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FEASIBILITY OF RFID TECHNOLOGY IN THE SUPPLY CHAIN OF ABB MEDIUM VOLTAGE PRODUCTS

Master's Thesis in
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ABBREVIATIONS

ABB	Asea Brown Boveri
AFI	Application Family Identifier
ASN	Advanced Shipping Notice
AWFM	Agent-based workflow management
CMOS	Complementary Metal Oxide Semiconductor
COMM	Communications Software
EEPROM	Electrically Erasable and Programmable Read-Only Memory
EIPR	Effective Isotropic Radiated Power
EMF	Electricity and electromagnetic fields
EPC	Electronic Product Code
GLN	Global Location Number
GTIN	Global Trade Item Number
HF	High Frequency
ICNIRP	International Commission on Non-Ionizing Radiation ID Identification Protection
IEC	International Electrotechnical Commission
IFA	Inverted-F antenna
ISO	International Organization of Standardization
JIT	Just In Time
LF	Low Frequency
LLRP	Low Level Reader Protocol
MTO	Make To Order
MVP	Medium Voltage Products
RF	Radio Frequency
RFID	Radio Frequency Identification
RNC	Reader Network Controller
ROI	Return on Investment
PCB	Printed Circuit Board
PML	Physical Markup Language
SGLN	Serialized Global Location Number
SGTIN	Serialized Global Trade Item Number
SO	Smart Object
SSCC	Serial Shipping Container Code
SUID	Sub-UID
SWOT	Strengths, Weaknesses, Opportunities and Threats

UHF	Ultra High Frequency
UID	Unique Identification
VMI	Vendor Managed Inventory
WIP	Work In Progress
WROM	Write Once/Read Many
XML	Extensible Markup Language

VAASAN YLIOPISTO
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Tutkielman nimi: RFID-teknologian toteuttavuus ABB Medium Voltage Productsin toimitusketjussa

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TIIVISTELMÄ:
Tämä pro gradu tutkielma käsittelee RFID – teknologian soveltuvuutta ABB Oy Medium Voltage Productin toimitusketjussa. Tutkimus toteutettiin tapaustutkimuksena käyttäen sekä laadullisia että määrällisiä menetelmiä. Tutkimuksen taustalla vaikutti yritysten tarve kehittää ja tehostaa tuotantoketjun toimintaa. Jotta yrityksen toiminta säilyisi kannattavana tulevaisuudessa kiristyvän kilpailun vallitessa, on nykyisillä resursseilla kyettävä toimimaan entistä tehokkaammin. Tutkielman viitekehyksen perustana oli alaan liittyvä kirjallisuus sekä tieteelliset elektronisessa muodossa olevat ajankohtaiset julkaisut. Osa teoksista oli julkaistu jo monia vuosia sitten, mutta perusajatukset RFID – teknologiasta ovat pysyneet muuttumattomina.

Tutkimuksen tavoitteena oli selvittää RFID – teknologian toteutettavuutta ABB Medium Voltage Productsin toimitusketjun eri vaihessa. Lisäksi tuotiin esille erilaisia ehdotuksia siitä, miten RFID – teknologia voitaisiin käytännössä implementoida ABB:lle. Tavoitteena oli myös selvittää ja vertailla eri investointimahdollisuuksien takaisinmaksuaikoja toimitusketjun eri osissa. RFID – teknologian osalta pääajatus oli kuvata teknologia ensin yleisesti ja sitten tarkemmin yrityksen toimitusketjujen ja eri prosessien näkökulmista. RFID – teknologian käytännön sovelluksia ja toteutuneita projekteja löydettiin myös ja niitä etsittiin siksi, jotta voitaisiin huomata miten toiminta käytännössä tehostui.

Keskeisin havainto oli huomata, että RFID – teknologia ei ole välttämätä aina järkevä investointi. Vaikka teknologia vaikuttaisi ensialkuun tehokkaalta ja luotettavalta, löytyy siitä useita ongelmakohtia ja haasteita joihin on tulevaisuudessa löydettävä toimivia ja kustannustehokkaita ratkaisuja. Tulevaisuudessa olisi tärkeää tutkia miten RFID tunnisteet saataisiin inegroitua piirikortteihin sekä kuinka teknologian käyttöönotto tehostaisi ulkoisen varaston tarjoajan prosesseja.

AVAINSANAT: Toimitusketju, tehostaminen, RFID, hallinta, teknologia, tapaustutkimus, tunnistus, takaisinmaksu

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ABSTRACT:
This Master's thesis deals with the feasibility of the RFID technology in the supply chain of the ABB Medium Voltage Products. The study was conducted by a case study but both qualitative and quantitative methods were also used. The reason behind the research was the companies' need of develop and further streamline supply chain's functions. Current resources have to be able to utilize more efficiently in order that companies remain profitable when the competition is constantly increasing. The thesis's context was based on the literature and up to date academic journals. Some of the literature was published many years ago but the basic principles of the RFID technology have remained unchanged all these years.

The goal of this thesis was to find out the feasibility of RFID technology in the different parts of the supply chain of ABB Medium Voltage Products. In addition examples were presented that how RFID technology could be actually implement to the different parts of the supply chain in the most efficient way. The goal was also to find out and compare the investment's payback times in the different parts of the supply chain. When talking about RFID technology the main idea was to describe technology first in general and then more detailed considering the different parts of the supply chain. Practical examples of RFID technology were also found and therefore realized projects were looked for in order to realize how the operations actually become more efficient.

The main observation was to notice that RFID technology isn't necessarily a attractive investment. Although technology seemed to be a really efficient and reliable system at the first place there were several problems and challenges which have to be able to solve cost efficiently in the future. When considering the future research possibilities it would be important to research how to implement RFID tag in the Printed Circuit Boards and also how RFID technology would make the external warehouse provider's processes more efficient.

KEYWORDS: Supply chain, efficient processes, RFID, technology, case study, identification, payback time

1. INTRODUCTION

In today's world companies are trying to find out how to increase competitiveness, reduce costs and further improve efficiency. Competition is fierce and there is no time to be lost in order to make sure that everything necessary has been done. RFID (Radio frequency identification) technology plays an important role in the race. Thanks to RFID technology it is possible to improve efficiency, decrease the amount of manual work, reduce mistakes caused by manual work and also improve the customer satisfaction when for example delivery errors have reduced.

Accurate inventory records, errors eliminated during manual material handling and automation considering manual work are the reasons why ABB (Asea Brown Boveri) is interested to research the feasibility of RFID technology. Also traceability and real-time information is very important and the situation becomes even more challenging when volumes are large and goods move rapidly. Obviously for example buyers in supply chain, production foremen, operation managers must know the current warehouse situation in real time accuracy. Technological development has been very rapid during past decades and therefore even more sophisticated solutions are now feasible.

RFID technology has been widely researched and there are many real life applications in several business areas like medical care, asset tracking, warehouse management and retail. RFID technology applications can be categorized into following areas: Animal detection, aviation, building management, construction, enterprise feedback control, fabric and clothing, food, health, library service, logistics and supply chain management, mining, museums, retailing and waste management. Operational efficiency related to supply chain management can be achieved by RFID because it gives ability to have real-time information and visibility. However there is still confusion how to actually implement RFID applications to the real life environment. (Ngai et al. 2010)

A RFID reader, a RFID tag and an information managing computer are the basic elements of an RFID system. A radio frequency transceiver module contains transmitter and receiver. RFID reader consists of a signal processor and controller unit, a coupling element (antenna) and a serial data interface and together with transceiver module they form an RFID reader. (Lehpamer 2012: 131) RFID is an identification technology which captures data and then forwards the information for example to the company's

information systems. There is no need for direct line of sight because of the radio waves and it is also possible to read multiple tagged items at the same time. EPC (Electronic Product Code) is required by the EPC global standards which makes possible to uniquely identify products. (Sarac, Absi, Dauzere-Peres 2010: 77-78)

The theory part in this study considers RFID system's technical and operational principles as well different possibilities and achievable possible cost savings what RFID technology can achieve when it is up and running. Empirical part of the study is conducted by analyzing possible implementation solutions. Companies are keen to find solutions that how to track shipments and pallets in the supply chain. RFID technology offers a viable option to detect and track items and also diminish and improve material flows in the warehouse operations.

RFID system has been very important and revolutionary technology for many companies around the world. Several companies are responsible for transporting billions of shipments to wholesalers and retailers. Tracking, controlling and maintaining the warehouse levels are a vital part of the day-to-day operations. RFID tags offer same kind of capabilities as a bar code but it is much more adaptive and efficient. RFID is a radio device which means that it can be read while the item or pallet is moving. Line of sight is not required while reading the tags and it is possible to store all kind of information to the tags especially when comparing it to the bar code. For example the retailer can track the movements of a single shipment. RFID is not a totally new system but the development of the radio waves, transistors and microprocessors have transformed it into a very potential technology. (Deal, III, Walter F 2004: 23-24)

RFID based identification system makes possible to achieve following features:

- Possibility to diminish inventories
- Faster and more accurate tracking and traceability of the shipments
- Reduced operation costs
- More efficient warehouse management
- Better traceability of the WIP (Work In Progress) products and inventories
- More transparency to the supply chain activities and JIT (Just In Time) shipments (Mehrjerdi, Yahia Zare. 2011: 112)

1.1 Research questions

The goal in this research is to find out the feasibility of a RFID based material identifying and logistics system in ABB MVP (Medium Voltage Products). Another important question is to find out that what is the cost saving potential in case of all the different supply chain processes. Right now ABB MVP is about to implement RFID technology to inbound logistics by using pallet RFID tags. Investment decisions are taken into a consideration during the whole research process. The research questions are following:

1: Is RFID technology feasibly in the case of ABB MVP in Finland?
2: Where in the supply chain RFID technology would give the best benefit?
3: What would be the possible cost savings after RFID technology is implemented?

Supply chain means in this case the following sections: supplier, external warehouse provider, inbound logistics, production, kanban, unit packing and final packing. A future vision is to attach tags in every single PCB (printed circuit board). It is important find out feasible RFID technology solutions related to different sectors of supply chain, what kind of cost savings and investments are needed and finally how to actually implement it.

1.2 Case study company

ABB is one of world largest manufacturer of power and automation technologies. Its headquarters is located in Zurich, Switzerland and it operates in about 100 countries and employs 145 000 people. Stock exchanges in Zurich, Stockholm and New York trade ABB's shares. There are five different operational divisions which are power products, power systems, discrete automation and motion, low voltage products and process automation. ABB Finland's turnover in 2012 was 2,36 billion Euros and received orders were 2,47 billion Euros. ABB employees about 6600 people in Finland mostly in Helsinki, Porvoo and Vaasa. (ABB 2013a)

MVP is part of the Power Products - division. MVP is responsible for producing and developing control and protective relays for the medium voltage network applications.

Considerable amount of medium voltage networks around the world are controlled and protected by the Finnish made protective relays. In case of an error situation protective relays detects an error, then relays the information forward and therefore protects equipments and also human lives. Electrical network will also work without any stoppages. MicroSCADA system is also developed in Finland which is vital equipment for industry and energy companies that possible errors and malfunctions are detected rapidly. Nowadays electric grids are so complex systems that monitoring, controlling and protection systems are very important. Therefore protective relays are becoming more and more automated. (ABB 2013b)

Picture 1. ABB Protection relay (Directindustry)

ABB in Finland has been integrating protection and automation into the same package since 1980s. MVP in Vaasa is also responsible for global developing and marketing of protective relays and also automation systems. (ABB 2013b) About 90 % of the products are exported and there are sales offices more than 70 countries. Manufacturing of the products in Vaasa is based on MTO (Make To Order) which means that the order has to be received before the assembly of the specific product can begin. There are also thousands of different variations around which the customer can order. The products are concentrated in several product families and the Relion family is the latest generation. Relion product family consists of 630 series, 615 series, 611 series and 610 series. There is a 630 series protective relay in the picture. Services for installed base are offered to every delivered protection relays family and technical product support makes sure that there are services available through the whole life cycle. (ABB General presentation material)

1.3. General structure and scope of the research

Scope of the research includes following supply chain processes. Inbound logistics, kanban, assembly, final packing and unit packing. Theoretical part of this research begins with a brief overview of the history of RFID technology which is then followed by introduction to the basics of supply chain. The most important theoretical part of this study is the technological review. All the basic operational principles and functions of the RFID technology are introduced together with different standards. After technology review several real life examples of RFID technology implementations are analyzed. There are several examples of significant improvements achieved by a successful implementation of RFID technology. Finally there is also a chapter about critical review of RFID technology related to security and technical issues.

Empirical part is based on the following sections. First of all the current supply chain processes are briefly described in order to see the general view and all the different stages which are related to it. Information has to be gathered in order to fully understand the current situation at ABB MVP. Process descriptions, observations, interviews and ABB's own databases are the ways to gather information. Process descriptions give the basic idea of how processes really work at the factory but observations need to be done in order to fully understand everything. Observations of the processes are conducted by walking in the factory, taking notes of the processes and finally analyzing them. Workers are also interviewed at the same time when making observations. By discussing with people responsible for the supply chain processes, it is possible to find out the real problems and issues. SAP and delivery error database are both a significant source of information but interviews also offers significant contribution so that there are enough amount of material to make reliable investment calculations.

The next step is to decide how to actually implement RFID technology in order it would improve the processes so that cost savings could be possible to achieve. SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is used to provide information and perspective that what will be the true benefits and threats if the RFID is implemented at specific process. Based on payback time calculations the payback time can be determined at every process and therefore the feasibility of the RFID technology is found out. It has to be remembered that those calculations are just estimations which leaves room for inaccuracies. The payback calculation method, which was used in this study, didn't take into account the interest rate. After the analyses and calculations and the following conclusions are done, it is then possible to compare all of the five

processes and draw the conclusion that where and RFID technology would be feasible to implement and where not.

1.4. Research methodology

This research is case study and it contains elements from both quantitative and qualitative research methods. Gathered data and payback time calculations form the basis of quantitative analysis. Data is gathered from SAP, delivery error database and process descriptions. Interviews, SWOT analysis and observations are both qualitative research methods. Interviews are conducted by interviewing both blue and white collar workers whereas observations were done by walking around the factory and writing notes at the same time. Theoretical framework is based on researches published in the academic journals, RFID technology literature and also articles from RFID Journal. Source literature is used as a primary source first to introduce RFID technology. Both academic journals and articles from RFID journal are then used to provide more details about examples of real life RFID technology implementations and what kind of benefits and improvements it will offer. In addition GS1 standards are introduced by using official web sources.

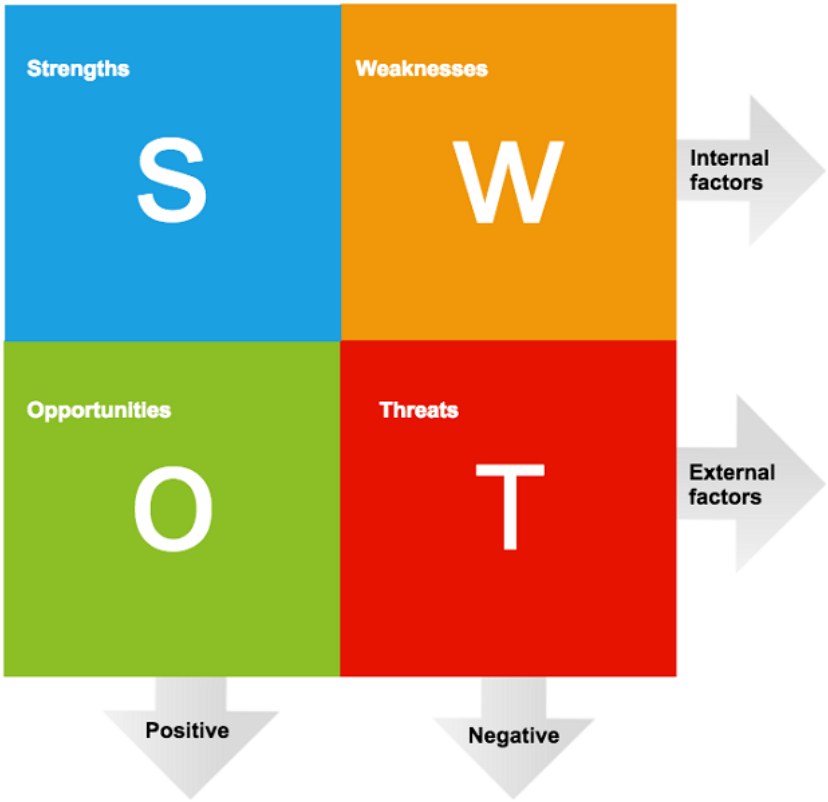
In a case study research there is often either one or several cases. Interviews, surveys and observations are important methods to gather either quantitative or qualitative information. The actual research process can be descriptive, theory building or theory testing. It is possible that a case study doesn't find anything new or revolutionary but the research process can bring out new and important beliefs considering the surrounding world. The case study answers to how and why questions so that it would be possible to explain cause and effect relationship and chain of events. The case study can also answer to what question as well as to be evaluative and descriptive research. There are some critique against lacking discipline, the difficulty of making generalizations and all the skills required by the researcher. (Järvinen & Järvinen, 2000: 78 – 82)

The research is based on theory which assumes that RFID technology will offer improvements over the current processes and increase efficiency and offer other important financial benefits. Observations and interviews conducted at ABB MVP in addition to quantitative analyses are used to find out evidences if the RFID technology could offer feasible solutions in order to gain savings and improve productivity in a case

of ABB MVP. Results from previous studies are used as examples that what kinds of improvements can be really achieved after RFID technology is successfully implemented. The cause and effect relationship, which is considered to be typical for case studies, is represented at the empirical part of this study because the specific payback times are achieved after a certain amount of investments have been made.

Observation tells what actually takes place and it reveals how people actually act. Because observation is a laborious effort, surveys and interviews are currently more popular research methods. Observation makes possible to gather direct and immediate information about how people act or behave. It is truly real world research and is also one of the qualitative research methods. Criticism have been made that observer might disturb the prevailing circumstances and how things take place. The presence of the observer might have an impact on the behaviour of the people who are being observed. Observing is also time consuming and there are also ethical problems concerning the amount of information what the examinees know about that they are being observed. There are two kinds of basic observation methods which are systematic and involved. Systematic observation is organized and the observer is an outsider. In the involving observation the observer is a part of the group and everything is freely adjustable. (Hirsjärvi, Remes, Sajavaara 2013: 212-216)

SWOT analysis is a way of build up different kind of strategies and people from corporate and business unit level can use an implement it effectively. SWOT analysis is very useful in situations but a challenging and tricky situation which demands actions and analyses, but when there is not much time available. SWOT is basically about dividing the situation of the company into a internal and external analyses. Internal analysis is about rating of the possible internal strengths and weaknesses, for example company culture, structure and image, important staff, operational efficiency and capacity, financial capabilities and possible patents. The idea is to have an overview considering company's internal factors and issues. (Kotler, Keller, 2006: 52, NetMBA)



Picture 2. (Thinkmarketing)

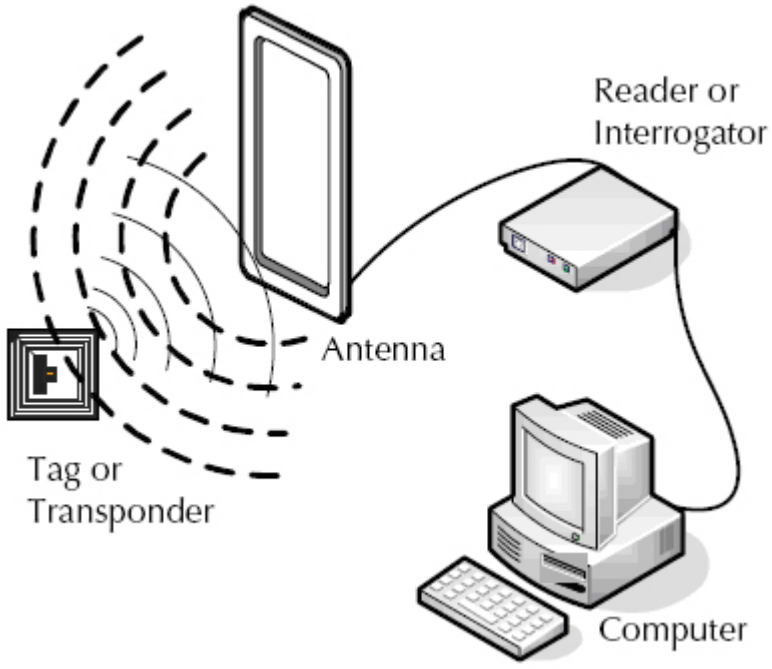
External environment analysis includes opportunities and threats. Macroenvironment force consists of for example demographic economic, natural, technology, social-cultural and political-legal factors. Forces affecting on microenvironment are customers, competitors, suppliers, distributors and new technology Companies have to be aware of the changes concerning macro and microenvironment factors because they have a clear effect on the financial performance of the company. After the data has been collected, the result is a SWOT profile which gives guidelines how to achieve goals, build strategy and finally how to implement it. Usually the data is collected by conducting interviews but the quality of the analysis can be improved radically if there are numerous stakeholders to be interviewed, like for example employees, suppliers, customers and partners. The problem in SWOT is that it usually makes the situation to appear more straightforward than it really is because the categorization of the environment made in SWOT doesn't necessarily match with the reality. Also depending on the point of view, a factor can be at the same time either threat or opportunity. (Kotler, Keller, 2006: 52, NetMBA)

Payback is the amount of time after the investment has paid for itself. The difference of the net cash inflows affects on the calculation of the payback period. The problem of the payback period method is the definition of payback period which is related to the time. It means the cash flow only during the payback period, not after that. If the project creates money after it has paid back the original investment cost, payback period method doesn't include these profits. It just reveals the time period when and how fast the project has generated money, not profitability. If other factors are identical, then the project which has the shortest payback period is the best choice. Companies usually reject investments which take too long to pay back the invested money. The payback period is just an indicative tool to compare different investments and eliminate investments which take too much time to be profitable. Therefore managers often use other tools in order to have enough information to make the final decision. (Horngren 2010: 514-516.)

$$\text{Payback period} = \frac{\text{Amount invested}}{\text{Expected annual net cash inflow}}$$

2. LITTERATURE REVIEW

RFID tags can be sorted as follow; Active tags has a battery that gives power to all the functions which the tag has, a semi passive tag has a battery which only gives power to the integrated circuit and a passive tag which doesn't have any battery at all. This means that passive tag is considerable cheaper than active tag and also more reliable. Nowadays tag designers face challenges in multiple tag standards, tag failure rates, installation and platform problems, need for cost-effective management, maintenance of readers, the need for smaller readers which could be fitted into structures and handheld readers, intellectual property protection and secure access control protocols. Also tag size, reader / writer antenna size, tag orientation and operating time, tag movement velocity, effect on metallic substance and metal items and multi-tag operations have an effect on the functionality of the RFID technology. (Lehpamer 2012: 131)



Picture 3. RFID system. (EPC-RFID)

Picture 3 presents a RFID system. It consist of tag, antenna, reader and a information system run by a computer. The whole system is seamlessly linked together. The two different RFID system categories are near-filed systems which works on inductive (magnetic) coupling of the transponder tag and far-field system which couples real power which is contained in free-space propagating electromagnetic plane waves.

