoor)

These numbers are from the first time XXL activated the automatic notification for delivery (5th of November 2018). The numbers in the table below illustrate the time the customer is notified by SMS that their package has arrived, and the time that the customer picks it up. As shown, the notification to the customer is sent out before 9 am in all cases. As we can see from the numbers, 14 customers picked up their packages before 3 pm and 3 more customers picked their packages up between 3 and 4 pm. Further, this may indicate that the customer appreciates getting the message early and that the customer can plan according to their working day.

Table: Time of SMS notification and pick up

SMS	08:47:10	Delivered	12:24:33
SMS	08:49:27	Delivered	13:10:25
SMS	08:44:13	Delivered	14:29:47
SMS	08:46:13	Delivered	12:52:33
SMS	08:51:07	Delivered	11:50:04
SMS	08:46:11	Delivered	10:27:15
SMS	08:49:47	Delivered	11:58:12
SMS	08:49:28	Delivered	12:02:09
SMS	08:46:27	Delivered	13:01:57
SMS	08:49:23	Delivered	10:29:12
SMS	08:46:18	Delivered	10:26:34
SMS	08:49:31	Delivered	13:59:02
SMS	08:49:38	Delivered	12:39:28
SMS	08:49:16	Delivered	11:33:07
SMS	08:50:10	Delivered	15:00:21
SMS	08:51:10	Delivered	15:27:49
SMS	08:47:12	Delivered	15:49:16