(Lehpamer, Harvey. 2012. 132-142) Antennas used in LF (Low Frequency) and HF (High Frequency) bands are coil antennas which primary function is to increase inductance of the antenna and thereby increase magnetic absorption. UHF (Ultra High Frequency) bands require dipole antennas and they are usually folded so that electrical qualities are better. Both dipole and coil an antenna are made by printing and thereby costs are low. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 33-35)

By improving passive tag antenna, lowering tag costs and increasing reading distance passive tags could be much more popular than they are now. Passive tags need to hold a certain amount of energy inside to work properly and it has no internal power system so therefore it is important that the tag can absorb enough energy. The trend is towards smaller antennas and tags but the problem is then that small antennas are not so good radiators. Also frequencies has to be similar across the world that the same tag could be used anywhere. Fractal antennas in the tags are a potential solution to solve size issues because they are small and the design of the antenna is very adaptable. The antenna can be bent and convoluted and it also offers more radiation power to the tag to be absorbed. As a result small fractal antennas are much more powerful and useful when compared to the normal antenna solutions. (Lehpamer 2012: 167-168)

LF and HF bands are useful when the reading distance is short and thereby near-field technology is mostly used. Longer range UHF and microwave systems prefer far-field coupling technology where the distance is longer. Antenna, integrated circuit (chip) and both with complex impedances form together a normal RFID tag. RFID reader transmits RF signal and it gives power to the chip. Noise can cause problems to the performance of the communication systems. There are thermal, intermodulation, cross talk and impulse noise. Also environmental detuning effects have to be taken into a consideration because for example metallic surfaces can weaken RFID's efficacy. Several RFID tags close enough each others can also be problematic because of the mutual inductances. (Lehpamer 2012: 132-142)

Antenna in the RFID tag is an important part because it affects on reading range and durability. Unsuitable materials in the product or in the package where the tag is about to be attached are an issue because it causes tag reading problems. This affects especially on UHF antennas because of the shorter wavelength. When HF and UHF technologies are different it means that the antenna material has to be carefully thought. UHF antennas are vulnerable to the skin effect meaning that the antenna material needs sleek and clean surface. UHF antennas have a certain inductance value because of the

structure which gives impedance matching for the chip. That is why there is a high resolution design together with sharp edges. Oxides on the surface can also decrease the performance gradually because it increases surface resistivity. However it is possible to resolve resistivity problem by using conductive polymers. (Miles, Sarma Sanjay E, Williams 2008: 54)

The choice between HF and UHF frequency has to be made by thoroughly researching all the possible facts and factors. The distance and all kind of different choices where tag can be placed have to be also considered. Knowledge about objects movements during the whole supply chain are important to understand and obtain but it is very expensive to actually get that kind of specific data. The final decision is often based on the best knowledge which is not necessarily the exact truth. Pilot projects are a good choice if the decision has to made rapidly because different applications and technologies can be compared easily. Pilot projects are also inexpensive compared to more complex investigations and analysis. (Miles, et al. 2008: 58.)

2.1. The history of RFID technology

In the beginning of 1900 century the knowledge about electromagnetic energy and its opportunities grew significantly. Part of the research work done in that period of time also gave valuable information about RFID technology. Because of the Second World War radio and radar technology developed massively and after the war researches carried on studies developing different applications considering peace time requirements. RFID technologies were researched thoroughly and US Army began to implement RFID applications in airplanes in the 1950s. First commercial implementations were done by installing theft protection systems to the department stores during 1960s and at the same time the massive potential of RFID was noticed. (Hunt, Puglia & Puglia 2007: 26 – 27)

RFID technology grew massively and became more common during 1970s because companies, universities and government institutes started their own research programs. Big companies like Raytheon, RCA and Fairchild began to develop electronic identification systems and by the 1978 passive transponder was ready. Most of the research work was also done by the 1970s which was a very crucial milestone considering the future of RFID technology. New commercial applications became more common during 1980s and for example the first RFID based road toll system was

introduced in Norway 1987. The final commercial breakthrough happened in 1990s because the technology became so widely spread. Continuous development process meant that more and more companies were able to invest and consider RDIF technology because it became affordable but more research work was still vital that the costs could be reduced further on. (Hunt et. al. 2007: 27 – 28)

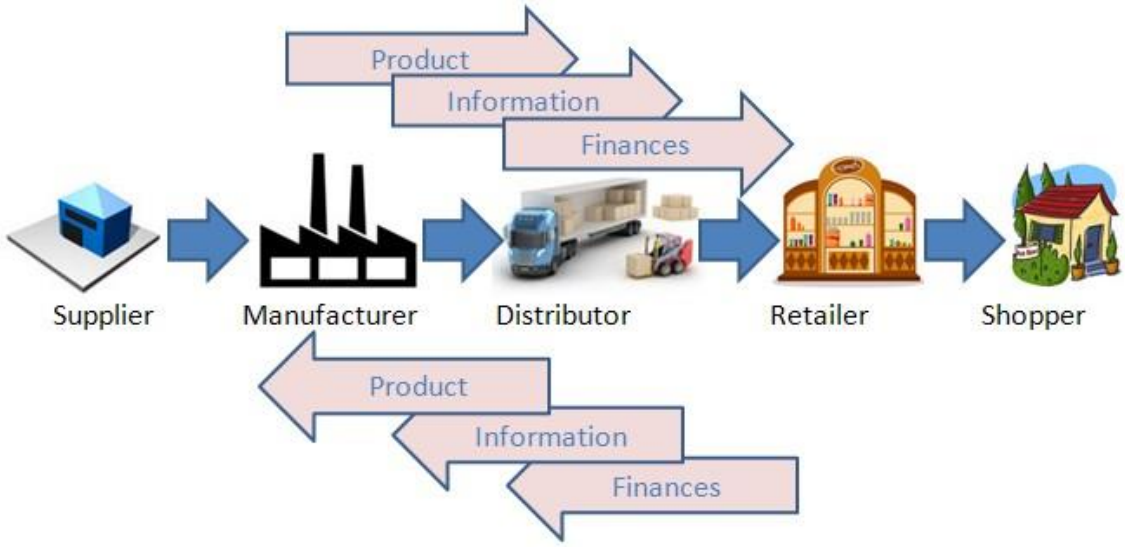
By the beginning of an new millennium it was very obvious that prices of an single RFID tags was possible to reduce into a few cents and even some day the barcode system could be replaced by the RFID technology. A significant milestone was Wal-Mart's decision to introduce RFID technology by 2005. Several other retailers have followed Wal-Mart's strategy like Target, Procter & Gamble and Gillette. RFID system suppliers have in that way a large customer base for upcoming orders and services. The overall costs were reduced and other companies are also considering to implement RFID technology. (Hunt et. al. 2007: 29)

First passive RFID tags were based on magnetic field and they used LF wave lengths to work. CMOS (Complementary Metal Oxide Semiconductor) technology made possible to develop passive tags. However the problem in LF tags was the high price of the coil winding which made the tag very expensive. That was one of the reasons to develop HF (High Frequency) technology and the price of the tag was possible to lower by improving also the manufacturing process. Using HF wavelengths it was possible to raise the reading distance significantly compared to LF wavelengths. Nowadays HF frequency is used around the world and there are also several ISO (International Organization of Standardization) standards around it. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 12-14)

EPC (Electronic Product Coding) was invented because there was a need for a global numbering system. UHF (Ultra High Frequency) technology was known to have much longer read distance than HF. At the first UHF devices were not doing so well but in the beginning of 21st century HF technology became a proven solution. Walmart began wide RFID test and they wanted UHF RFID tags in their shipments. After Walmart's decision UHF technology became very popular and several pilot projects were launched around the world. However at the beginning UHF readers were expensive and many of those were also rather unreliable. In the mobile phone industry NFC (Near Field Communication) technology has become almost a standard feature for mobile phones. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 12-15)

2.2. Supply Chain.

Supply chain joins together the network of service, material and information flows of the company. Those factors are connected to customer relationship, order fulfilment and supplier relationship of its suppliers and customers. Depending on the products or services there might be several different supply chains inside a single company. Supply chain management is about strategy developing activities, controlling and motivating of the resources related to the movement of the services and materials. A supply chain strategy determines the form of the company's supply chain so that it meets the requirements and priorities of the company's operations strategy. (Krajewski, Malhotrja, Ritzman 2007: 372.)



Picture 4. Structure of the supply chain (Biz Development)

The logic of the supply chain is represented in the picture 4 where the flow of the products, information and money goes back and forth. The basic idea of the supply chain for a manufacturing company is to control the inventory through the material flow management. In a manufacturing company about 60 percent of the total sales income is spent on services and materials which are related to the production. Because of the large quantities of materials what manufacturing companies have to buy, it is easy to increase profitably by minimizing the costs of the purchased materials. Inventories are materials which are in stock in order to cope with the customer demand and also provide support to the production. Inventory levels depend on the level of input and output flow of materials. The scale of the scrap flow effects on the amount of usable material in the

inventory. For example low quality of the purchased materials causes scrap flow. (Krajewski et. al. 2007: 374-375)

Raw materials are required for the production of the materials in a manufacturing company. They are inputs for the company's production processes. WIP (Work-in-process) means usually components in the production line which are utilized to manufacture an end product. WIP inventories can also be found for example from service environment, such as repair shops, restaurants or package delivery centers. Finished goods are present in warehouses, factories or retailers which are ready to be sold to the customers. It has to be remembered that some finished goods can be other company's raw material. Customer relationship, order fulfillment and supplier relationship processes are closely related to supply chain. The state of each these internal processes have to be observed precisely like the whole supply chain. The state of the customer relationship is possible to monitor by analyzing order intake, order completion time and customer satisfaction. (Krajewski et. al. 2007: 376-379)

2.2.1 Inventories

Theoretically there would be no need for storages in a company if the demand of the products is well known beforehand and manufactured products could be shipped right away to the customer. Usually the demand isn't stable enough that companies could abandon inventories completely and also there are no solutions around which might offer constant, solid and absolutely reliable inventory replenishment all the time. That is why companies use inventories that the demand can be coordinated in a cost efficient way. Warehouse and material handling costs compensate the costs caused by transportation and purchasing activities. Companies are protected against fluctuation of the demand by having inventories and also the transportation costs are lower because inventories make possible to use much larger and thereby cheaper shipping quantities. (Ballou 1999: 245-246)

There are four main reasons why companies want to keep storages. First they want to minimize costs caused by transportation-production, secondly coordination of the supply and demand becomes possible and thirdly inventories help production and marketing processes. Fourthly seasonal products are problematic because the demand is difficult to forecast beforehand. Warehouses are a suitable solution when the supply and demand has to be coordinated. There are also products which need to be a certain amount of time in storage before the customers can buy them. For example cheeses or

wines have to be kept in warehouses for some time. When inventories are close to the customers, it's easy to offer fast and reliable deliveries which also affect on customer service and might even increase customer's sales. (Ballou 1999: 246-247)

Inventory holding and materials handling are the two significant reasons for the storage system. Loading, unloading, order picking and moving of the products are all material handling activities where the storage of the materials means that items are kept in a warehouse a certain amount of time. Holding and protection of the inventories are the most common reasons for having a warehouse. Warehouses can be for example long-term storage, general-purpose warehouses or just short-term storage depending on the type of the products. Consolidating is useful when there is need to merge small shipments into a single large shipment which decreases transportation costs. A warehouse is an important place where the shipments can be reorganized correctly. Break-bulking is also used when there is more inbound than outbound movements of the shipments and customers require small quantities. Finally storages can be utilized to efficiently mix shipments together if customers order products from several different manufacturers. (Ballou 1999: 248-249)

2.2.2. Utilizing Vendor Managed Inventories system

VMI (Vendor Managed Inventory) has been considered a long the best way to integrate the supply chain functions together. It's also an effective way to reduce bullwhip effect on warehouses and inventories. The idea of VMI is to remove factors which could cause variability and offer enhancement. A manufacture company orders items in the traditional supply chain without giving any further information about their material needs. The supplier and purchaser then operate independently by adjusting their own operations without knowing anything what the others might be doing at the same time. This kind of operations strategy is very expensive and ineffective when everyone are speculating what the final outcome could be. (Niranjan, Wagner, Tahkur-Weigold 2011: 40)

Customers have to be willing to let suppliers to have access in their systems in order that VMI implementation becomes successful. There also has to be enough trust and confidence between the companies. VMI implementation cut costs down because administration work, order making process and inventory levels can all be reduced. Response time and stockout are increased which has a significant impact on customer service. Written agreement makes sure that everyone knows the upcoming

responsibilities. For example specifying billing instructions, what to do with obsolete inventories, how to make contracts and forecast strategies and when inventories should be replenished. (Krajewski et. al. 2007: 387)

VMI is a revolutionary way of improve supply chain because now suppliers are able to see the actual demand and inventory levels of the customer which thereby helps supplier to adjust the order quantities correctly. There is no need to do purchase orders or uncertain production plans anymore when the information is easily available for the vendor. However it's a well-known fact that VMI is not the best choice for every company because the unique characteristic of company, product and supplier determines the final outcome. There has to be a sufficient amount of trust between the different functions that the VMI would actually work and be effective. Suppliers seek to integrate their important customer to the supply chain based on the sales figure percentages. All the products must be standardized and replenished frequently and the demand should also be stable. (Niranjan et al. 2011: 40)

In a study the evaluation was done by researching four different companies in Switzerland about their readiness to implement VMI and how it would effect on the performance of those companies. The first case company was an aerospace company RUAG which manufactured products by using built-to-order strategy. However because of the small and unstable volume of the required materials there was no need to implement VMI of its suppliers. In the second case the Swiss sportswear brand ODLO used VMI with suppliers and customers because the availability is improved together and sales loss diminish although complex master data causes issues with the supply chain partners. The third case company Novartis, which is a manufacturer of pharmaceutical products, utilized VMI very effectively in its operations which meant that the company could now focus only on core processes when the VMI handled the routine processes. Novartis' suppliers were given access to the data which helped their own planning work significantly. The last case was about Procter & Gamble which used VMI to a part of the consumer response service. It was all about optimization of the supply chain logistics according to specific sales data. (Niranjan et al. 2011: 42-44)

2.2.3 Supply chain strategies

Insufficient supply chain coordination causes significant losses when the managers don't have the understanding about the demand of their company's products. It reflects into the supply chain strategy planning and decision making if the demand can't be

satisfied. There are two different designs which companies can utilize in order to get competitive advantage. Those two strategies are efficient and responsive supply chain. Efficient supply chain is the best choice for companies which demand is very predictable. The idea is to keep inventory levels low and have efficient material flows. The most important factors are low-cost operations, stable quality and on-time deliveries. Responsive supply chain gives the best results in changing environment where the demand fluctuates constantly and thereby quick decisions are needed. Without effective development activity, fast delivery times, variety, customization, volume flexibility and high quality it would be impossible to be constantly competitive. (Krajewski et. al. 2007: 395)

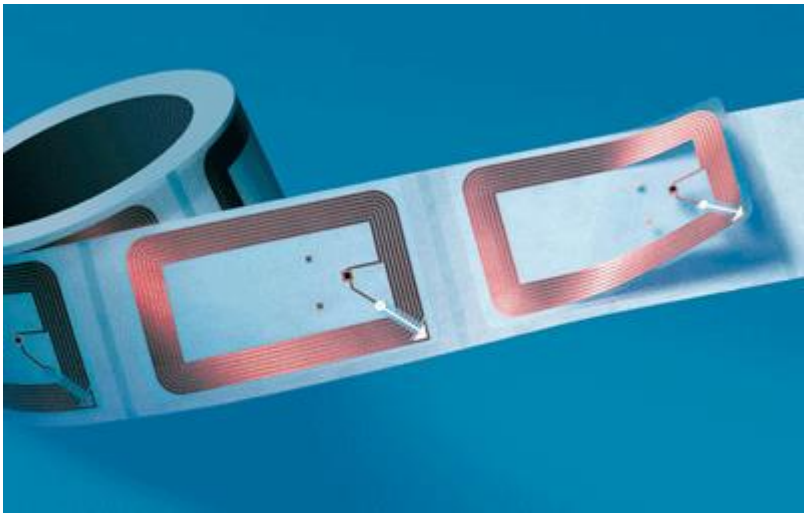
It's possible that companies are forced to combine both efficient and responsive supply chains in their operations. It can happen if there are specific market segments or supply chain is possible to be divided and segmented according to different requirements. Line-flow strategy is most likely in companies which have high volumes and standardized products. Therefore efficient supply chain requires suppliers which have small buffers because it cut downs unit cost. Short lead times are very important but extreme actions should be avoided in order to cut down lead times because in the worst case scenario costs might also increase. A responsive supply chain has to be flexible and possess large buffers. Delivery speed is improved by WIP inventories but expensive finished goods lying in warehouses are not economically sustainable. Reducing lead times is important because it gives more time to do decision which increases flexibility. Rapid deliveries, customized service or components, high quality and ability to adapt changing demand are very important factors in the supplier selection process. (Krajewski et. al. 2007: 397)

2.3. RFID tags

There are several kinds of RFID tags at the market today. Read range depends on several matters and there are also engineering trade-offs which also have an effect on read range. Frequency of RFID system, power of the reader and all other RF (Radio Frequency) devices has to be taken into a consideration when determining read range. Following requirements are vital when the decision is made considering about the type of the tag. Regulations of the country determine the frequency band which has to be used. The size of the object determines how big the tag can be. It has to be small enough that it will fit where it has to be without causing any problems. Read range depends on the minimum required range where tag can still be read. Regulations of the specific

country also decide what the EIPR (Effective Isotropic Radiated Power) is. (Lehpamer 2012: 150)

The RFID tag is a kind of programmed data device and which consists a coupling element and a low-power CMOS (Complementary Metal Oxide Semiconductor) IC (Integrated Circuit). Then the IC chip consist an analog RF interface, antenna tuning capacitor, RF-to-dc rectifier system, digital control, EEPROM (Electrically Erasable and Programmable Read-Only Memory) and data modulation circuits. The basic idea behind RFID is its capability of contactless reading and writing of information in the RFID tag by using RF signal. The signal is emitted by the reader and data exchange happens when the tag is close enough to the reader. (Lehpamer 2012: 131)



Picture 5. Passive RFID tags on a roll. (Libramation)

In the picture 5 there is an example of passive RFID tags which can be attached to all kinds of different items. Objects around the tagged object can cause changes in the tag performance but it can be overcome by designing and adjusting tag's antenna so that the best result can be achieved. Reader's field is an important part of the read range and tag placement compared to the reader's field can cause issues to the reading distance. HF and UHF bands are affected on orientation of the tags. The best case is if the tags are parallel to each other. High and effective tag read rate might not be achievable in the rear field of RFID reader if the system is not fully adjusted to cope with the doppler effect. The cost of tags causes restrictions on antenna and materials. Temperature, humidity, label placing, printing and lamination are closely related to the reliability of the tag. Power of the tag is related to the tag type. The reader gives power to passive

tags, semi passive tags have power to the transmission from the reader and an active tag doesn't need any kind of power from the reader to work. (Lehpamer 2012: 152)

Picture 6. Different size of RFID tags. (Wikimedia)

Picture 6 represents the opportunities of RFID tag design. Read-only systems are very useful when expenses and energy consumption has to be low. It contains just a serial number which is then passed on back to the system. Because of their simplicity they can be used to replace bar codes. More expensive tags have logics and memory and thereby it is possible to remotely update and change data. Obviously the energy consumption increases when there are more and more sophisticated electronics. The microprocessor allows complicated algorithms, security and encryption to be executed seamlessly. Normally the information is printed to the read-only tags during the manufacturing process. (Lehpamer 2012: 152)

A Read-only tag usually consists of ID (Identification) number which is like a serial number. Read/write tags have also a feature which means that a tag can be identified from a large amount of tags around. Information to the WROM (Write Once/Read Many) can be written just once but it can be read repeatedly afterwards. It is a very useful when the information can be joined to the specific item compared to the situation when it has to be decided before a tag is even manufactured. Read/write tags means that

information can be written and changed afterwards if it is needed to do so. For example maintenance history can be seen very easily and also manufacturing processes can be changed to more flexible when the information is possible to be obtained smoothly. The data from the tags is also possible to save for the possible further analyses and use but the security factors has to be taken care if there are sensitive information floating around. Time to read is an important fact considering the design process of the RFID system. 1-kbps transfer rate means that 96-bit tag is read in 0,1 seconds. (Lehpamer 2012: 153-154)

2.3.1. Passive tags

When talking about passive tags it's important to notice that there is no power supply or a battery system in the tag. RFID reader sends an electrical current which then gives power to the passive tag and the information is then relayed back to the reader. The lack of internal power supply means that the transmission is rather limited and the range of transmission is shorter compared to the active tags. Usual implementations which have utilized passive tags are inventories, product shipping and tracking, hospitals and theft prevention systems. Silicon device (chip) and antenna circuit are the main components of a passive tag. Read range of a passive tag is closely related to the antenna circuit and its size. The antenna circuit consists of LC resonant circuit antenna which is determined by the carrier frequency. Frequencies less than 100 MHz are the most common ones in the case of LC resonant circuits. The magnetic coupling then makes possible the communication between the reader and tag. (Lehpamer 2012: 153-154)

The presence of an integrated power source is the main element of an active tag and in most cases it is a battery which means that the tag can work independently. If needed all kind of sensors and microprocessors and be embedded to the active tag. The information is able to be stored to the tag for possible later need. A battery in the active tag is about as big as a coin and it the transmission range is about 30 meters. Passive tags are much cheaper than active ones but amount of data what active tags can possess is much higher. The important feature compared to passive tags is that active tags can preserve information which was received from a transceiver at the first place. If there is a significant electromagnetic presence around active tags will still work without problems. However active tags are about 50 times larger than passive tags and are mostly used for tracking expensive equipments. (Lehpamer 2012: 157)

2.3.2. Active tags

There are two kinds of active tags on the market today; wake-up rag systems and awake tags. Wake-up tags are sleeping until a reader or interrogator sends a message. An awake tag doesn't need any message at all to become activated. They are also cheaper than wake-up tags because the data transfer rate and memory sizes are much lower. Thereby there is no need for a big battery unit. Passive tags are the best solution if there is a need for tracking continuing material flows which are also controlled and there is no need for high security or data recording. More dynamic and inconsistent material flows needing also storage capability and security require active tags. The prices of active tags are between 10 $ to even 50 $ when the passive tags are much cheaper, normally less than 1 $. (Lehpamer 2012: 159)

It is also possible to have integrated sensors in a RFID tag which means that sensors are able to reveal all kind of information for example about the conditions what the tagged item has encountered while moving through the supply chain. Usually tags don't have these kind of sophisticated functions at all. Conditions like for example temperature, vibration, chemicals and gases give all kind of vital information and it is possible to draw a conclusion is the product still in order and intact. In active tags the energy and battery power is not a problem but passive tags are more challenging ones because there is no internal battery. It is the reader which reads the information about all the data which tags sensors have gathered. (Miles, Sarma Sanjay E, Williams 61-63: 2008)

2.4. RFID readers

A reader is the part in RFID technology which interrogates tags information and then transfers it forward to the computers and systems. Passive tags require the energy field of the reader in order to work but active tags are more like transmitters because they transmit signal periodically. Antennas in the reader are for sending and receiving signals and data decoding is made by transceiver and a processor. It is not uncommon that there are several readers to cover every corner of the warehouses, stores and factories. Usually one reader uses just one radio frequency and if there are tags from different manufactures using different frequencies, then there has to be several readers around which increases costs. Handheld readers are normally used at terminals while fixed readers are located at store entrance or assembly lines. There is an example of a

handheld reader in the picture 7. The display and buttons of the reader makes it possible to perform all kinds of tasks and information is easily readable. (Lehpamer 2012: 172)

Picture 7. An example of a handheld RFID reader (Motorolasolutions)

Fixed readers are most effective while reading large volumes of shipments like for example near doors and entries where the material flow goes through. Every single tagged shipment which goes nearby is read if it within the range of the reader. Handheld readers are used mostly when there is a need to complement fixed readers. For example boxes can be read and identified by using handheld reader. Customer mandates are easily obtained in that way by handheld reader. Handheld readers are also practical situations when there are boxes which have failed to read at some point or there are misplaced labels. Inventory cycle counting can also be improved, especially if there is a need to find an exact item from the warehouse. Mobile RFID readers are the latest in the RFID reader category and those systems are cable-free, self-contained and equipped with battery, antennas and wireless communications capabilities. It is possible to place mobile readers to forklifts, clamp trucks, skate wheels or on mobile carts. Mobile readers can move near to the item which has to be read what fixed readers can't do. Handheld device work using the same principle as mobile readers but mobile readers can be operated hands-free. (Lehpamer 2012: 173)

Reader is often just a read-only device but an interrogator can also read and write. Interrogator communicates with tag by command pulses. Reader's price is closely related to its features and complexity. The carrier is used to transmit radio signal of the reader and it gives energy to the tag and picks up modulation data. Interrogator's information is transferred back to the tag by using carriers as a middleman. RF carrier generator, an antenna and a tuning circuit form together the RF transmission section while data decoding is done with microcontroller. RF signal transmission, incoming data decoding and communication with host computer is done by the firmware algorithm in the microcontroller. (Lehpamer 2012: 173)

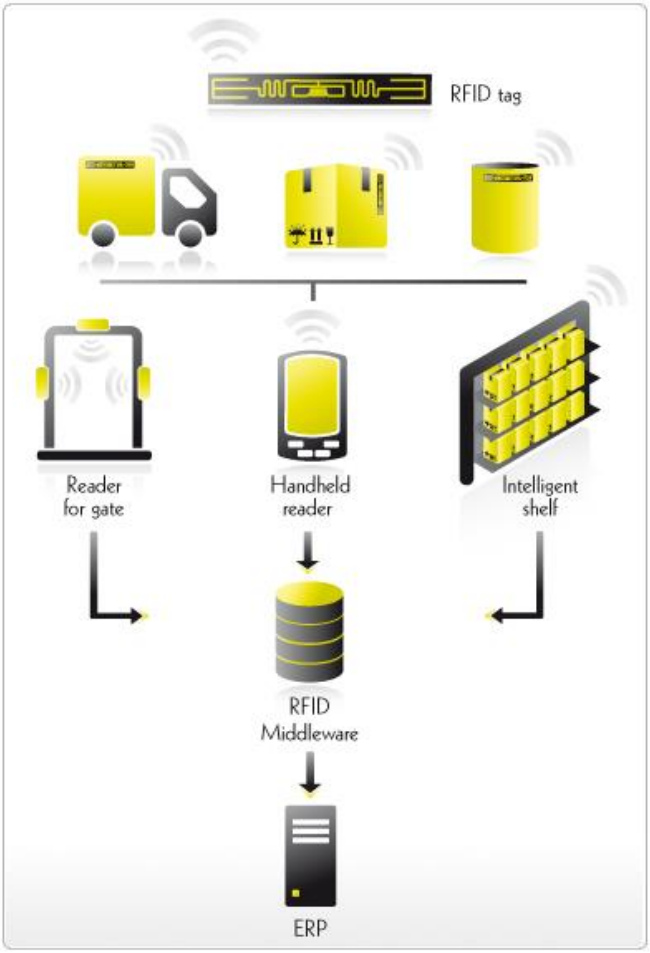
There are several criteria which have to be taken into a consideration when choosing the right reader. Operation frequency (LF, HF, UHF) has to be determined together with protocol agility that the reader supports ISO, EPC or proprietary. Regional regulations are different in around the world, for example UHF frequency is from 902 to 930 MHz in the USA and 869 MHz in Europe. Power limitation is 4 W in the USA and 500mW other countries. Network capabilities can be TCP/IP, Wireless LAN, Ethernet LAN or RS 485. There can also be several antennas, normally four per reader and antenna has also to be able to cope with different conditions. Interface to middleware can be an example of that. (Lehpamer 2012: 173-174)

A connection between reader and the electromagnetic wave is formed by the reader. HF frequencies needs coil antenna to work and a coupling has to be as strong as possible with the tag. The design of the UHF frequencies reader antennas can vary a lot. High-gain and highly directional antennas are best choice when the distance is long. The maximum emitted power is limited by the regulations because maximum emitted power in the certain direction is also limited. Antenna size is connected to the antenna gain and the larger the antenna physical size, the larger the antenna gain is. Thereby directional antennas are not useful in handheld readers and are normally patch antennas, half wave dipoles and helix antennas. However stationary readers can easily cope with large antennas. Weaker signals are received and transmitted more easily by high-gain antennas. Dipole antennas transmit power over larger area and have therefore lower gain. (Lehpamer 2012: 175)

2.5. RFID system software

Information which readers have acquired from tags has to be processed and decoded before any decision can be made how to proceed. There are different kinds of levels of activity around and the first level handles the management of the unit. All kind of control and configuration actions require optimum execution and there are is a lot of parameters in EPC Gen II devices. The second level is about data acquisition by the reader because there might be false negative and positive detections of the tags. The third level handles all the actions. It is very important that there is pre-defined value which tells when the data in the tag disappears. It has to be remembered that data collected from RFID tags is quite vulnerable for example missed and stray reads. The final level is about the interface. EPC Information Service is a standard developed by the EPC global and it means that companies can communicate and change data between each other. (Miles et. al. 2008: 20)

Server, which controls the readers, is connected to the databases and information systems. The idea of the information systems, which are working in the background, is to control the readers and process the data in order it is in the usable form. For example managers might need to use the data when they are making operational decision. Information systems can vary significantly depending on the surrounding business environment where the RFID system is implemented. The actual benefit is possible to achieve only when the information received from the tags is also connected to all other systems around the organization. By combining data it is possible to create entirely new information which was too laborious and complicated to do before the RFID technology. By picking and selecting interesting data from the database according to the tag's information gives exact view to the current situation. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 36- 37)



Picture 8. Structure of the RFID information systems (Etilux)

The picture 8 represents how RFID middleware is linked to the whole system. As can be clearly seen a middleware system is situated between reader and current system. It function is to ensure that only the usable information is transferred to the company's systems in order to prevent the information overflow. Existing systems possess a major challenge to successfully integrate the RFID technology with older existing systems. The solution for this problem is a RFID middleware system. It is used to link current systems into newly acquired RFID technology. The lack of a common standard means that there has to be a middleware system because otherwise the collected data can't be utilized at all if the current systems is incompatible. (Weinstein 2005: 32, Glower & Bhatt 2006: 137-138)

RNC (Reader Network Controller) is the system which controls the reader by sending orders and inputs to the reader. Information reading, writing, modifying and deletion are then executed by the reader according to the inputs which it has just received from the

server. The certain protocol interconnects server and reader to each other. ISO standards protocols and LLRP (Low Level Reader Protocol) are the most common ones. The server also relays information to all data systems by using certain data transfer standard. For example XML (Extensible Markup Language) based PML (Physical Markup Language) language is one of the standards. Information sent by the server is connected to the information which is located at the database and the user of the reader can see that information too. But then the information sent by the reader is possible to save to the database for later use. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 36)

Smart Gateway technology is basically a server system which connects every SO (Smart Object) of the production line to each other and maintains the whole system. SOs are for example RFID readers or handheld devices which have memory, services, communicating capability and logics inside them. Smart Gateway makes possible to construct a unified platform for a company and they can be either stationary or mobile gates which reads RFID tags. Agent concept consists of all kind of SOs which are connected to Smart Gateway. The word smart means the capability to adapt to the environment and share collected data. All-in-one structure has to be innovative enough that it can offer benefits to the data capturing from very changing and complicated processes through the whole production. Agent models have to be used efficiently that they can wrap SOs. (Zhang, Qu, Ho, Sun 2011: 538-549)

Service-oriented solutions enable development, deployment and operation of agents and thereby it's possible to make use of web service technologies. There is no need for special external assistance to be able to use such system. AWFM (Agent-based workflow management) has to be built to integrate the agent into workflow management. As a result is possible to collect specific data from any point of the manufacturing process and AWFM system makes sure that agents of the Smart Gateway know how to collect the data correctly. (Zhang et al. 2011: 538-549) HF RFID reader equipped with COMM (Communications Software) interface and UHF RFID using a Bluetooth interface was used in this research to gather data from the production line. In the future there is a need to develop Smart Gateways which could be used around the production line and its workstations. When SOs are gathering data from Smart Gateways it is important that Gateways are also connected to the whole production line. There is also a need for a data adaptor so that information is able to move in real-time between application system, shop floor and Smart Gateways. (Zhang et al. 2011: 538-549)

2.6. RFID Frequencies and standards

Table 1. RFID bandwidths. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 41)

Bandwidth	LF (Low Frequency)	HF (High Frequency)	UHF (Ultra High Frequency	Microwaves
Frequencies	30-300 kHz	30-30 MHz	300 MHz-3 GHz	2-30 GHz
Connection	Magnetic	Magnetic	Electromagnetic	Electromagnetic
RFID-frequencies	125-134 kHz	13,56 MHz	433 MHz or 865-956 MHZ	2,45 GHz
Estimated reading distance	< 0,5 m	< 1,5 m	433 MHz: <100 m 865-956 MHz: 0,5-5m	< 10m
Transfer speed	ca. 1 kbit/s	ca. 100 kbit/s	433-956 MHz: 640 kbit/s	Ca. 100 kbit/s
Typical features	Short distances, small transfer speed, passes water but not metal	Longer distances, rather good transfer speed, passes water but not metal	Long distances, high transfer speed, simultaneously reading possible, doesn't or water and metal	Long distances, high transfer speed, doesn't pass water or metal
Typical application	Smart cards, animal recognition	Access control and security	Logistics	Road tolls

There are four different bandwidths currently available for the RFID technology because the goal is to be able to offer right solution for every possible application. Table 1 illustrates the differences between each bandwidth. Higher the frequency the further and faster it is possible to transfer information. It should be remembered that higher frequencies cause more issues around liquid and metallic materials. The four frequencies are LF (under 135 kHz), HF (13,56 MHz), UHF (869 MHz-928 MHz and 433 MHz and Microwaves 2,45 GHz and 5,8 GHz. UHF frequencies are mostly used in logistics applications and it is also faster developing frequency because its' physical features. The chosen application determines the frequency and lower frequencies are

most usable where the required range is short and the security requirements are tight. For example new bio passports are a good example of lower frequency applications. Long-distance requires higher frequencies when there is a need to detect shipments from far away. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 40)

Radiation pattern, input impedance, radiation efficiency and resonant frequency are all affected by the metallic surfaces and objects. The effects caused by the metallic items depend on the size and form and also the distance between the antenna and the object. Metallic surface reflects incident electromagnetic wave. In the case of a dipole antenna tag antenna receives electromagnetic wave sent by the reader. The surrounding metallic surface reflects incident electromagnetic wave and backscatter is also present. The radiation pattern of the antenna is thereby affected by the reflections. Negative image currents are build up when the dipole antenna is near to the metallic area which also causes troubles to the radiation performance. Dipole antenna doesn't work properly when on the metallic surface because the antenna is short-circuited with metallic surfaces and thereby it won't receive enough energy to be able to work properly. (Sydänheimo, Ukkonen, Kivikoski 2005: 898)

A metallic plane and reflective features can be utilized when designing a tag which works also on metallic surfaces. It is possible to use metallic surfaces to gather energy which improves the performance of the antenna. Size of the tag antenna causes limitations to the performance of the tag because higher antenna gain, larger antenna is needed which gives longer read range. The best possible antenna solutions to be put on the metallic objects are IFA (Inverted-F antenna), microstrip antenna and printed IFA. Structure of the antenna, input impedance and changes in the near proximity caused by the metallic objects are important facts which all has to be consider when selecting the right antenna. The study conducted by (Sydänheimo et.al.) revealed that printed IFA tag antenna doesn't give a good read range when it’s fixed to a metallic surface compared to microstrip antenna which gives a good performance when fixed to the metallic object. Printed IFA tag works best when it’s not connected to the metal. Also the larger size of the metallic plate decreases IFA tag’s performance while microstrip antennas offer better and better performance. (Sydänheimo et.al. 2005: 899)

LF frequencies are mostly used together with passive tags where the data transfer rate is quite low. Liquids, metals, snow or dirt doesn’t affect at all to the LF tags functionality compared to UHF tags which are more sensitive and failures occur more common. Orientation isn’t problem for LF tags and they require also little energy and the price is

also low and affordable. However the noise can be a problem with LF tags. HF frequencies also use passive tags and they work moderately near metals and liquids. Orientation is slightly higher problem when compared to LF tags but noise doesn't cause any issues. HF tags are usefully especially in hospitals where there it doesn't disturb other equipments. UHF tags can transfer information fastest when compared to other tags but metal and liquids are also problematic. UHF frequencies have become more common in recent years. Microwaves offers long reading range and fast data transfer but metals and liquids cause still problems to the reading efficiency. Passive microwave tags are considerably small because of the microwave's higher frequency. (RFID. Osa 1: Opas. Johdatus tekniikkaan 2010: 42)

ISO and IEC (International Electrotechnical Commission) have defined several standards for the RFID tags. Structure of the information and communication methods are the facts which are defined by the standards, not appearance of the tag or used materials. ISO 11784, ISO 11785 and ISO 14223 are for example standards for the tags which are used to detect animals. ISO 10536, ISO 14443 and ISO 15639 are then standards for the smartcards. ISO/IEC 18000 series of air interface standards is defined for the tags which are used to identify and track shipments and items. (RFID. Osa 1: Opas. Johdatus tekniikkaan 2010: 45)

Table 2. ISO standards. (Fox 2005: 8-9)

Features	ISO 18000-2	ISO 18000-3	ISO 18000-4	ISO 18000-6	ISO 18000-7
Frequency	< 135 KHz	13,56 MHz	2,45 GHz	860-860 MHZ	433 MHz
Type of the tag	passive	passive	Passive or active	passive	active
Transfer speed	Slow	Slow	Very fast	Rather fast	Fast
Size	Thick	Slim	Small surface area	Thin and small surface	Thin and small surface

Table 2 illustrates ISO standards. ISO/IEC 18000 series of standards determines the air interface to the RFID applications which are used in items and objects. UID (Unique Identification) code is used to identify the 18000 - series tags by using 64-bit long UID code which is determined to each tag during manufacturing process. It is also possible

to use just a specific part of the UID code and still be able to recognize items. That is why there is also a narrow UID code which is known as Sub-UID (SUID) code. SUID is 48 bit long and contains 8 bit long manufacturing number from the UID-code and 40 less important bits from the UID codes serial number. (RFID. Osa 1: Opas. Johdatus tekniikkaan 2010: 83)

UID is used to recognize items. The explicit recognition is very important during reading and writing situations. Without a reliable recognition method the whole system is in troubles. It is also possible that UID-code is not needed in the reading or writing process because the presence of the reader is enough that the system works. UID-code doesn't need to be a permanent code because contents, position or response time can also be used to detect tag. AFI (Application Family Identifier) -code is also determined by ISO and it makes possible to separate different tags and its information from each others. It indicates that which kind of application the tag is for. It is possible that information read by the reader is designed to be used in a totally different application which causes error situations. For example in the library other tagged items doesn't trigger an alarm because their AFI-codes communicate to the reader and tell that it is not a library application. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 61-64)

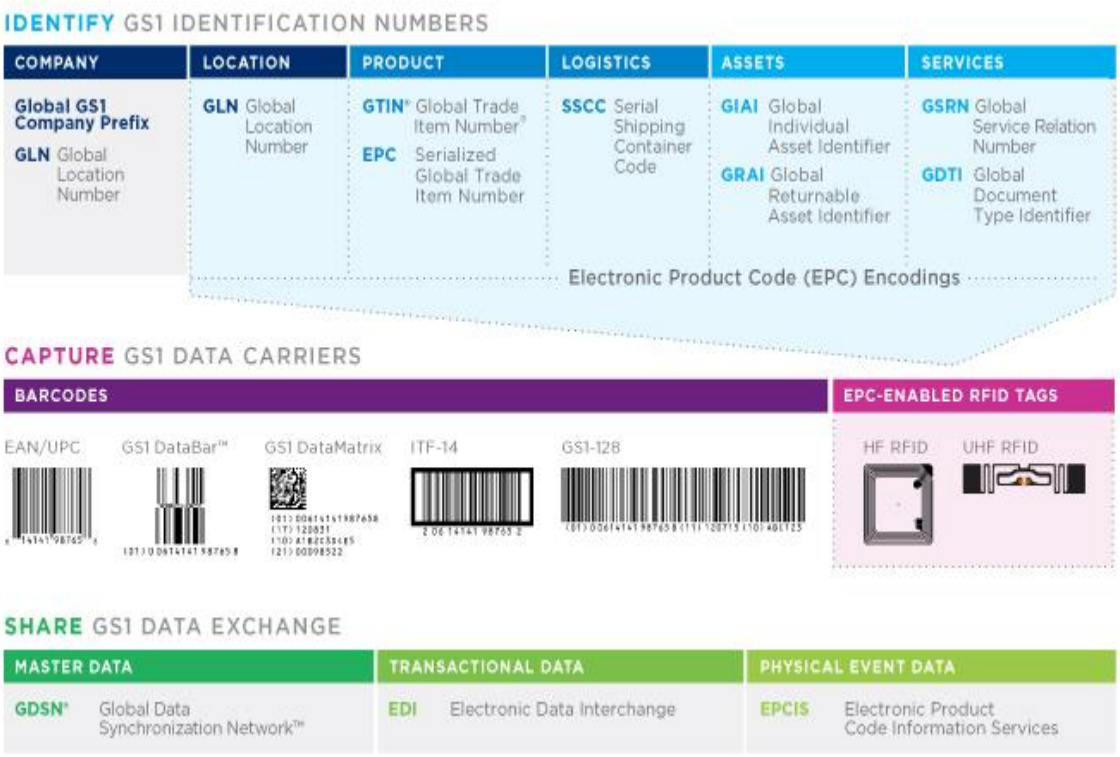
2.6.1. EPC Standard

EPC identification code is developed and run by the EPC global organization and it is based on the GS1 product code. GS1 is a not-for-profit association which has members in 100 countries around the world and it is responsible for 6 billion daily transactions. GS1 designs and implements global standards and applications in order to further develop supply chain. There are GS1 codes in almost every items and goods marked as a bar code and number series which are sold by the local retails. Its standards and solutions are globally most implemented ones when compared to the other standards in supply chain. Bar codes, electronic business message systems, global data synchronization network, data quality, traceability, sustainability, business-to-consumer solutions, supply chain upstream integration and visibility are the main products and service what GS1 is able to offer its customers. Healthcare, retail, transport and logistics together with other industries like for example car manufactures and financial services are using GS1’s products and services. (RFID. Osa 1: Opas. Johdatus tekniikkaan 2010: 56–57, GS1a)

Header determines the length and type of the EPC code. The product code in the header could be for example GTIN code (Global Trade Item Number) or SSCC code (Serial Shipping Container Code) or GLN code (Global Location Number) which all are different kind of GS1 codes. Filter value means the type of the object or usage where the tag is attached. For example item, inner pack, case and pallet are all coded differently. Company prefix reveals the company or organization which has either manufactured the item or owns it. Object class gives information about the type of the object by meaning how the object is being used or where it belongs. For example object class tells us that the item is furniture and values of the object class then reveal the exact usage of the item. Serial number contains unique data which makes it possible to identify unique items and products from each others. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 57-58)

EPC Gen2 air interface standard, first introduced in 2004, is currently the standard in different industries related to UHF frequency RFID solutions. It specifies the requirements of physical and logical aspect for the RFID system considering passive tags and interrogators in the 860 MHz – 960 MHz UHF frequency. EPC code was developed in order to recognize all kind of products, not only products for sale. It also has to be comprehensive so that every single product could be identified. The idea behind EPC standard RFID tags is the compatibility of the current barcode-based identification systems. (GS1b, GS1c)

There is no risk that investment in current identification systems becomes worthless because EPC makes possible to integrate every single existing GS1 standard into the same information system. This improves visibility and makes everything traceable through the whole supply chain. Tags information related to the object is saved to the chip as a binary form. EPC codes can be 64, 96 or 256 bits long depending on the amount of information which is needed to identify the object. Header value, filter value, company prefix, object class and serial number are normally included in the EPC code. (RFID. Osa 1: Opas. Johdatus tekniikkaan 2010: 56–57, GS1b, GS1c)



Picture 9. Structure of the GS1 identification codes (GS1c)

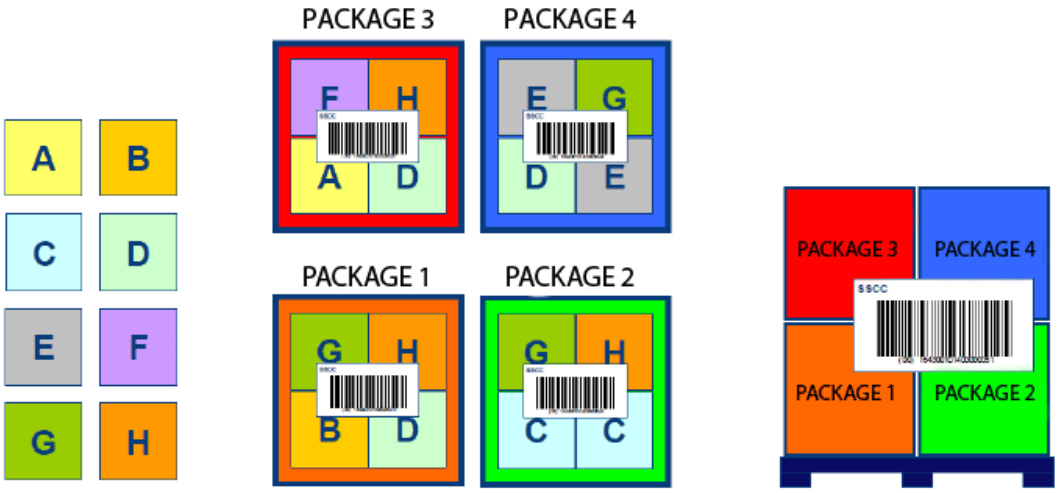
Picture 9 describes all the GS1 standards which are incompatible with the EPC standard. However GTIN and GLN are not directly transferable to the EPC standard and therefore require other standards to be incompatible. Those are SGTIN (Serialized Global Trade Item Number) for GTIN and SGLN (Serialized Global Location Number) for GLN. (EPC c.)

EPC consists of unique number which helps the system to recognize exact items in the supply chain. Tag stores the EPC information and a secured database is used to merge the data after EPC is being read by the reader. Pallets, cases or single products can be identified by EPC RFID tags. It resembles closely to the bar code by it doesn't need a direct line of sight to be recognized because radio waves are utilized to read the information. Radio waves make sure that EPC RFID tags transfer item level information fast and reliably. The newest EPC Gen2v2 standard is completely backward-compatible, there are features related to tags and readers which prevent unauthorized communication and user memory is capable of store various information related to good's life cycle. The major future goal is to include Gen2v2 as a part of the ISO 18000-63 standard. (EPC a, GS1b)

By using EPC counterfeiting can be reduced considering different products. For example pharmaceutical counterfeiting is very expensive because yearly lost revenue can be as high as 200 billion $ and lives can be also lost. Military supplies and shipments are delivered precisely by using EPC. Tracking of products becomes easier and in case of diseases the source of the contamination can be easily tracked down. Product freshness and usability is also possible to ensure through EPC. Visibility also increases and retailers can easily see the inventory levels and thereby it makes replenishment simple and effective. EPC and RFID technology together can increase economic growth, high-tech investments and makes possible to invent new applications in the future. EPC offers privacy and protection of the sensitive information to the consumer and consumers are also notified when there are EPC tags in the consumer products and how to remove or destroy them if necessary. (EPC a, EPC b)

2.6.2 Serial Shipping Container Code

SSCC (Serial Shipping Container Code) makes possible to track all kind of logistics units when they go through the supply chain. Especially the individual identification of the units makes possible to automate good receiving process and track orders and deliveries. It is also possible to carry out ASN (Advanced Shipping Notice) and obtain specific information related to the content of the delivery by using SSCC. It has to be remembered that if the logistic unit is re-packed for one reason or another SSCC has to be created again. SSCC is incompatible with EPC tags which make the reading and scanning easy. (GS1d) Manufacturers can use the SSCC first during the manufacturing process to improve their processes and also be able to track the final products after the shipment has been sent forward. The main idea is that the supplier is responsible for creating of the SSCC which is then utilized through the whole supply chain. Every time the item moves from one organization or facility to another place the SSCC is being read, although it is possible to utilize the same SSCC inside one facility. (GS1d, GS1e)



Picture 10. Structure of the SSCC standard (GS1e)

Picture 10 reveals how packages consist of different cartons. Every package gets its own SSCC information and then a pallet, which includes all the SSCC equipped packages, gets also SSCC information. Thanks to the SSCC real-time information related to quantity, production facility, manufacturing date and warehouse location can be easily obtained and checked if necessary. The carrier is able to easily get specific transportation and delivery information. The consignee then reads every SSCC from the materials and compares the data to the information located in the database. This makes sure that everything what has been ordered has really arrived and balance of account of the warehouse will be in order. SSCC is suited best for companies who are looking for an efficient handling of the logistics unit and pack different kinds of products in the same logistics unit. Also if the content of the logistics unit varies, companies want to trace and track it and there has to be supply control related to pallets and shipments, the SSCC will be the right choice. (GS1e)

2.7. Supply chain management challenges

Kang and Gershwin (2004) have discovered out problems and inconsistency considering inventory levels causes troubles in the management of supply chain. Several companies have tried to solve problems caused by the inaccuracy by developing automated inventory management systems but there are still issues when the actual amount of material doesn’t match with the data in the system. DeHoratius and Raman

(2008) think that companies are not efficient enough if there are issues in the inventory levels and it has been revealed that 65 % of the 370 000 inventory records from 37 different stores had inconsistency in the inventory data. Raman et al. (2001) found out that the companies' profit will diminish about 10 % because of the problems in the inventory levels.

Issues in the inventories can be categorized as follow: transaction errors, shrinkage errors, inaccessible inventory and supply errors. (Raman 2000) concluded that transaction errors are caused by shipment errors, delivery errors, scanning errors and misidentification of the items. (Lee et al. 2005) Mistakes in the shipping are expensive because the company has to send and pay also another shipment which has the right items to the customer (Raman 2000). Delivery error happens when there the delivered amount of items doesn't match with ordered number. (Lee and Ozer 2007) Wrong items in the delivery or wrong destination are also defined as delivery errors. (Alexander et al. 2002) Scanning error can happen if the employee does mistakes in the scanning process, for example processing accidentally the same item twice. (Agarwal 2001)

All kind of issues which can cause loss to the product for sale can be defined as shrinkage errors. Employee theft, shoplifting, administration, mistakes in the paperwork and vendor fraud cause a considerable amount of the shrinkage errors (Chappell et al. 2003). For example Fleisch and Tellkamp (2005) have found out that thefts are a major issue in supermarkets because they cause 1-2% loss of total sales. Misplaced products are classified as inaccessible inventory and are thereby unavailable for customers. Rekik et al. (2008) found out that misplaced products can easily become obsolete which increases costs considerably because those kinds of products can't be sold anymore. Sales loss can be as high as 25 % caused by the misplaced products according to findings by Raman et al (2001). Lee et al. (2005) offered RFID technology solutions to tackle the traceability issue because it's possible to easily obtain real-time data of the product's movements through the supply chain by using RFID. However Zipkin (2006) wants to reminds that not all errors can be eliminated by using RFID, it's possible to detect issues and then decide how to solve them.

Changing customer demand increases variations in the supply chain significantly, especially at the beginning of the chain. Changes in the customer demand increases variance back in the supply chain considering retailers, distributors and suppliers. This causes an effect which is known as bullwhip effect. Forrester (1958) has discovered the bullwhip effect and it is mainly caused by the problems and issues in the sharing of the

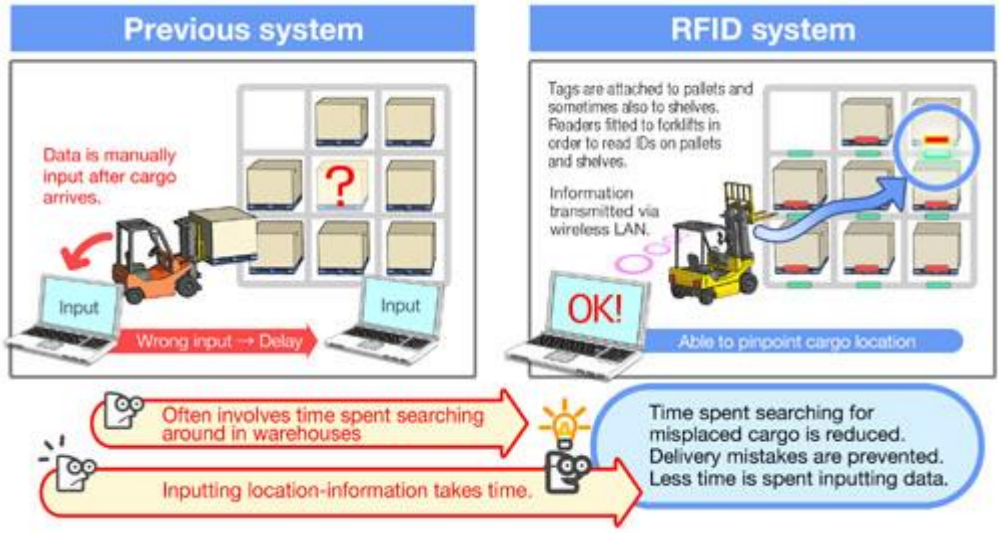
information. Forecasting demand, batching orders, and gaming principle can all cause the bullwhip effect. Lee et al. (1997). Improving information sharing, eliminating unnecessary safety buffers and inventory locations throughout the supply chain and finally enhancing visibility in the supply chain reduces the bullwhip effect. (Holweg et al. 2005) (Wamba et al. 2008). If the bullwhip effect can be eliminated totally from the supply chain the profits will grow about 15-30%. Metters (1997)

2.7.1 Improvements achieved by the RFID solutions and implementations

Inventory replenishment procedure makes possible to define the size and the frequency of the order so that customer satisfaction is as good as possible while the stock levels are low. RFID technology makes possible to have real-time and accurate inventory and warehouse information. (Sarac Aysegul et. al. 2010). Lee and Ozer (2007) have found out that RFID technology eliminates 90 % of errors caused by the transaction mistakes. Also inventory cost caused by the transaction errors are reduced 5,9 %. Heese (2007) has claimed that it's possible to eliminate all shrinkage errors by using RFID applications but the best outcome would be achieved in decentralized supply chain. Sounderpandian et al. (2007) researched the costs and benefits what RFID system can achieve with manufacturer, distributor and retailer. Tags were attached at items, cases and pallets and it was clear that automatic checkout process is improved and storage losses are minimized which thereby cuts inventory costs.

It has been found out that it's possible to minimize bullwhip effect by implementing and using RFID applications. Information sharing is very important because it increases visibility which is closely related to the size of the safety stocks and the whole supply chain. Bottani and Rizzi (2008). Replenishment procedures can be improved by using RFID applications which thereby makes accurate forecasts possible. Imburgia (2006). Also visibility in the supply chain improves by using RFID technology and gathering the real-time information becomes easier. Saygin et al. (2007). But they also say that if there is too much gathered data around then it becomes impossible to filter just the important data. Zhou (2009) has researched the item-level RFID tagging and they have found out that it makes the information system is very agile and the data is visible in several points all the time which makes decision making easier. O'Connor (2008b) has found out that a company called Gelal, which is one of major sock manufacturer in Europe, has been able to improve its productivity about 40 percent by RFID technology. Tags have replaced bar-codes which help to reduce manual scanning. Thanks to the new

tracking system company's labor costs have reduced significantly when the amount of personnel has dropped from 20 workers to just 12.



Picture 11. Benefits of the RFID technology. (Monohakobi)

In picture 11 there is a comparison between non RFID warehouse and a warehouse equipped with RFID tags on pallets and shelves. Also there is a RFID reader on the forklift. The combination of RFID tags and readers improves the efficiency of the warehouse because the amount of manual work decreases reducing errors considerably.

Wamba et al. (2008) have concluded that integrated RFID and EPC network on b2b e-commerce makes shipping, receiving and put-away processes very effective. Every member of the supply chain has to change their own processes if they are going implement RFID technology because the exchange of the information has to be solid and automated. Tzeng et al. (2009) have found out that RFID is a valuable factor in healthcare industry because it improves customer happiness and efficiency together with offering more flexibility to the process designing and also adjusting human resources. Cost sharing and collaboration all in all is very important if they want to have the maximum effect from the RFID system. Huber and Michael (2007) have researched supply chain related shrinkage issues in the retail industry and found out that RFID offers significant visibility to the inventories and recall process is also improved through the possibility to reliably authenticate products. Errors and mistakes caused by humans are also minimized.

It’s possible to collect all kind of information from the shipments by using RFID technology. The way how all the collected information is utilized is very important because it’s the data screening which increases the performance of the RFID solutions. Delen et al (2007). The amount of labor at warehouses can be reduced 14 percent through the implementation of RFID Burnell (2005). For example in the American Apparel, a retailer company, the manual inventory counting process disappeared because of the RFID tags and employees had now about 60 weekly hours to spend more efficiently during their working day (O’Connor 2008a). Wal-Mart Canada found out that implementation of the RFID reduces manual orders 42 percent and it prevents overstock situations, minimizes unnecessary shipments and transports which is also environmentally friendly. (O’Connor 2007)

Staples concluded a pilot program test with RFID tags attached into their incoming and out coming cases and pallets. It had a major time saving impact on the receiving process and also delivery center processes become faster. Furthermore purchase orders were on-time 95 percent compared to 85 percent what the manual receiving process could achieve. (O’Connor 2006). Holmqvist and Stefansson (2006) have researched and found out that arrival inspection process became about 10 to 50 percent faster when using mobile RFID solutions. Burnell (2005) concluded that truck unloading time reduces from 20 minutes to 15 minutes thanks to the RFID. A pharmaceutical company RitaCare decides to improve their warehouse management and attach RFID tags to every storage bin. Also the mobile solutions have made the picking process less error-prone. Thereby inventory levels diminished 50 percent and there were much less mistakes in the made orders than before RFID. (O’Connell 2008 c) According to Chow et al. (2006) RFID tags increases pallet shipping accuracy to customers from 92 % to 99 % and it also effects positively on customer satisfaction when there are few shipping errors. The need of manual labor is reduced when outbound shipments are checked automatically and loaded onto the correct truck.

A company called Durakon Industries has been able to eliminate packaging errors by attaching RFID tags to the prepackaged install kits. As a result there is a right assembly kit in every shipment. If there are wrong items in the shipment, the system will inform workers and corrective measures are possible to execute before the shipment is send to the customer. It is also possible to track and measure the assembly times and analyze how long each phase takes time. During the first six months there has been not a single packaging error. It is expensive to send shipments back and forth all the time when items are missing and consumer satisfaction can as well decrease. (Bacheldor 2007)

RFID technology can also be utilized in a kanban system where the materials and products are moved from stocks to the consuming location according to received signals. For example in hospitals RFID makes possible to automatize the replenishment signal sending process by attaching movable RFID tags to the bins. When the bin is empty, the tag is moved to the board which creates the replenishment order. Two-bin replenishment kanban system is possible to achieve considerable benefits in the supply chain. Because of the RFID based automation nursing staff is no more responsible for replenishment processes and service level is increased considerably because nurses have more time to spend with the patients when manual material ordering is no more their job to do. There are almost no backorders and the need of stock counting diminishes. (Bendavid, Boeck, Philippe 2010)

2.8. Issues considering RFID technology implementation

Challenges for RFID implementation are diverse including issues in standards and technology itself, costs and adaption in general, problems related to ethical, security, data sharing and privacy matters and finally challenges related to RFID tracking adoption considering organizational and inter-organizational issues. Although RFID is a technology which can have a serious impact on the business processes or the value of the service, it is not certain that the potential of the RFID can be fully utilized. Optimization of the whole supply chain through local and individual solutions and implementations is impossible and a local RFID projects can only improve the system locally. Before implementing RFID system there are certain things to take into a consideration. Incomplete processes, long lead times and unreliable systems cause serious problems. It's very important that all the information collected by RFID system is possible to store and utilize in the whole organization. (Rappold 2003:37) (Hinkka 2012: 204-207.)

2.8.1 Technical issues and limitations

The lack of global RFID standards is a major obstacle in the implementation of the RFID technology in general. The two major standards are ISO and EPC. Both of these standards can exist together so that the system is interoperable considering the supply chain. Water and liquids have a considerable effect on the performance of the RFID system because they absorb radio energy or signals which limit the range and makes reading impossible in some cases. Also metals usually make an impact on the deflection

of the radio waves by changing their path but it doesn't necessarily block the reading if the waves can find their way out. Frequencies of the other devices, like for example a mobile phone, may disturb RFID's activity if the frequencies are close to each other. However shielding of the reader normally solves the issue. (Ngai, Hunasekara. 2009: 2-3.)

Sufficient middleware and data management systems are important in order to utilize the full potential of the RFID system. Problems in the data management can be related to the data collection and storage, data integration, synchronization, ownership, privacy, interpretation and analytics. Ownership of the RFID data has also to be decided. The performance of the tags can vary significantly and it is recommended that companies inspect the bought tags in case of malfunctions. The whole RFID system has to be strong enough to cope with failed tags as well. There are two main reasons why tags might not work properly. First is the electrostatic discharge which can break the chip and the second is the damage during the manual application if the antenna area tears off from the chip. (Ngai, Hunasekara. 2009: 3-4.)

There has to be a process which makes sure that tags are physically in shape and written correctly before shipments and items are moved forward. Training and education of the personnel is seen difficult but important task. Companies have admitted that they don't posses enough numbers of skilled personnel who understand how RFID technology actually works. For example in Asia companies might also face difficulties when they are looking for local RFID system suppliers. Implementation process can be difficult if the senior management doesn't support it. Expenses of RFID technology implementation can however be very expensive consisting hardware, software, middleware, tags, consultancy and training costs. It is possible that maintaining of the system is so expensive that smaller companies can't afford RFID at all. ROI (Return on Investment) calculation is an important tool when managers have to be convinced that there is a real need for an investment. However a basic ROI calculation doesn't give necessary information if there is a lot of maintaining work. (Ngai, Hunasekara. 2009: 5-6, Hinkka 2012: 205)

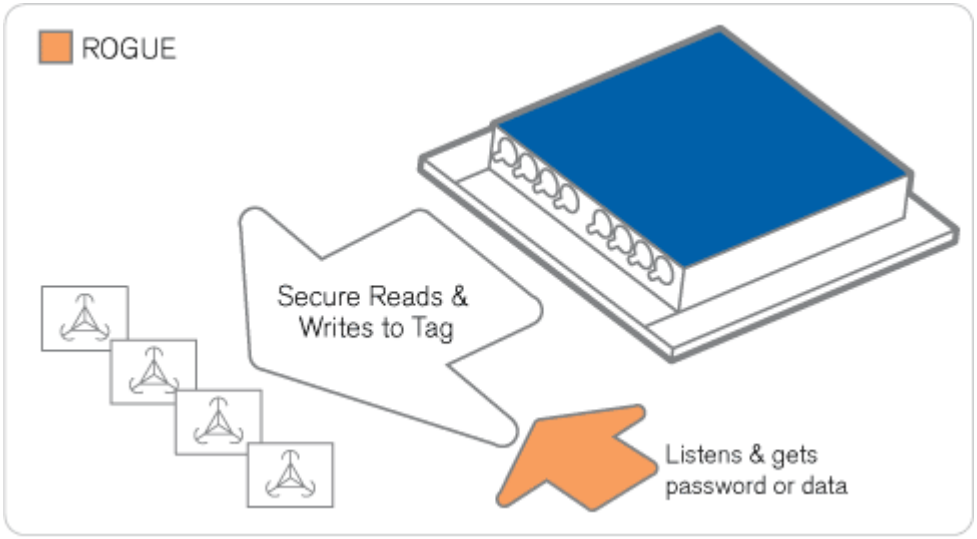
Brown and Russel (2009) have found out that RFID investment is so significant that the processes have to be readjusted and managers need to be committed in order to achieve the implementation goals. Asif and Mandiviwalla (2005) suggest that the best outcome is obtained when supply chain management and marketing strategies are put together but it might be very difficult. The reason for this is that supply chain manager's focus

just on costs and money when marketing people would also think about the customers and how the RFID would benefit them. Soon and Gutierrez (2008) say that the moment when the tag is attached to the product or pallet in the supply chain is important because it is recommended to do as early as possible. Dutta et al. (2007) realized that companies in the downstream of supply chain will often get the full benefit while the manufactures are responsible for most of the expenses.

Insufficient managerial commitment is a major obstacle in the RFID implementation process. Senior managers can find RFID new and strange technology no matter how effective it is or how much costs it can cut. After RFID is implemented it is still possible that not everyone is using it, every single item might not be tagged and some companies don't have money at all to be able to invest RFID. Another big issue together with managerial commitment is the cost caused by the implementation. Successful implementation process requires cost-benefit analysis and also a clear reason that there really is a strong need for RFID technology. Most of the costs are caused by hardware, software, middleware, tags, training, consultancy and also the integration of RFID systems to the current older systems. (Ngai, Hunasekara. 2009: 5.)

2.8.2. Security and ethical issues

RFID can collect and store all kind of sensitive and detail information and if there are failures in the data security practice and policies, it's very likely that all the detailed information can fall into the wrong hands. There are small microchips which can be attached into a human or an animal without causing any issues or complications. Privacy matters have to be ensured that no detailed information will ever leak and there is also a problem if the system is collecting information without asking anyone's permission. Consumers are a bit confused and unsure whether the RFID tagged product will keep on sending information to some third party or not after purchase. Privacy concerns are a natural matter to worry about and new technologies are always a challenge when it comes for example to the privacy issues. Possible misdemeanors are always a challenge especially when there is a risk that people private matters could leak out. (Deal, III, Walter F 2004: 26)



Picture 12. Risks of RFID technology. (Thingmagic)

Picture 12 reveals the possibility how third party people, represented by the smaller orange arrow in the picture, might capture sensitive information and use it in their own purposes. Grafinkel (2002) has addressed five principals which help to retain privacy for consumers who have bought and used RFID tagged products. First there must be right to know whether the product is tagged or not. Secondly the consumer has right to delete, switch off or destroy the tag during the purchase. Thirdly there must be same kind of service available which doesn't use RFID technology at all. Fourthly all the information which was saved to the tag should be available. And lastly there is right to know when, where and why tag information is being read.

In practice it would be possible to notify which product has a RFID tag. Removing or destroying the tag is not going to be easy because in the future tags are likely to be embedded to the structure of the product so that thefts couldn't remove tags too easily. However it's possible to amortize tags for example after the purchase they don't transmit anything. The hardest part is to notify consumers that when the tag is being read. A solution would be if the reader sends voice and light signals while reading the tag but the limitation would be the unauthorized reading which doesn't send any kind of messages to the RFID system. There could also be a coded message in the tags memory which counts the amount of readings. Government agencies might be able to track and trace citizens through the RFID tagged products when for example the customer pays his shopping using credit card because it's possible to connect the credit card owners' information to the bought items. The location of the person can be tracked down if the

tag of the product is read somewhere using a RFID reader. (RFID. Osa 1: Opas Johdatus tekniikkaan 2010: 97-99)

EMF (Electricity and electromagnetic fields) are surrounding our world and society but long-term effects of the EMF exposure are still unknown. Countless RFID devices and EAS systems use EMFs as their operational principal. It has been researched by The ICNIRP (International Commission on Non-Ionizing Radiation Protection) that there are no evidence of heating or thermoregulatory stress which RFID system could cause. However there can be dangerous situations considering the medical devices like pacemakers because powerful electromagnetic fields are known to cause problems with electronic devices. For that reason hospitals have for example restricted the use of mobile phones to minimize the possibility of dangerous situations. (Lehpamer 2012: 294-295)

The traditional identification mechanism is to use passwords and many tags posses enough capacity to process passwords and PIN codes so there are no extra costs caused by the increased processing capacity. The saved password is executes certain commands after it receives the right password from the reader. The problem is that reader has to know the PIN code of the tag first before it can connect right password to the commands. This means that tags need to transmit their PIN codes without a secured connection and the certainty that who is the receiver. Third parties can have readers and pretend to be the right reader or tag and thus spy information sent by the real parties. It is very important that each side is identified reliably before any sensitive information is sent. (RFID. Osa 1: Opas. Johdatus tekniikkaan 2010: 98-99)

There have been several experiments that even a passive RFID tag can transmit information farther than it has been assumed before. That could be a problem when the consumer possess RFID tagged products and no one really knows what kind of information does the RFID tag actually transmits and how far away. Databases which collect and gather information from RFID tags are vulnerable for privacy attacks because there can be very sensitive and detailed information about private individuals. For example frauds, identity thefts and blackmailing are a serious concern if the information in the database leaks can be accessed. Tags can also be cloned, changed, break or otherwise disturbed. (Neumann & Weinstein 2006: 136)

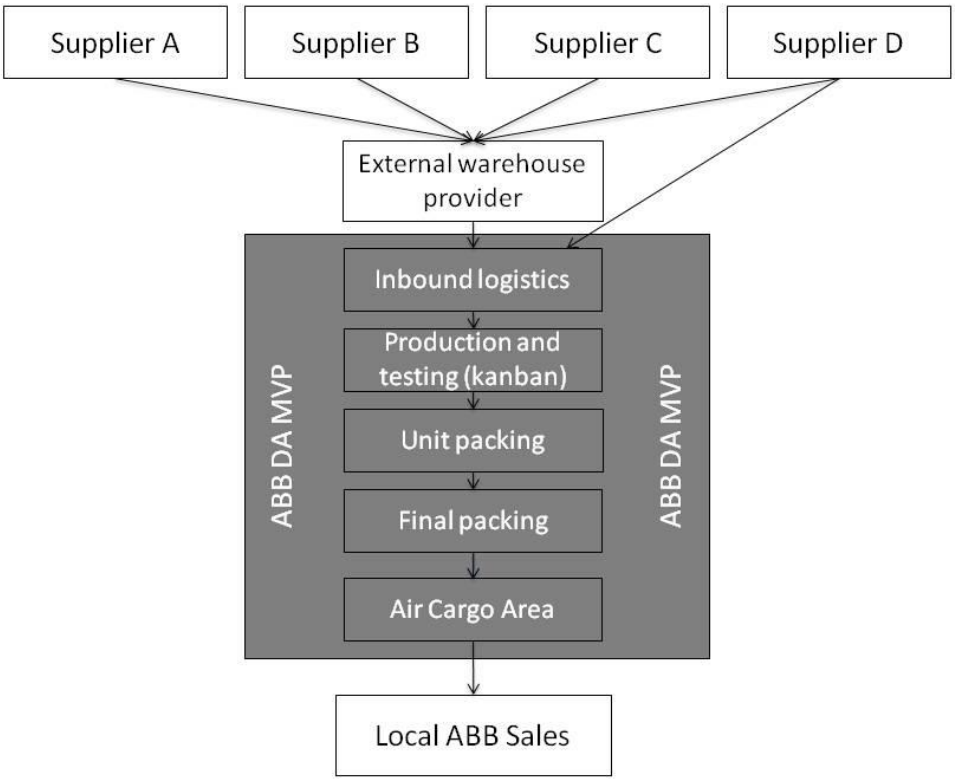
It is possible to use RFID to transmit viruses into the data systems because RFID system can also be very vulnerable to external threats. However sustainable and sensible system

planning can reduce the risk considerably. Viruses can hide in the memory of the rewritable tags without causing any problems to the functions of the tag. When costs of the RFID decrease and the whole technology become more common it's very likely that all kind of virus attacks increase significantly. Luckily it's possible to prepare for different kind of attacks by using the knowledge of the experts. When the attacks become more and more common, it's likely that there will be investments to the different kind of security systems and countermeasures will be developed and integrated into RFID tags and their security systems. (Talbot 2006: 28)

It is very important that the possible security risks are properly defined and the black spots of the systems are well known before the detailed security and risk assessment plans are made. There are five questions which has to be answered first and those are who, what, when, where and how because it is possible that there are people who are interested in to attack and steal information from the RFID system. Who question reveals that what kind of organization might be interested to attack. What question tells that what kind of information the attackers are looking for? It's vital to know and understand that when they could possibly attack and where exactly the attack plans would be the most easiest to execute. Finally how question needs to answered because if the thefts are going to utilize the fragility of RF, then it's possible to reduce the range of transmitted RF waves. (Lindstrom & Thornton 2005: 170-171)

3. LOGISTICS PROCESSES AT ABB MVP VAASA

As the research question defined, the goal of this thesis is to find out that what kind of advantages and disadvantages RFID technology offers for ABB Medium Voltage Products Finland. The supply chain consists of the following processes where RFID is possible to implement and those processes are inbound logistics, kanban, assembly, unit packing and final packing. Those processes are first described in detail and then all the problems related to those parts of the supply chain are examined so that the SWOT analysis is possible to carry out. The purpose of this SWOT analysis is to determine what kind of strengths, weaknesses, opportunities and threats RFID technology will face. After that a RFID based solution is proposed in order to improve current processes, increase productivity and also minimize or even eliminate all the current issues. However testing processes have been mentioned only briefly because during the research process it became clear very soon that RFID technology doesn't offer any significant improvements when compared to current processes.



Picture 13. Supply chain of ABB MVP

In the picture 13 the black arrows represents the material flow from suppliers to local ABB Sales. The following research process focus mostly on activities done at the ABB MVP facility but external logistics provider is also taken into account during the research of inbound logistics. All the tags will be passive because they are cheaper than active tags and passive tags can easily achieve the required read range is and all the information, which is stored to the tag, can easily fit to the memory of the passive tags. Tags and readers will be all UHF compatible because it is widely considered the best option for the logistics systems. Frequencies from 865-956 MHz offers reading distance from 0,5 meters to 5 meters, and considering the state of current logistics systems and processes, that kind of reading distance will be enough. High data transfer speed and simultaneous tag reading capability makes possible to operate the logistics identification system in a very effective way. However metallic parts can cause issues to UHF frequency which has to be taken into account when designing the system.

The operating standard for the whole RFID system will be EPC Gen2v2 standard because it is incompatible with all GS1 standards. EPC is also one of the most known standard in the UHF frequency area. The latest Gen2v2 standard offers state-of-the-art features and ensures the usability of the system now and in the future. Security issues have to be taken into consideration because tagged cartons are travelling across the world and for intruders there would be a plenty of opportunities to capture sensitive data and information about the material quantities and specifications. Fortunately EPC standard offers protection against unauthorized data capture and thereby makes the whole system very secure.

SSCC will be used to identify the incoming logistics unit because the content of the deliveries varies and there has to be a possibility to follow and trace the shipments when they move across from supplier to external logistics provider. The efficient handling of the logistics unit is very important and SSCC provides all the vital information. One of the reasons why SSCC should be chosen is that it is a common standard which is known across the world. The shipping information, which is saved to SSCC, makes possible to automatize the material receiving process and trace orders and deliveries.

Table 3 represents the costs of different RFID system’s components and all the figures were checked from one of the system supplier. Therefore it the same information is used when calculating investment costs. However it has to be noticed that the cost of IT system depends heavily on the requirements of ABB and it varies depending on the requirements of each process.

Table 3. RFID technology components.

Item	Price
Tag	0,15 €
Fixed gate or antenna	3000 - 5000 €
Annual gate license payment	4000 €
Handheld reader	2000 €
Printer	2300 €
Information system	Depends on the requirements of each process, around 22000-36000 € per one solution. Includes for example project management, server installation, software specification and other expenses.

In order to conduct a sensitivity analysis supply chain payback time calculations related to inbound logistics, assembly, kanban and final and unit packing include two different kind of payback calculation scenarios. The first scenario assumes that suppliers and other partners are willing to take care of the operating and investment costs. In the second scenario ABB will pay the operating and investment costs for the others. Both scenarios include ABB MVP's investments and operating costs. Obviously the first scenario is a better choice for ABB but it is possible that some of the suppliers might refuse it. Because of the characteristics of assembly process' two payback calculation scenarios are bit different when compared to the others. The amount of gained savings is different while both the investment and operating costs remain unchanged.

It should be noted that ABB has already made a decision based on their needs and priorities to implement RFID technology first to inbound logistics. In addition sensitivity analysis is also conducted by adding 20 % to the IT system costs because integration process might face unexpected issues.

3.1 Inbound logistics

Shipments sent by the suppliers first arrive to external warehouse provider. They store and then forward shipments to MVP based on the consumption but they are also responsible for the management of the buffer stock in respect of certain items. Some suppliers also deliver goods directly to the MVP. When the delivery arrives on a truck either from the external warehouse provider or supplier to the MVP facility, reception

worker transfers all the pallets form the truck to the reception area of the factory. External warehouse provider sends goods twice a day, in the morning and in the afternoon, and there are usually about five to seven pallets per each delivery. The delivery is on time when the truck arrives at the door of the MVP factory exactly when it is expected but if it's late just one minute then the current shipment is determined as a late delivery. Each pallet contains several cartons and the whole pallet is wrapped in plastic in order to protect the shipment. Pallets are then unloaded and all the materials are transferred in shelves to the designated production lines. FIFO (First-In, First-Out) method is used to manage the inventories and different material types are separated from each other by using unique identification codes.

Goods reception personnel are also responsible for the visual material inspection. They make sure that right amount of material have arrived when they manually count the received material and compare the result to the delivery note. Reception workers check manually that the material cartons are intact and also count that the delivered amount of material is correct. If the delivery is lacking of items or there are completely wrong materials, all deviancies are written down and reported to contact person in the procurement department. The purchaser then reports to external warehouse provider that there are items missing in the delivery. Deliveries coming from the external warehouse provider don't require the signing of bill of lading but shipments coming directly from suppliers require this. Finally workers do the manually goods reception in SAP system by either reading the covering note information using a barcode reader or manually entering the necessary data to SAP. After this all the materials have been moved successfully from external warehouse provider's to ABB's balance of account.

The example below gives an idea how the inbound material shipment is constructed. One shipment usually contains several pallets which then contain several material cartons.

Pallet

- 12 x PCB cartons

PCB carton

- 24 x PCBs

3.1.1 Current issues

Manual material reception is time consuming, prone to human errors and non-value adding activity. Mistakes done during the material counting have a direct impact on the warehouse inventory levels if the received and checked numbers of materials don't match with the reality. As a result inventory levels are inaccurate and in the worst case scenario production of the relays might stop if there is not enough material available. Supplier or external warehouse provider might have sent by accident an insufficient amount of material or completely wrong cartons which no one has noticed. Workers in external warehouse provider and ABB are both responsible for the inspection of the inbound material and warehouse transfers. The warehouse transfer process is also entirely manual work when the barcodes from the consignment notes are being read or in some cases every detail related to the delivery has to be manually entered to SAP if there are no barcodes available. This is very slow and error prone activity and it is easily possible that for example typing mistakes take place. At the same time the whole receiving process slows down considerably because everything is carried out manually. Checking of the stock balances requires manual work and it is also a laborious effort considering the large amount of material.

3.1.2 RFID based solution

Five of the largest material suppliers are required to attach RFID tags into the pallets which are used for the shipment of the material cartons. Purchase order, number of the packing list, quantity, item and supplier are the information which has to be stored in the tags memory. Material suppliers use RFID compatible printers to print tags and at the same time they also create the SSCC code to the tag which is used to identify the logistics units when it arrives to the external warehouse. When the shipment coming from the supplier arrives to external warehouse provider, the material reception process is completely automatized.

A fixed RFID gate located at the door recognizes the tags located at the side of the incoming pallets and RFID information system then automatically makes the stock transfer. After the shipment has been transferred to external warehouse provider workers then unload all the pallets and organize them to the warehouse shelves. Based on the ABB's material need workers at external warehouse provider collect all the cartons and pack them on pallets. After everything is collected they use a RFID compatible printer to print RFID tags which are then attached into the side of the

pallets. Tag contains information related to material code, purchase order, supplier and quantity. Shipments are delivered twice a day to the ABB facility.

Picture 14. A inbound logistics door.

At ABB MVP goods reception personnel transfer pallets one by one from the truck through the door inside the facility. The door presented in the picture 14 leads to air cargo area but the picture is taken from inbound logistics area. When materials arrive at the MVP facility's inbound logistics area trough air cargo area the fixed RFID gate located at the door recognizes all the carton tags and the RFID information system carries out the warehouse transfer automatically from external warehouse to ABB's facility. All incoming material shipment information is located at SAP and the information system then compares the data read from the tags to data located in SAP. If there is lack of materials the system will automatically inform the reception workers. By

using RFID technology the whole goods reception process will be completely automated. Reception workers just unload the pallets and transfer materials to the shelves. There is no more need to manually inspect and count the amount of received materials. The need for manual material transfer also disappears.

The information gathered from the goods reception gives information how many cartons have actually arrived to the factory which reduces the need of manual inventory checking. Production stops are also an issue if there is not enough material available. It is possible that everyone have thought that there is sufficient amount of material at the factory but in reality some pallets might be short of a critical number of cartons which could halt the whole production. Tagged pallets make sure that there will be fewer errors in the goods reception. All workers have to make sure that all the RFID tags located at pallets are intact

3.1.3 SWOT analysis

Strengths

- No more manual material counting and material transfers from one warehouse to another, barcode scanning and inspection
- Labour costs reduce
- Receiving process becomes faster
- Receiving and inspection errors diminishes
- Production stops reduce significantly

Weaknesses

- Supplier might forgot to attach tags to cartons
- If there are missing items inside the carton, then the inventory level information becomes therefore unreliable
- Doesn’t prevent damaged goods caused by mishandling
- Employees might feel that RFID threatens their job
- Stocktaking still requires manual inspection and counting of the printed circuit cards
- RFID tags may damage during transport

Opportunities

- Improves external warehouse provider’s processes furthermore

- After few suppliers have implemented the technology and realized its potentiality, other companies will also be encouraged to implement RFID technology
- Offers possibility to monitor suppliers' buffer levels in the future

Threats

- Tags might carry viruses into ABB's information system
- Suppliers or external warehouse provider's processes might not be incompatible with RFID technology
- Implementation process could face all kind of unexpected issues

3.1.4 Investments, operating costs and benefits

Necessary investments at MVP facility are a fixed RFID gate, SAP integration work and creation of the information system. In addition to investment costs at MVP facility there are two possible scenarios how rest of the investment and operating costs can be diveded. In the first scenario both material suppliers and external warehouse provider will be responsible for acquiring RFID printers and tags and external warehouse provider will acquire a fixed gate and take care of annual gate license payment. Operating costs are only related to annual license payment for the gate located at MVP. In the second scenario in addition to investments made in MVP ABB will also acquire the printers for suppliers and external warehouse provider and acquire a fixed RFID gate for the external warehouse provider. Operating costs consists of the consumption of tags at supplier and external warehouse provider facilities in addition to two annual gate license payments. The more tags are printed the higher the operation costs will be.

Manual material warehouse transfer process at SAP will be automatized when using RFID system. As a result the need for manual searching of the materials decreases because RFID systems makes sure that there is fewer errors in material reception process. The number of production stops related to mistakes occurred at the material reception reduces and the need to manually check and fix stock balances.

Table 4. Inbound logistics, scenario 1.

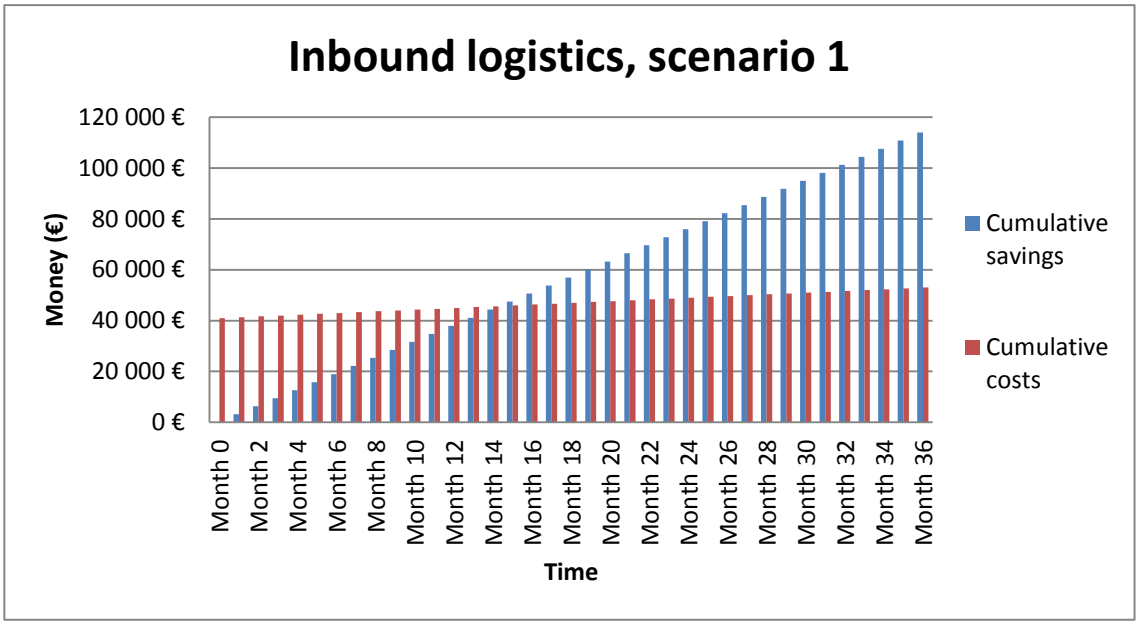
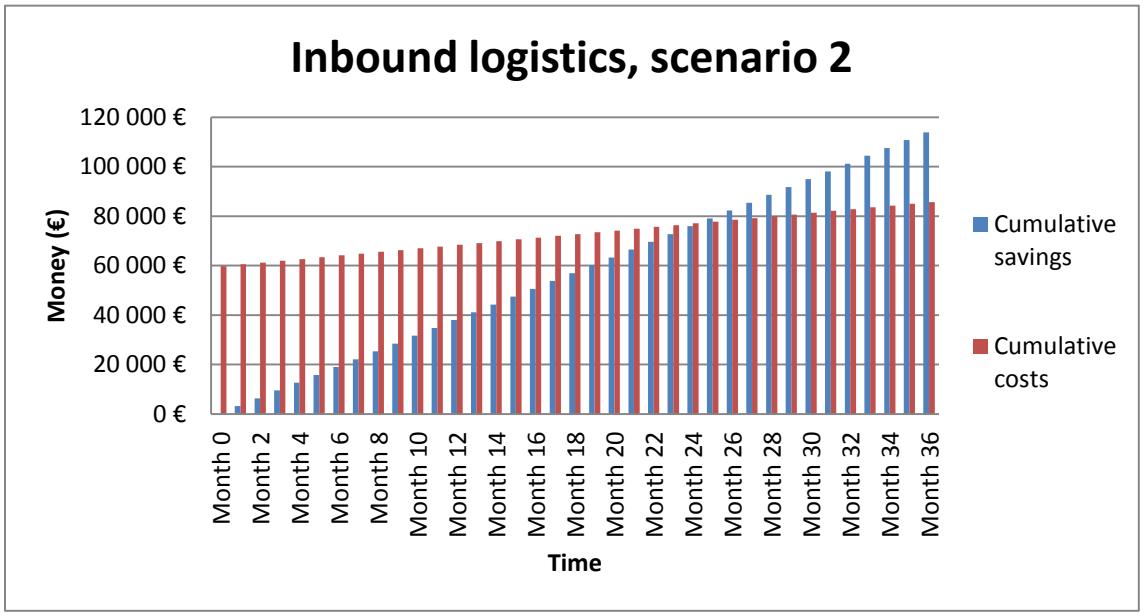


Table 4 and 5 represents the two possible scenarios. Cumulative costs in the tables 4 and 5 include both operating and investment costs. Table 4 reveals the outcome of the first scenario and the payback time of the investment is 1,21 years. The development of savings gained from the improvements is rapid and significant. Table 5 represents the second scenario. The investment's payback time is 2,04 years.

Table 5. Inbound logistics, scenario 2.



External warehouse provider will also benefit from the RFID technology when the material inspection, counting and receiving processes becomes automated and manual errors reduce which are included in the savings. It can also be seen that the amount of costs for the external warehouse provider are higher than in the first scenario but both scenarios are highly feasible options. The second scenario is much better alternative for the ABB because suppliers and external warehouse provider are both responsible for all of the investment and operating costs.

3.2 Kanban

The current kanban system makes sure that the material replenishment process works without problems. There are kanban shelves around in the immediate vicinity of production lines. External warehouse is responsible for handling most of the kanban deliveries based on kanban orders but there are some suppliers deliver goods directly to the factory. The current system requires direct input from the assembly workers because when a certain batch of material is about to run out from the production lines, the worker goes to the SAP, selects the correct materials and manually creates the input for replenishment order. When workers at external warehouse receive kanban orders, they manually convert and then print out the material requirement list, gather then all the required materials from the warehouse and finally deliver material to ABB MVP. The size of every kanban is predetermined and it varies a lot depending on the type material.

Most of the items are replenished by kanban but not all. There are also materials at inventories which are replenished directly by the vendors which obviously mean that those items are not in the kanban. Items such as screws, general tools, manuals and other materials which are delivered with the completed relay are replenished by the vendor. In practice this means that representatives of the suppliers act independently when they are checking the inventory levels regularly. If the situation requires faster actions it is possible that ABB’s purchasing department asks the supplier’s agents to come and check inventories.

3.2.1 Current issues

The current Kanban system depends solely on the manual input of the workers. Manual work is error prone and it is very likely that in some point mistakes will happen. There are so many different material items in the Kanban SAP application which means that

assembly workers could easily order wrong items by accident. Items are separated from each other's by a different material number and mistakes could easily take place especially in a hurry. As a result of an error in the material order process there is a possibility that the production line will stop if there is not enough material available. Automated material replenishment procedure would improve productivity because mistakes and also a non-value adding work could be minimized. Employees in external warehouse provider can't see in real-time the consumption of different materials which means that they can't estimate beforehand the amount of work which is required to collect and deliver all the materials on time to MVP facility.

Mistakes could also take place at external warehouse provider during the manual conversion procedure of the ordered material which is done in order to get the material list which has to be delivered. Occasionally employees order too much material to the MVP facility. When the production rates are about to grow in the future it is very important to control the amount of material in the warehouses which relates directly to the amount tied up capital. By automatizing the replenishment process the possibilities of overstocking disappears and at the same time inventory levels stay at the reasonable level. The available shelve space at the factory for the material is rather limited which means that in case of overstocking the corridors are full of cartons which haven't fit in the shelves. Workers might also forget to order more material when it has ran out from the shelves. External warehouse provider's ability to deliver materials on time suffers when orders accumulate unevenly.

3.2.2. RFID based solution

The idea is to replace current manual kanban replenishment system, which is used by ABB MVP and external warehouse provider, with RFID technology. There are materials around the factory which are replenished by kanban but the new RFID assisted replenishment system is about to be implemented to PCB cartons consumed by the production lines. Due to this material cartons delivered to production lines by the external warehouse provider have to be equipped with RFID tags. As a result five of the largest PCB suppliers are required to attach RFID tags to the material cartons. After the assembly worker has taken the last item from the carton, the empty carton is taken out of the shelf and put to the separately defined area. There is a RFID antenna placed in a predetermined area where empty material cartons are gathered. The range of the reader has to be carefully adjusted because otherwise the reader would read all nearby cartons tags which is not the purpose. Carton tags are being read by the reader after they have

been inside the reading area for 30 seconds. This makes sure that those cartons are deliberately placed in the reading area, not by accident. Workers have to be clearly instructed that they know where to put empty cartons.

Picture 15. A kanban shelf at the assembly line.

When the antenna reads the last carton tag of the kanban, it updates the material consumption information to warehouse provider. After the last carton of the predetermined kanban size is read by the antenna, material consumption information system triggers kanban material replenishment order. Workers in external warehouse can monitor material requirements in real-time and deliver the right amount of material at the right time. There is a example of a kanban shelf in the picture 15. RFID system makes possible to fully automatize the ordering system and it increases process visibility radically. In case of overtime work there has to be a possibility to manually override the RFID kanban system because the RFID based system doesn't allow ordering cartons to the stock and not every kanban carton is replenished by the new system. That is why the current SAP based system has to be kept in operation as well.

When the overtime work and material need is known to occur, the assembly worker goes to SAP and manually orders all the needed materials. Otherwise the SAP interface is not used during daily operations because it is just a backup system. When the number of cartons on the shelf diminishes, assembly workers have to visually estimate what would be the right time to order more goods. The other major limitation is that the RFID kanban system works only with the cartons. All the other materials, which are delivered in larger pallets or containers, still require manual replenishment input from the assembly worker. Workers in external warehouse could still make mistakes when they are gathering the ordered items from the warehouse because it is still manual work.

3.2.3 SWOT analysis

Strengths

- The need of manual material orders disappears
- No more errors caused by manual material ordering process
- Production stops are unlikely to happen
- There is no overstocking anymore
- Inventory levels can be lowered
- Material replenishment process becomes faster

Weaknesses

- Assembly workers might forget to put empty cartons in the reading area
- In case of overtime work the RFID kanban technology doesn’t work
- Impossible to be implement in every single kanban slot
- Workers in external warehouse might misinterpret the information and deliver wrong items

Opportunities

- Suppliers could use carton tags in order to improve their own process
- Suppliers could have access to the kanban database in order to further increase visibility in the supply chain

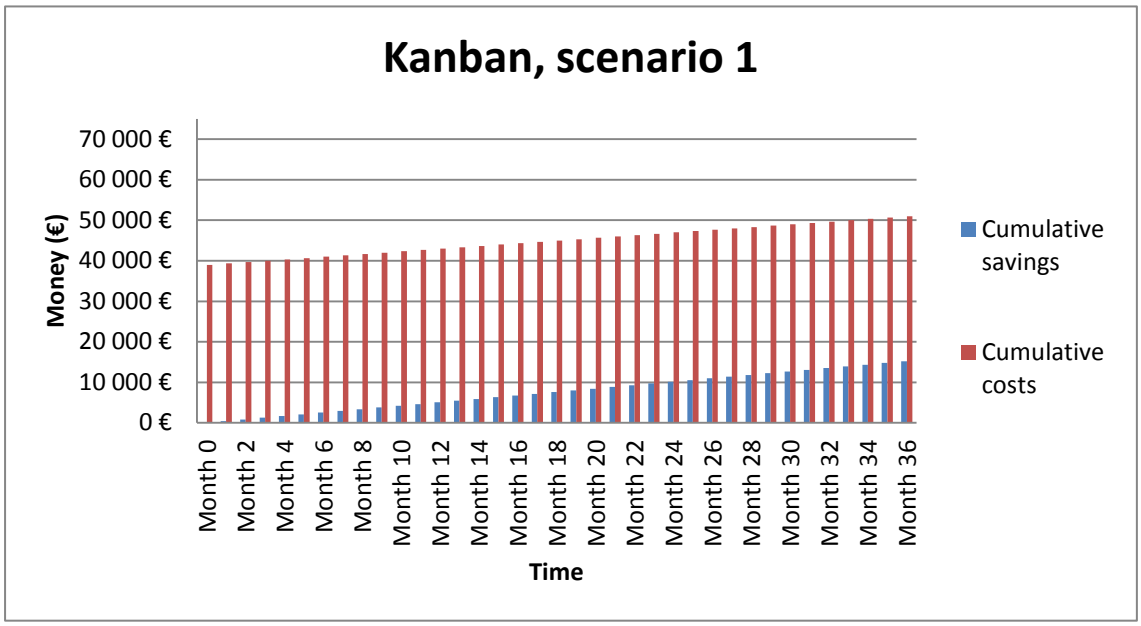
Threats

- Challenges to integrate with external warehouse provider's systems
- External warehouse provider might be interested in adopting a completely different information system than RFID based

3.2.4 Investments, operating costs and benefits

Acquisition and installation of a fixed reader, annual gate license payment, acquisition of information system and designing of the new material consumption information systems for external warehouse provider are the required investments by ABB. In addition to investments made by ABB there are two possible scenarios that how suppliers will share the rest of the costs caused by RFID technology. First scenario assumes that every supplier will acquire RFID printers and take care of all the costs related to tagged PCB cartons. In the second scenario ABB will handle of all acquisitions of RFID printers and costs related to tags.

Table 6. Kanban, scenario 1.



First scenario's operating costs are only related to annual gate license payment. Cumulative costs in the tables 6 and 7 include both operating and investment costs. Table 6 describes the first scenario and the payback is 36,75 years. It means that it takes way too long that the investment would pay itself back.

Table 7. Kanban, scenario 2.

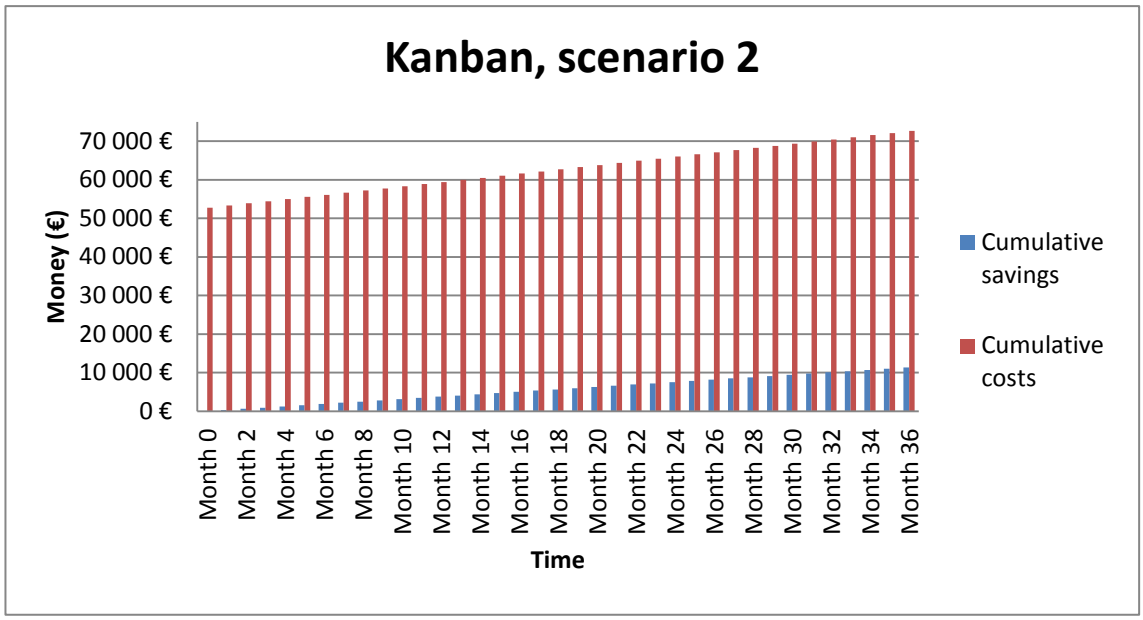


Table 7 represents the result of the second scenario. Second scenario's operating costs are cause by consumption of tags and annual gate license payment. Because of the operative costs cumulative costs grow constantly year after year and therefore savings never reach or even exceed the total costs. Therefore it can be stated that there is no payback time. Although there are problems with the manual ordering system and like all manual systems it is prone to manual errors but it still works surprisingly well. During the research process it was found out that there has been not a single production stops related to the mistakes done in the manual kanban replenishment process. Overstocking at MVP facility isn't as bad as it could be and inventory levels are also in a good shape.

3.3 Assembly

Assembly process begins when the worker first opens SAP, then navigates to the work list and prints out the material list related to the specific order. The printer also prints device decals for each relay. The actual assembly process starts from the plug-in unit assembly where the PCBs are attached one by one to the relay case. Before the PCBs are attached inside the relay, all the module stickers are manually removed from circuit boards and other components and then put aside. After all the PCBs are fastened inside the relay, module and device stickers are then attached one by one to the side of the relay case. Device decal is read first by using a barcode reader so that the system

recognizes the relay. Then all the module stickers are read one by one at the same way to make sure that the components have been attached to the relay. The following example presents all the important components and material which are related to a protection relay. However the combination of different PCBs varies a lot and this is just a one example of a possible relay.

Protective relay

- 1 x Relay case
- 1 x Display
- 1 x Backplane
- 1 x COM PCB
- 3 x BIO1 PCB
- 1 x TRM PCB
- 1 x PSM PCB

3.3.1 Current issues

Attachment of the stickers is a slow and time consuming because it is entirely manual work. First every module stickers have to be removed from the components without tearing them apart and sorted to the table next to the specific relay. Then the actual module sticker has to be carefully removed from the sticker paper and finally attached one by one to the side of the relay case. Stickers might get lost when they are on the table, mix with the other module stickers, damage when being removed from the components or attached into completely wrong relays especially if there are more than one relay at the table where the relays are assembled. All of the above mentioned is non-value adding work.

The removal of the stickers from the PCBs is time consuming because it’s manual work. If the worker forgets to remove a sticker before the component is fastened inside the relay case, then all the other components has to be disassembled in order to take off the missed sticker from the PCB. Barcode reading is rather slow when every module sticker has to be read one by one because simultaneous reading isn’t possible. The scanning is also slow if the reader doesn’t instantly recognize and reads the barcode. This requires several reading attempts occasionally and it takes time. If the assembly worker attaches wrong components by accident, then the sticker has to be removed from the side of the relay box.

Picture 16. A relay case and module labels

Picture 16 illustrates the module labels which are attached to side of relay case. Sometimes customers return products which mean that they have to be disassembled after they have arrived to the MVP facility. All the PCBs are disassembled from the relay case and put back to the cartons in order to be used again. Also every module sticker has to be removed from the side of the relay case. The problem is that those same stickers can't be reused again because it is impossible to remove stickers successfully without tearing them apart and attach those stickers back to the PCB. This means that assembly workers manually regenerates one by one all the module stickers and attach those back to the disassembled PCBs. Assembly workers could working on with new orders instead of creating module stickers.

3.3.2 RFID based solution

RFID tagged PCBs are the main element of the new and improved assembly line. Non-value added work can be greatly reduced by mounting a RFID tag to every PCB and removing the module label stickers. A proposal has been already made to ingrate a RFID tag to the PCB. The idea is to attach tags to PCBs during the manufacturing phase of the PCBs at the same time with all the other components. RFID tag equipped PCBs

will be introduced to the best-selling protective relays families. Those protective relays families include a lot of different PCBs.

The new assembly process begins at the same way as before. The worker goes to SAP, prints out the material list and then collects all the needed material related to order. But before the PCBs are fastened inside the relay there is no more need to manually remove the module sticker from the PCBs. After everything is in place the worker takes the handheld RFID reader, selects the specific order and finally reads all the tags from inside the relay case. If there are wrong PCBs in the relay reader automatically notifies the errors and informs the worker that which PCBs have to be changed. Finally the device label which is then attached to the side of the relay just like before but now when every device label also contains a RFID tag where the information related to the content of a relay is coded to tag's memory. In addition to tag the device label contains a bar code and information about the relay and from now on the RFID tag and all the other information are combined at the same label. During the maintaining process of the relays all the information can be easily obtained by reading the device label and there will be no need to open the relay in order to read the PCB tags.

Next worker attaches the tagged device label to the side of the relay at the end of the assembly process. It has to be remembered that the back side of the relay has to be open when PCB tags are read because radio waves can't pass through the relay after it is closed. Most importantly the assembly process becomes more straightforward than before because there is no need to manually attach all the module stickers to the side of the relay case. The information will be coded to the RFID tags which also make the reading process faster. It is also important to notice that there is no more need to regenerate module tags when there has been either a human error during the assembly phase or relays have returned from customers. Assembly workers can focus on entirely to the manufacturing of relays and the amount of non-value adding work diminishes dramatically which will have a direct effect on general efficiency. Also when all the PCBs are tagged, it means that there is no more need to regenerate module stickers to the PCBs which are from the disassembled relays. Worker can just put the removed usable PCBs back to cartons without reprinting of the module label. All workers have to make sure that all the RFID tags are intact.

3.3.3 SWOT analysis

Strengths

- No need to scan every barcode one by one
- No need to attach several barcode tags to the side of relay box
- Speeds up production
- Dissambling of the returned relays becomes faster
- Current printers can print RFID tags

Weaknesses

- Assembly process depends on the hand held RFID readers
- A RFID tag has still to be manually attached to the side of relay box
- Metallic parts in the relay box can interrupt the reading
- Assembly workers could refuse the transition from barcodes to RFID tags

Opportunities

- RFID tags are already attached to the relay box considering unit packing, final packing and aftersales services
- Production supervisors can easily see in the future how the manufacturing process is proceeding and how many relays are currently at the stock

Threats

- PCB supplier might refuse to attach tags to PCBs
- Tag implementation process to PCBs might be costly and face difficulties.

3.3.4. Investments, operating costs and benefits

The biggest investment cost is the research and development work when finding a way how to mount a RFID tag on the PCB. Research and Development department together with all the PCB suppliers has to collaborate and find a suitable solution together which doesn't affect on the performance of the protective relay. The integration process requires several modifications to the layouts of the PCBs and other documents as well. There are about a lot of different PCB's and when every one of those is equipped with

RFID tag the modification work must be done to each of them. The costs of the integration work is not included at the investment costs because Research and Development department will take care of all the costs related to the modification and redesigning work. In order that the manufacturing process would work as smoothly as possible, there has to several readers which means that multiple hand held readers have to be obtained. However RFID compatible printers don't need to be acquired because all the existing printers at the assembly line can print RFID tagged labels as well. Another major investment is the designing of the RFID middleware system in order to provide a link between SAP and handheld readers. There are two possible scenarios how the savings can be achieved.

The first scenario assumes that it would be possible to save eight seconds per one module label in the assembly. The second scenario is more cautious because it assumes that it would be possible to save just six seconds per one module label. The investment and operating costs are the same in both scenarios. Operating costs are caused by the amount of manufactured relays because every assembled relay contains a tagged device label. As a result of tagged PCBs the assembly phase, becomes faster. There is no more need to remove, attach and read module labels one by one. The benefits are significant because amount of saved time is significant every month. Also the disassembly process becomes more faster and savings are related to time savings. Cumulative costs in the tables 8 and 9 include both operating and investment costs. Table 8 represents the outcome of the first scenario and thanks to the rapid development of the savings the payback time is 2,17 years.

Table 8. Assembly, scenario 1.

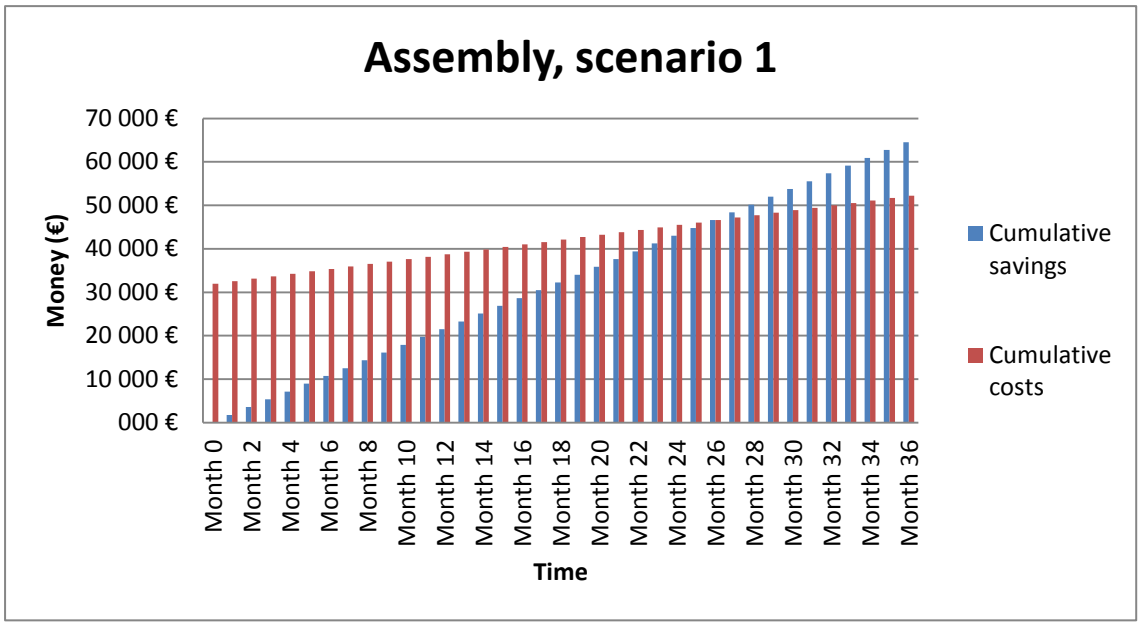
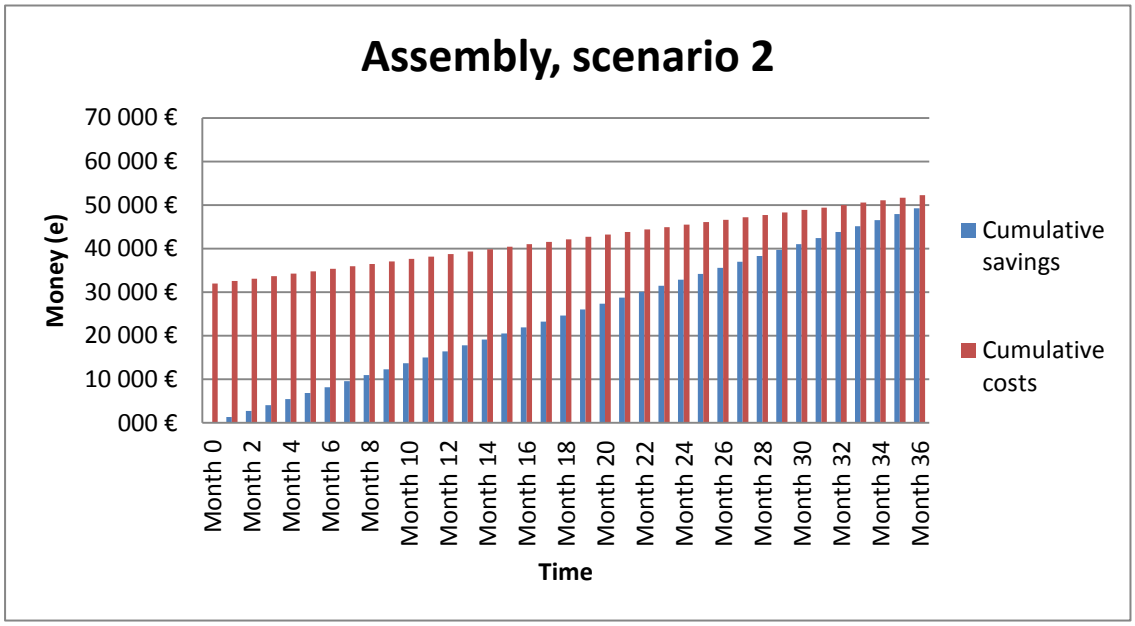


Table 9 describes the situation of the second scenario. Investment and operating costs are exactly the same when compared to first scenario but the amount of achieved savings is different. The two seconds difference affects to the amount of gained savings. As a result the payback time is 3,31 years.

Table 9. Assembly, scenario 2.



3.4. Unit packing

After the assembly the relay moves to testing where it is tested and the software is programmed to memory of the relay. If relay doesn't pass the test procedures it goes back to the unit assembly where faulty PCBs are replaced. Then relays are aged in order to find faulty components from the PCBs which would otherwise break when the relay is installed to the customer. After the relays have been taken out from the aging they are ready to be packed. The worker arranges relays at the same place so that all the relays related to the same order can be easily found. Then the picking list is checked where all the important information about the order and accessories is listed.

At the unit packing relay is packed in the carton together for example with connector set, cable and in some cases other accessories too. A sales order might contain a wide variety of possible accessories which are delivered together with the relay. In addition of accessories the second half of the carton label is put inside the carton without attaching it to the side of the carton. All the accessories and relay are checked by reading the bar codes from the list which is attached at the unit packing work station. Finally after everything is packed, the first half of the carton label is attached on the side of the carton. When all barcodes related to the specific order have been read, the order status updates in SAP's Packing Work Queue and notifies that it is ready to be picked up. Cartons are then moved to the shelves next to the unit packing workstation to wait until picked up and moved to final packing. In the case of larger orders all the relays are packed into a pallet.

The example below presents general contents of a relay carton which are packed inside the carton during the unit packing. It should be noted that the content of the unit packing varies considerably between every production line.

Protective relay carton

- 1 x Protective relay
- 1 x Connector set
- 1 x Cable
- 1 x Manual
- 1 x Carton label

3.4.1 Current issues

According to delivery error database there have been reports of missing accessories caused in the unit packing. For example here have been reports that customer has received wrong kind of cables. Although accessories are checked by reading the barcodes from the separate lists it doesn't necessarily mean that the item is really packed in the carton. The worker can for example get distracted for example when holding the cable which is just about to be put inside the carton. Thereby orders can be short of certain accessories. That is why the barcode reading system isn't a foolproof system at all because it doesn't guarantee that all the needed accessories have been packed inside the carton. Accessories could be left lying at the table of a workstation if the worker gets distracted. It also takes time when the worker has to check the accessories by manually reading all the barcodes from the barcode list. There are several different lengths of cables in the shelves, all in their own places, but they all look and feel the same and it is impossible to distinguish between them when they are side by side on the table. It is also possible that the worker takes a wrong cable from the shelf by accident for the same reason because they all look and feel similar.

Picture 17. Accessories

These kinds of mistakes are expensive to the ABB because the customers becomes unsatisfied, quality of the products and further expectations decrease which might harm the upcoming sales efforts. Picture 17 gives an example of accessories. It costs a lot to

send the missing parts afterwards to the customer and it is also very time consuming to sort out the mistakes thoroughly.

3.4.2. RFID based solution

The idea is to implement the RFID technology to the unit packing by equipping all the accessories with RFID tags like for example cables, connector sets, loose parts accessory bags and mounting kits. Also the second half of the carton label, which is attached to the side of the cartons during the unit packing, will also be equipped with RFID tags. These kinds of implementation plans mean that ABB and accessory suppliers need to work together in order that everything goes as smoothly as possible. In the case of smaller accessories, such as screws and dust covers, there is no possibility to attach RFID tags into them. Unit packing becomes more faster when accessories can just be put inside the carton because workers don't have to read the barcodes manually one by one anymore. Smaller deliveries can be packed in cartons but in a case of bigger orders all the cartons are put in the bigger pallets. Workers have to make sure that all the RFID tags are intact.

A RFID gate will be installed next to the door which leads to air cargo area and it first recognizes the RFID tag from carton label, which is on the side of the relay and then all the tags located in accessories. RFID information system then compares all the information received from the tags to data located in SAP. A carton label determines the specific delivery which has to include all the required certain accessories. If accessories are missing or completely wrong items have been packed, RFID information system will notice the errors on time well before the delivery has left the MVP facility. Delivery errors will decrease dramatically because tags will ensure that all the right accessories are in the relay cartons. Customer satisfaction will increase when they can be sure that everything which has been ordered is in the shipment. However tagged accessories don't eliminate the manual work during the unit packing. It means that human errors are still possible and if the order is short of material, the carton has to be opened and errors corrected. But when compared to the current situation it is a better to notice errors at the factory than let the customer receive incomplete delivery.

3.4.3 SWOT analysis

Strengths

- No more manual barcode reading

- Delivery errors disappear
- No more lack of accessories (connector sets or cables) in the deliveries
- Packing process becomes faster
- Current printers can print RFID tags.

Weaknesses

- Every single accessory has to be equipped with RFID tag which is expensive
- Manual work is still needed to pack everything into cartons
- Because of the manual unit packing process human errors can still occur

Opportunities

- Possibility to be integrated into the fully automated unit packing system
- Thanks to the improved quality of the deliveries customer satisfaction improves significantly which affects on the whole image of the company

Threats

- Accessory manufactures might be reluctant to attach tags into their products
- Sensitive information related to accessories can be captured

3.4.4. Investments, operating costs and benefits

Several investments are necessary so that RFID technology can be successfully implemented to unit packing. ABB has to acquire a fixed RFID gate and design a information system in order to provide connectivity with SAP. There are two possible scenarios to share rest of the costs. In the first scenario it is assumed that every supplier is willing to invest on RFID printers and take care of the tag related costs. First scenario's operating costs are related to annual gate license payment and consumption of tagged relay cartons at ABB. In the second scenario ABB will acquire RFID compatible printers for every accessory supplier and handle all tag related costs. Second scenario's operating costs are related to annual gate license payment, tag equipped accessories and carton labels printed at ABB. Those tagged accessories will be a significant cost for

ABB because every accessory coming from suppliers must be equipped with tags. One tag doesn't costs much but in great numbers the total operating costs will be rather substantial. The more accessories are being delivered by the suppliers the higher operation costs will be.

The greatest benefit of all what the RFID technology can offer is the elimination of accessory related delivery errors. Also the packing of the relays becomes faster because there will be no more need to manually read the accessory barcodes from the separate barcode lists located at the unit packing working stations. The elimination of accessory delivery errors significantly improves the customer satisfaction but it is very difficult to estimate the actual amount of savings what the reduction of unsatisfied customers can achieve. All the manual non-value added work, which is caused by clearing up delivery errors, also reduces and the employees will have more time to focus on other tasks in the future. Cumulative costs in the tables 10 and 11 include both operating and investment costs.

Table 10. Unit packing, scenario 1.

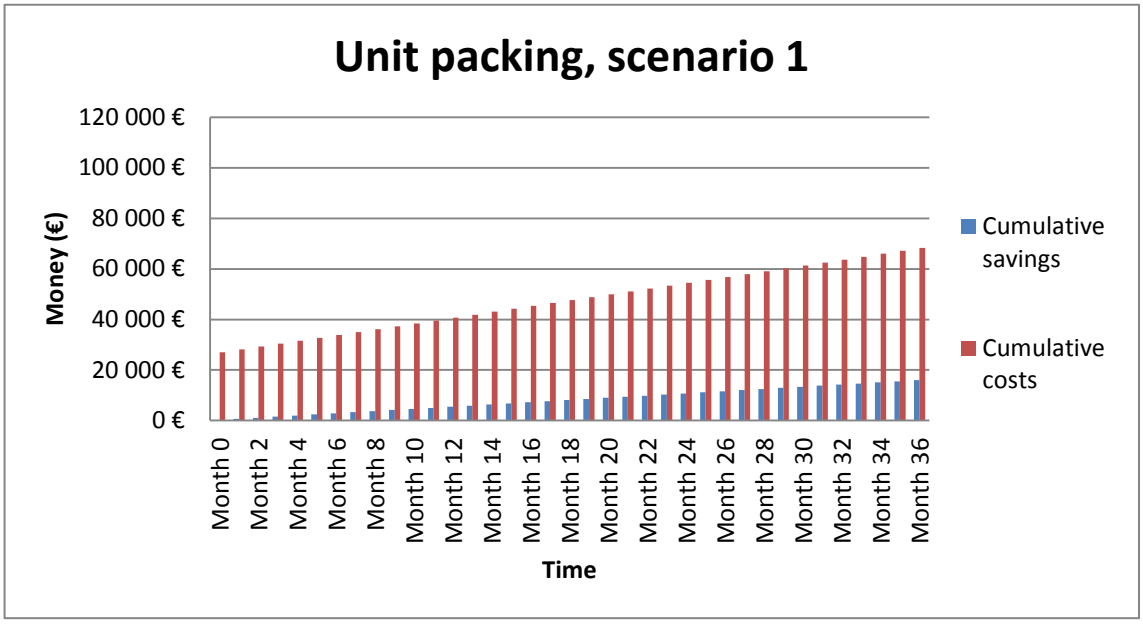
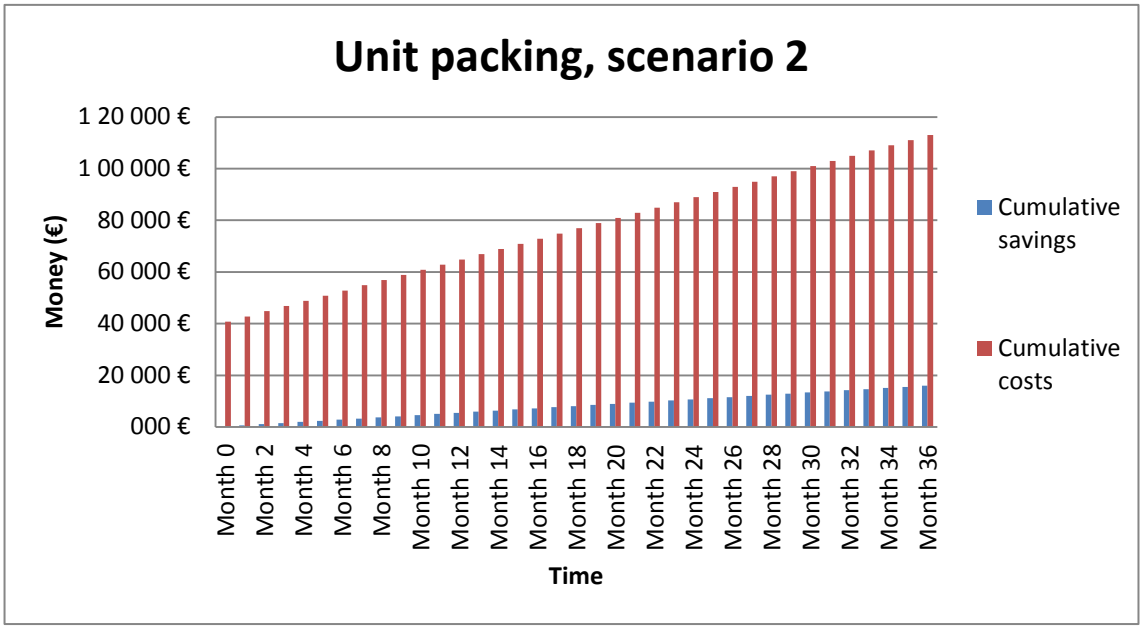


Table 10 represents the outcome of the first scenario. As can be seen the amount of cumulative costs is so big that savings will never reach the amount of accumulated costs. Therefore the first scenario is infeasible solution and there is no payback time.

Table 11. Unit packing, scenario 2.



The same can be said about the second scenario as well. Table 11 illustrates the development of both costs and savings. The development of costs is even faster and there is no chance that the investment never becomes feasible. There is no payback time neither for the second scenario. It can also be noticed that the amount of delivery errors is rather small which means that the current process works rather well.

3.5 Final packing

Completed and packed relays are located at the end of every production line either already inside the pallets or in the shelves. After the order is ready to be picked up, the worker sees that by looking at SAP's packing work queue. The worker prints the picking list and then goes to pick up the orders. In order that right relay cartons have been picked up a barcode from every relay is read by using a portable barcode scanner. Collected relays are then transferred to the final packing department where the workers choose a suitable pallet for every delivery. Large deliveries require a pallet but smaller ones can be easily fitted in cartons. Customers usually order all kind of different trading goods. Those trading goods can be for example cables, lens sensors or other products, for example relays or transceiver modules which are manufactured elsewhere. All the ordered trading goods are packed together with relays. The portable barcode scanner is also about to be implemented to the checking of the trading goods until a better solution

is found. After everything is picked and packed, the pallet is then measured and weighted and a packing label is attached to the side of pallet or carton. The pallet also gets a unique identification number which makes possible to identify it. A packed order is checked to the production management system and the order is then transferred to the dispatch department where it is stored until picked up. After orders are collected, picking details related to the order is printed and then taken to the forwarding department.

Shipments, which are lacking of certain trading goods, can be temporarily stored at the final packing department until all the missing trading goods have arrived and everything is ready to be packed. Those accessories are then merged directly to the specific deliveries. Customer orders may consist of just trading goods. The free space at the dispatch department is used for the storage of the consignment. Depending when the shipments are about to be sent forward, pallets are stored either on the upper shelves or down at the floor level. When the forwarding department has given permission that the shipment is ready to leave the factory, the dispatcher, who is responsible for the guidance of the forwarding company picks up a packing list and a bill of lading. There are finished relays in the pallets which are about to be packed in the picture 18.

Picture 18. Relay pallets

The list below gives an idea what kind of combination of goods a customer order normally is. A customer order usually consists of the combination of trading goods (cables, relays and all kind of other accessories) and relays which have been manufactured at the MVP facility. Sometimes customers might order only trading goods. Orders can be much smaller and bigger. Connector sets and cables are a common example of trading goods which relate to the order.

Pallet

- 12 x Relay carton
- 12 x Connector set
- 12 x Cable

3.5.1 Current issues

There have been delivery errors related to trading goods according to delivery error database. For example when customers order certain amount of cables or other accessories workers has to pick up them manually and carefully count them that the collected amount of cables match with the customer order. Collecting and counting of the trading goods is completely manual work and mistakes can easily happen. Especially cables are error prone items. Worker might pick up wrong or insufficient number of materials. For example considering all the different kind of cables, which are one of the trading goods, it is almost impossible to tell the difference between them.

It is possible that workers pick up wrong relays from the unit packing shelves because there have been reports of wrongly delivered relays. However the portable barcode scanner reduces picking errors but workers could still scan one relay carton and pick up a wrong one. If the customer has received a wrong relay it has to be returned back to the ABB and dismantled because it is highly unlikely that other customers will order exactly the same kind of relay. The worst case scenario is that customers receive a completely wrong product because it is a very expensive mistake. However these kinds of mistakes are rather rare but still possible. The biggest concern is arguably the missing trading goods. The portable barcode scanner will improve the accuracy of the picking process further on

3.5.2 RFID based solution

RFID tags will be attached to cables because delivery errors which are caused by missing or incorrect cables and thereby RFID tags make sure that there will be no more lack of cables in the future. Accessory suppliers will be responsible for the attachment of tags during the manufacturing process. It would be possible to tag every trading good but that would be rather expensive to place tags into every single accessory item because the volumes of the trading goods are so large. It has also to be remembered the smallest suppliers might not have the necessary resources or interest to implement RFID technology. In addition to tagged cables a packing label, which is attached to the side of the carton or pallet during the final packing, will be also equipped with RFID tag. Also the carton label, attached to the side of a relay carton during the unit packing, contains a RFID tag in order to make sure that all the relays related to the order have been properly collected and also packed in the right pallet. SSCC is also created in order to provide compatibility in the supply chain. Information in the carton label should include at least sales order number, quantities and material numbers.

Picture 19. Cables

Picture 19 gives examples of the most common cables located at ABB. All the information related to every delivery is located in SAP. Packing label tag is used to determine the specific delivery while both carton and cable tags are connected to the packing label tag information. In order that the delivery contains all the right relays and

cables RFID information system first recognize the packing label tag and then all the other tags and compares the collected information to SAP data. Every packing label RFID tag contain order code, production type, serial number and sales order number. All workers have to make sure that all the RFID tags are intact.

After the order is packed it is transferred to the air cargo area to wait for the delivery there will be a fixed gate next to the door which leads there. The reason why RFID gate is next to the door leading to the air cargo area is that there would be time to notice and correct the mistakes done in the final packing. There will also be a LCD display next to the door where the information is clearly presented so that corrective measures can be easily executed. If quantities, cables' material numbers or relays' serial numbers don't match with the packing label's information then there is lack of accessories or cartons and the system notifies the error immediately.

3.5.3 SWOT analysis

Strengths

- Eliminates the possibility that wrong relays have been picked up
- Makes sure that there are right amount of trading goods in the delivery
- Informs when cartons and pallets have been moved to the air cargo area
- Delivery errors reduce significantly

Weaknesses

- Suppliers can forgot to attach tags to trading goods
- Tags might damage, break or tear apart when pallets are moved around
- Tags are not possible to attach into smallest accessories
- RFID tagged packing label can be attached into a wrong carton or pallet

Opportunities

- Other ABB facilites can easily utilize RFID technology when every outbound shipment is RFID tagged
- Provides credibility that deliveries contains precisely all the required accessories which thereby increases sales in the future

Threats

- Trading goods manufacturers can refuse to attach RFID tags into their products
- Sensitive information related to the deliveries can leak to third parties

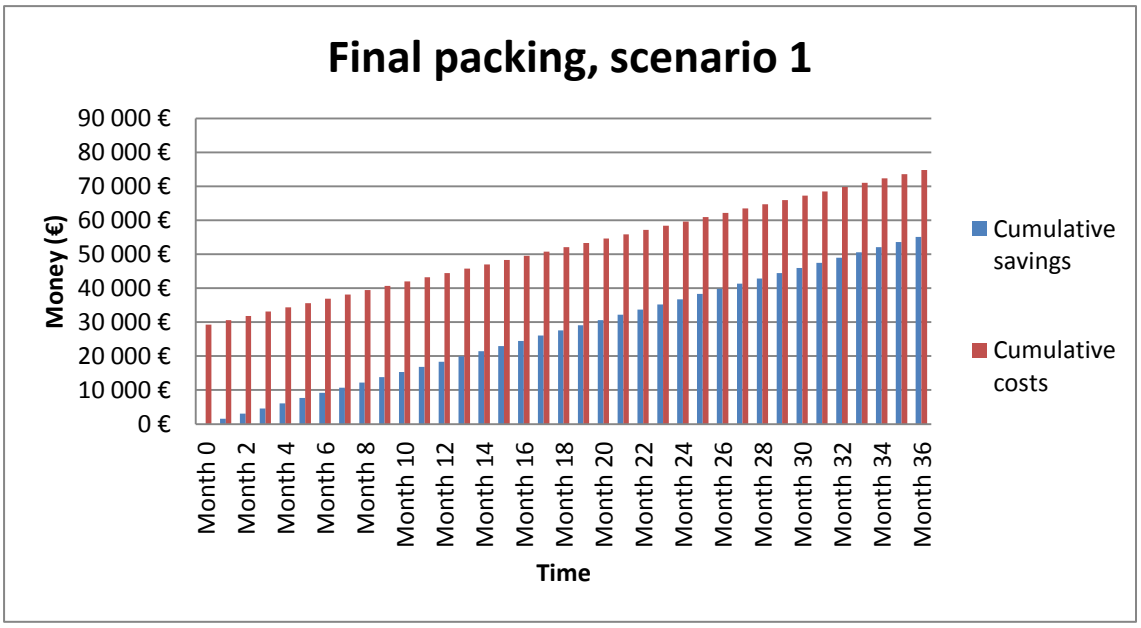
3.5.4 Investments, operating costs and benefits.

At ABB MVP a fixed RFID gate, RFID compatible printer and RFID information system are required investments. In addition ABB handles all the costs related to carton and pallet tags which are packed and delivered from MVP to customers. There are two alternative scenarios that how rest of the costs can be shared. In the first scenario a cable supplier is asked to acquire a RFID compatible printer and also take care all of the tag related costs. First scenario's operating costs consists of annual gate license payment and RFID tag equipped carton and packing labels printed at ABB. If cable supplier isn't willing to do the required investments and handle the operating costs then ABB has to do it. In the second scenario cable supplier doesn't have to invest anything because ABB takes responsibility of the RFID printer acquisition. Annual gate license payment, RFID tags installed in cables in addition to all tags printed at ABB form second scenario's operating costs.

The more packing labels are printed the higher the operating costs will be. The biggest economic benefit is by far the reduction of delivery errors. Errors caused by the lack of cables or completely wrong cables will cost a lot of money and have a negative impact on the customer experience. It is very time consuming work to solve those errors which are easily avoidable by identifying all the cables individually. Time savings are therefore easily achievable when there is no more need to use time to sort out the delivery errors. RFID tagged cartons, pallets and cables ensure that all the deliveries, which leave from ABB, contain exactly the right items what the customer has ordered.

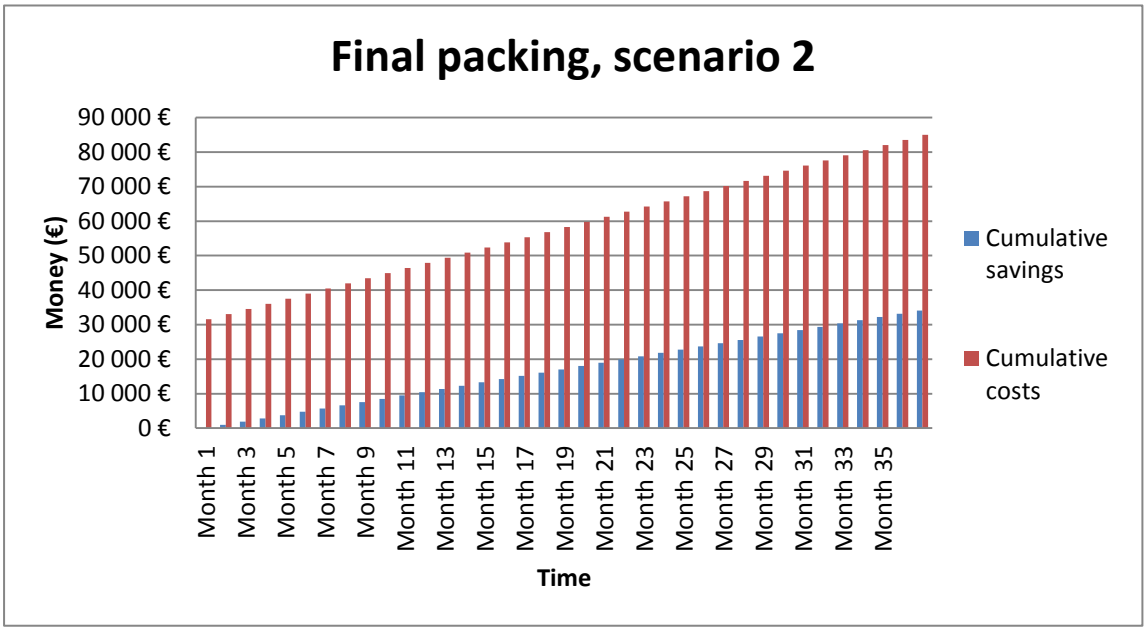
Cumulative costs in the tables 12 and 13 include both operating and investment costs. Table 12 represents the result of first scenario. The payback time is 9,16 years which is not in the target time. Therefore the investment would not be feasible to impalement. ABB will be responsible for acquisition of RFID compatible printers and RFID tags for the cable supplier. However the amount of required carton and pallet tags is going to be much less than the consumption of all the cables.

Table 12. Final packing, scenario 1.



The outcome of the second scenario can be seen from table 13. There is no payback time for the second scenario which means that the investment will be infeasible. Investment costs include operating costs depending on the consumption of the carton and pallet tags. Furthermore acquisition of both RFID compatible printers and tags for the cable supplier also increases costs.

Table 13. Final packing, scenario 2.



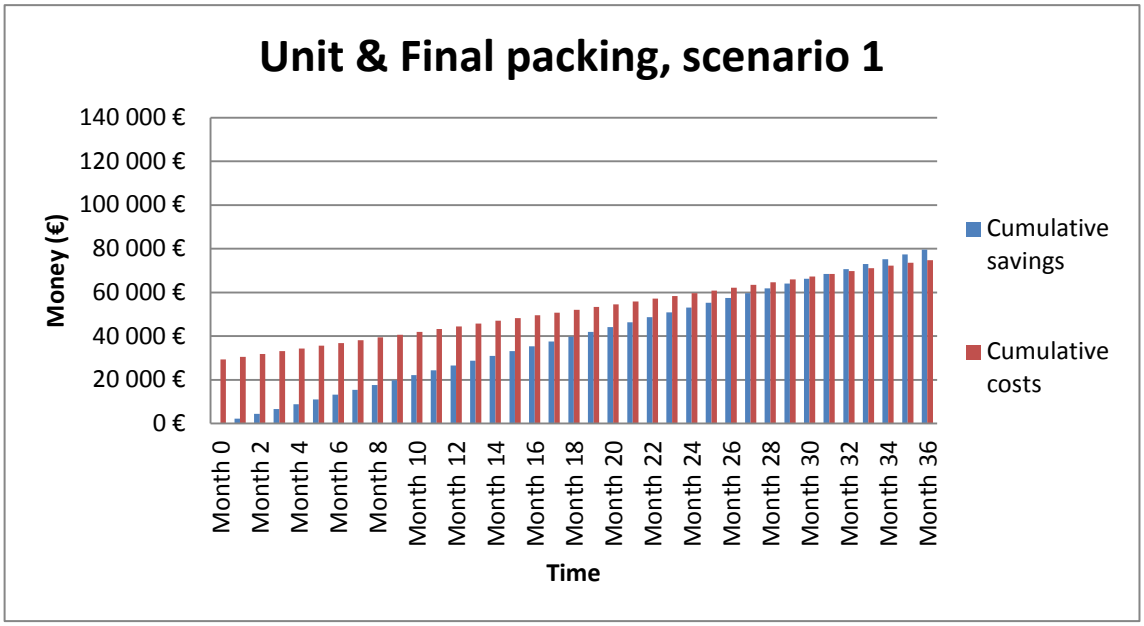
3.6 Combined investment of the Unit & Final packing

Both chapters 3.4 and 3.5 consider unit & final packing as a two separate projects in order that all the other payback calculations related to inbound logistics, assembly and kanban remain comparable with each other. But considerable synergies would be possible to achieve if RFID technology was implemented simultaneously to unit & final packing. In addition unit & final packing are closely related to each other which makes possible to execute the two implementation projects at once. Investment costs consist of RFID printer, a fixed gate and an information system. Consumption of the tagged relay cartons, packing labels and cables form operating costs in addition to annual license payment for the fixed RFID gate.

The most important synergy potential related to investments and operating costs comes from the fixed RFID gate and annual license payment because one gate and one license payment per year is enough to reduce delivery errors related to accessories, cables and wrongly collected relays. Therefore the operating costs will reduce because annual gate license payments for a one RFID gate will be much lower especially in the long run. Also the same information system together with the same tagged relay cartons and packing labels can be easily utilized operations related to both unit & final packing.

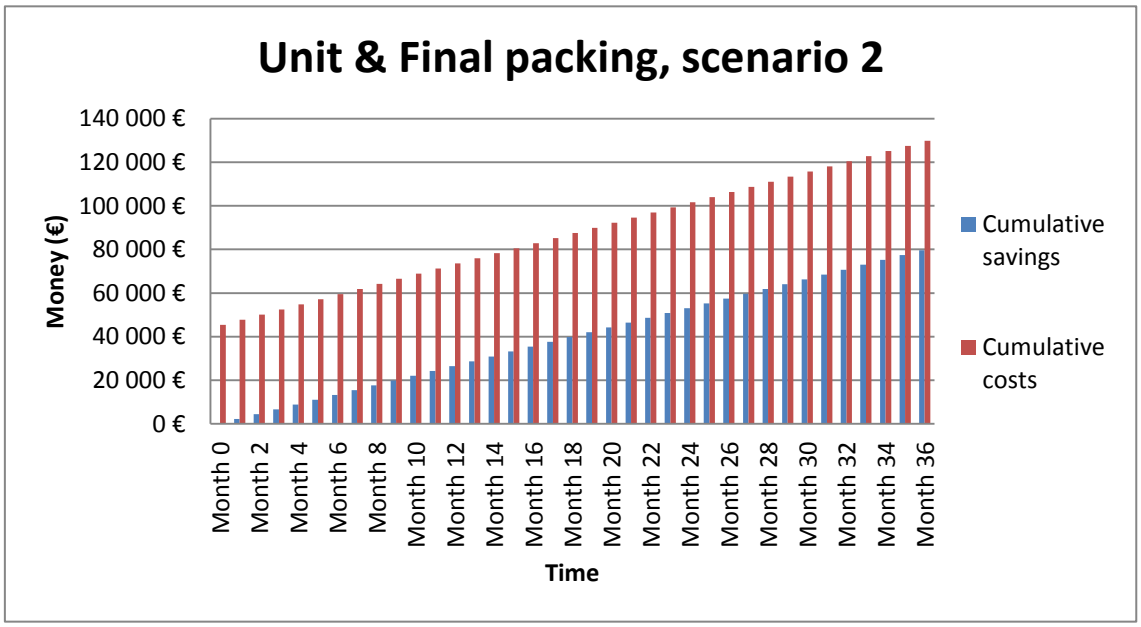
In addition savings gained from unit & final packing can be added together. Elimination of accessory, cable and relay related delivery errors, time savings gained from the accelerated unit packing process all summed up creates a significant amount of savings. Increased saving potential together with decreased investment and operating costs makes a combined RFID implement project a very lucrative option. At ABB a fixed RFID gate, RFID compatible printer and RFID information system are required investments. The first scenario assumes that cable and accessory suppliers are responsible for acquiring the RFID compatible printers and taking care RFID tag related costs. First scenario's operating costs include annual gate license payment and consumption of RFID tag equipped packing and carton labels at ABB. In the second scenario suppliers don't have to worry about the acquisition of the RFID printers and tags because ABB takes care of it. Second scenario's operating costs consists of annual gate license payment and RFID tag equipped cables and accessories delivered by suppliers. Tagged packing and carton labels printed at ABB are also included to operating costs.

Table 14. Unit & Final packing, scenario 1.



Cumulative costs in the tables 14 and 15 include both operating and investment costs. Outcome of the first scenario is presented at Table 14. Investment's payback time is 2,58 years. Table 15 then presents the accumulation of the cost and savings of the second scenario. Because of the cumulative costs there is no payback time and the whole investment is infeasible.

Table 15. Unit & Final packing, scenario 2.



4. CONCLUSIONS

The purpose of this research was to find out is RFID technology a feasibly solution to improve the efficiency of the supply chain at ABB MVP. Financial figures and two different payback scenario calculations were presented at the end of the every process description. The idea for this was to connect all the existing issues, SWOT analysis, a proposal of RFID technology implementation and payback time calculations to present that what kind of potential each RFID system solution could offer to the specific part of the supply chain. Conclusions were done based on the following results and findings.

As a reminder, first scenarios of every payback calculations assumed that suppliers and the external warehouse provider would be willing to acquire RFID printers, gates and tags all by themselves. As a result it is possible that it might increase the price of the accessories when suppliers need to have the same margin from their products than before the additional costs caused by RFID tags. In the case of second scenarios ABB took care of the required investment. This kind of scenario reduced both the suppliers' and external warehouse provider's costs but at the same time ABB's expenses increased. However it is possible that when ABB took care of operating and investment costs for suppliers it decreased the pressure to raise the price of the accessories. It has to be noted that due to the characteristics of the assembly process all the investment and operating costs were the same but the first scenario assumed that time savings were bigger than the savings in the case of second scenario.

Table 16. Payback times

Name of the process	**Payback time (years)**
Inbound logistics: Scenario 1	1,21
Inbound logistics: Scenario 2	2,04
Assembly: Scenario 1	2,17
Final & Unit packing: Scenario 1	2,58
Assembly: Scenario 2	3,31
Final packing: Scenario 1	9,16
Kanban: Scenario 1	36,75
Final & Unit packing: Scenario 2	-
Final packing: Scenario 2	-
Unit packing: Scenario 1	-
Kanban: Scenario 2	-
Unit packing: Scenario 2	-

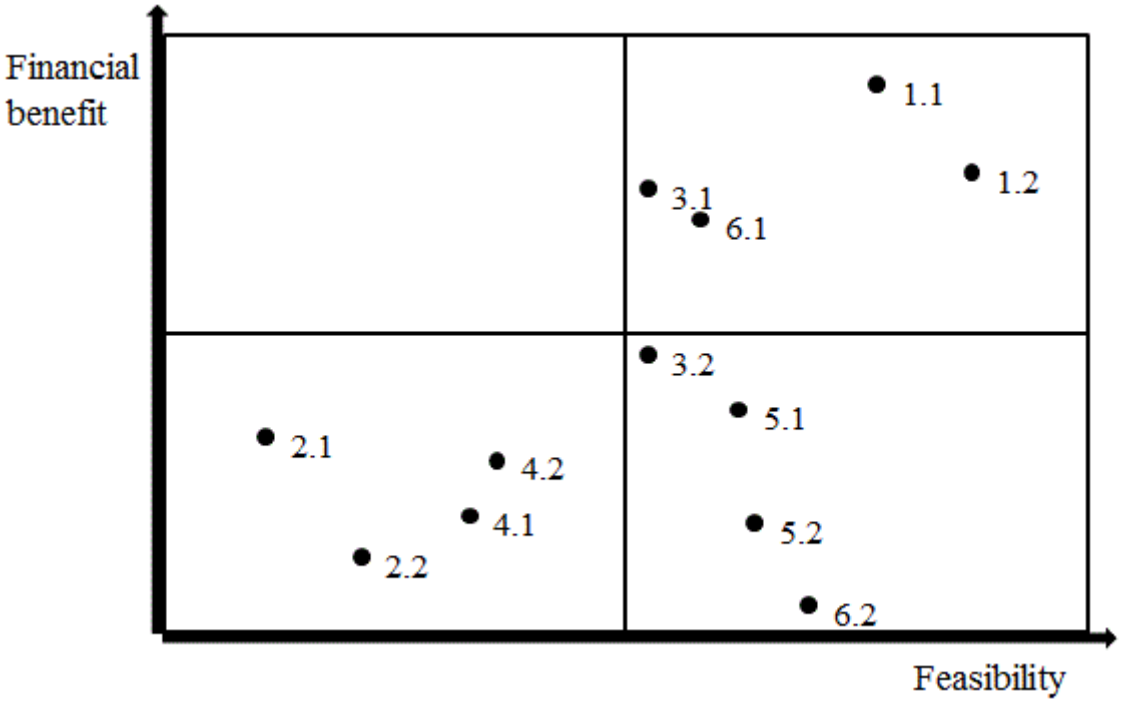
Table 16 presents all the investment payback periods from the shortest time period to the longest. ABB's requirement for a suitable payback period for investment is three years, or 36 months. Highlighted rows in Table 16 reveals that both inbound logistics' scenarios, assembly's first and unit & final packing's first scenario achieve three year payback time and are therefore feasible investments. However kanban's first and second scenario, unit packing's first and second scenario, final packing's first and second scenario, assembly's second scenario and also final & unit packing's second scenario are infeasible investment options and have to be rejected until further notice. When making the calculations it is assumed that every scenario is a separate project and all the investments are described case-by-case except the final and unit packing which is analyzed as a combined project in addition to separate case-by-case analysis.

Table 17. Description of the processes.

Name of the process	**Number**
Inbound logistics: Scenario 1	1.1
Inbound logistics: Scenario 2	1.2
Kanban: Scenario 1	2.1
Kanban: Scenario 2	2.2
Assembly: Scenario 1	3.1
Assembly: Scenario 2	3.2
Unit packing: Scenario 1	4.1
Unit packing: Scenario 2	4.2
Final packing: Scenario 1	5.1
Final packing: Scenario 2	5.2
Unit & Final packing: Scenario 1	6.1
Unit & Final packing: Scenario 2	6.2

It has to be remembered that information technology is the most problematic expense when trying to estimate the total costs of RFID technology implementation. In order to conduct sensitivity analysis further on it is assumed that costs related to information solutions implementation will be 20 % higher than compared to the previous calculations. It can be noted that the 20 % increase on investment costs will have a direct impact on payback times. However all the scenarios, which payback times have been under three years will stay under three years even when costs have increased 20 %.

Picture 20 combines the financial benefit and feasibility of the investment into a single view Horizontal axis presents feasibility of the RFID technology while vertical axis describes financial and table 17 describes what process each number means.



Picture 20. Financial benefit and feasibility of RFID technology

It can be seen from the picture 20 that that inbound logistics' both scenarios, assembly's first scenario and unit & final packing's first scenario are feasible and offer attractive payback time. Like mentioned ABB has already made the decision to implement RFID technology first to inbound logistics. It is an understandable and good decision because the payback time is shortest, improvements are significant and technology can be easily implemented. When thinking about the current challenges and problems the elimination of cable related delivery errors is very important. In order to increase quality of the shipments and achieve cost savings RFID technology would be next implemented together in unit & final packing.

As found out in the chapter 3.5.5 the most feasible way to successfully implement RFID technology to the unit & final packing would be execute it as a joint project because otherwise RFID technology implemented as separate projects doesn’t offer feasible solution. Only first scenario offers a payback time which is less than three years. Although RFID technology implemented in assembly offers a shorter payback time when compared to unit & final packing, it would be more feasible to introduce RFID

technology first to unit & final packing than to assembly because it would took many years, even decades in order that every PCB would be modified and equipped with RFID tags.

Delivery error related costs caused by missing cables, accessories and wrongly delivered relays are the main reason why unit & final packing would greatly benefit from RFID technology. When there is only one cable supplier related to final packing and a handful of accessory suppliers when talking about unit packing the introduction of RFID tagged cables would be possible to implement smoothly and cost efficiently. When talking about final packing missing cables aren't the only problem around because delivery error database reports have revealed that also other kind of missing trading goods have been responsible for delivery errors. The situation would be much more complicated if all the trading goods would be equipped with RFID tags. Significant improvements can be easily achieved by equipping cables, unit packing related accessories and relay cartons with RFID tags. However if suppliers aren't willing to take part on investment and operating related costs the benefits gained from the elimination of delivery errors is not enough to cover the investment and operating costs.

When RFID technology is up and running in the inbound logistics and in unit & final packing it is time to move forward. Payback calculations showed that assembly process first scenario's payback time is attractive short like mentioned before. Also the amount of non-value added manual work reduces. Although assembly process first scenario's pays itself back rapidly than unit and final packing's first scenario, it would be a better not to implement this project until RFID technology has been implemented to final and unit packing. The main reason for this, as mentioned before, are the costs related to the redesigning and updating work of the PCBs which is time consuming and expensive when because there are hundreds of PCBs to be modified.

All the major modification work of the PCBs would be sensible to implement gradually. In order to save costs all the other important and necessary modification work, which are not related to RFID project in any way, can be all done at once. When a whole new protective relay family is designed and created it would be sensible to update the PCBs to be compatible with RFID tags. This kind of R&D project would also be ambitious and thereby risky for all parties. The possibility of failure is the largest when compared to the other processes because the functionality of protective relay has to be ensured at

any condition which furthermore increases the challenges. It must take into account that not all suppliers might find the implementation of RFID tags into their PCBs.

Although a RFID assisted kanban system doesn't seems to be a feasible investment at the moment but when incoming material flow increases significantly in the future, the current situation might change dramatically. It is still unclear how much the capacity increase affects the functioning of the current kanban replenishment process but it is likely that the amount of the manual work related to kanban ordering increases if the current ordering system remains unchanged. In the worst case scenario more and more human errors take place and therefore for example production of the protective relays suffers when there is no material available. Inventory levels will grow uncontrollable, overstocking will be a regular issue and material replenishment process becomes slow and unreliable. Such changes in the business environment mean that all return on investment calculations have to be re-evaluated again. It is possible that the investment becomes more feasible and attractive option when the incoming material flow grows considerably sometime in the future.

As a conclusion it can be said that RFID technology is worth to implement in inbound logistics, unit and final packing and finally assembly in that specific order.

Previous researches about benefits gained from RFID technology implementation are presented at chapter 2.7.1. Those studies have found out that for example manual material counting, packaging errors, transaction mistakes and manual labor have reduced thanks to RFID technology. When comparing the results of this study to the results of all those previous studies it can be easily seen that exactly same kind of benefits are possible to be achieved in a case of implementing RFID technology to ABB MVP's supply chain. Because all previous case study companies are from different sectors it is therefore safe to assume that RFID technology in general would improve all the processes significantly and achieve cost savings also at ABB. Still it has to be remembered that every case study company is a bit different which means that exactly same kind of RFID applications might not be suitable solutions everywhere. Payback times have revealed that the amount of achieved benefits varies quite a lot between supply chain processes of this study and the main reason for this is that every ABB MVP's supply chain process is different.

Earlier studies have also found out that third parties can cause security issues. It is also possible that sensitive information can be captured from the shipments leaving from

ABB. The possibility for such event is low but still possible and it has to be taken seriously. In addition viruses might be a problem if RFID tags are infected deliberately. Those viruses could achieve significant damage to the ABB and there have been reports that RFID technology is used to transmit viruses to information systems. Luckily EPC standard is known for its security which means that the chance of a virus attack is very slim. Studies have also revealed that RFID tags might be physically damaged when goods are moved around. Therefore it is very important that all the workers at suppliers' facilities and also in ABB make sure that RFID tags are intact.

4.1 Alternative solutions

Because RFID technology doesn't offer automatically solutions and improvements for the existing problems, it is therefore justified to discuss about other possible solutions. Surprisingly RFID doesn't offer any significant improvements to the kanban and the reason for this is the current process which is working rather well. Therefore RFID assisted replenishment system is not going to be a wise investment at the moment and other alternative solution for improving the replenishment process has to be considered. One possible solution is to train all the workers to make the replenishment orders only when it is absolutely necessary and thereby overstocking could be avoided. In addition workers should be more careful that they would order exactly right materials. The user interface could also be re-designed in order to be more user friendly so that user related errors can be minimized.

Surprisingly RFID technology doesn't offer as much benefits to the unit packing as it was thought at the beginning of the research process. The reason for that, despite delivery error reports related to missing cables and other accessories, is that the amount of unit packing delivery errors has been rather small. It can be said that the current unit packing works well. It is easily possible to eliminate delivery errors by equipping all the accessories with RFID tags but when thinking about all the necessary investments and feasibility of the new technology in general, there are other alternative solutions which have to be also considered. First of all there are so many different accessories, including cables, installation kits and other accessory related items that it would be very expensive to tag every single of them, like noted in case of the second scenario payback calculations. If suppliers would be ready to take care all of the operating cost, it would cause pressures to the cost of the accessories. In addition there are several accessory suppliers which make the implementation process harder. In addition some of the

accessory items are metallic which would further raise the costs and increase the challenges of the implementation process.

An alternative and more cost effective solution to reduce unit packing related delivery errors is to equip all of the accessories with bar codes because they are much cheaper to print than RFID tags. In addition bar code scanners are already used at the unit packing so it there would be no further investment costs either. During the unit packing workers would check all the accessories packed by reading the barcodes directly from accessories. When compared bar code tagged accessories to the current system where there is a separate list of barcodes or even no bar code list at all to check that everything is packed correctly to a situation where every accessory is equipped with barcodes, this would be a major step ahead in order to improve the quality of deliveries. However accessory bar code solution can't still make sure that the checked accessories are actually being put inside the cartons. But when comparing the investment and operating costs of the RFID technology to bar codes, the cheapest solution would be to equip all accessories with bar codes.

Like mentioned earlier on, RFID tags will be installed only on the cables in the case of trading goods because cables have turned out to be the most problematic items. By equipping all the other trading goods with barcodes in addition to tagged cables is an option worth to consider. A portable bar code scanner is already introduced to final packing in order to make sure that right protective relays have been picked from the unit packing's shelves until a better solution is found. The idea is to further expand the portable barcode scanner also to the trading goods. When technology and necessary equipment are in place, bar codes can be easily introduced to all the other trading goods. Although cables have been responsible for a lot of delivery errors, other trading goods have also caused problems. However the best outcome in order to reduce delivery errors cost-efficiently would be achieved by equipping cables with RFID tags and all other trading goods with barcodes. The reason why it isn't a good idea to attach barcodes to cables is the large amount of cables which customers order because barcodes from every cable should be then read one by one which would be very time-consuming work.

4.2 Answers to the research questions

This research was able to find answers to all the research questions which were determined at the first chapter of this study. As a reminder research questions were following:

1. Is RFID technology feasible in the case of ABB MVP?
2. Where in the supply chain RFID technology would give the best benefit?
3. What would be the possible cost savings after RFID technology is implemented?

In generally speaking RFID technology is a feasible solution for ABB MVP but when looked more closely there are considerable differences in the payback time and general feasibility of the new technology. Best benefits are achieved when RFID technology is implemented to inbound logistics, assembly and also final & unit packing. When the goal is to minimize manual errors caused by the non-value adding work and automatize the material receiving process then the most suitable choice is to implement RFID tags to inbound logistics. When talked about delivery errors the advantage offered by the RFID technology is tremendous and that is why RFID technology suits well for unit & final packing. And if the goal is to make assembly process faster RFID technology offers a lot of opportunities to reduce non-value added work. Both scenarios suggest that RFID technology is a feasible solution to implement in inbound logistics. When talked about unit & final packing the first scenario is the only feasible choice. According to payback calculations assembly's first scenario is the feasible solution to be implemented.

Table 18 presents the achieved cost savings after three years. As can be seen the inbound logistics offers the biggest cost savings after unit & final packing and assembly.

Table 18. Achieved cost savings.

Name of the process	**Cost savings after three years**
Inbound logistics: Scenario 1	113 925,00 €
Inbound logistics: Scenario 2	113 925,00 €
Assembly: Scenario 1	64 523,20 €
Final and Unit packing: Scenario 1	79 569,25 €

4.3 Research limitations

Most of the data used in this research was gathered by analyzing information from SAP and ABB's various databases. If there has been wrong information for example related to material quantities or some reports has been missing completely reports in the case of delivery errors, it will have a direct impact on all the payback time calculations and conclusions. All the calculations were based on the year 2013 information and reports. If the production quantities are going to change considerably, all calculations had to be checked and re-evaluated again in order that all the investment calculations would offer reliable information. In that case it is possible that some of the implementation plans, which are unfeasible at the moment, would become more feasible in the future. It was assumed that all the costs related to the RFID technology, for example tags, readers, middleware systems were the same in every part of the supply chain. If some implementation processes were more demanding than others, then payback calculations were inaccurate. The shortcoming for payback time method is that it doesn't include any cash flow after payback period. When projects create profit after the payback period the payback time method doesn't take account of these cash flows. As a result shortcomings of the payback time calculation method are a considerable research limitation.

The limitation related to observations is that the behavior of the observed person can change while being observed by the researcher. It is possible that workers in ABB changed their way of working when they saw that observations were made. The challenge of making generalizations, which is a usual shortcoming of case studies, has to be also remembered. This study achieved the goals set by ABB by finding where the RFID technology would offer significant benefits. However when the case company is completely different, the exactly same calculations and assumptions used in this case study can't be reused because every case and company is different. Some applications and solutions might not be feasible solutions at all. Still there are conclusions which can easily be done based on this study. Also in case studies the individual skills of the research are very important.

4.4 Future research suggestions

When considering the future research possibilities, one of the most interesting questions is to find out how to further utilize RFID technology in the supply chain. The scope of this study only includes MVP's factory logistics which means that there is room to conduct further research. Some of the processes of external warehouse provider were analyzed in this study but not all of them. External warehouse provider stores a large amount of material in its warehouse which means that there is a significant potential to gain major improvements and savings. For example significant cost savings could be achieved by introducing RFID technology to the whole warehouse including forklifts. The implementation process of RFID tags to PCB's will be a major task which also opens up possibilities to conduct several academic researches. Possible research subjects could be for example the how to mount the RFID tag to PCB and design the antenna such that the solution it would be economically and technically feasible. It should also be researched that what kind of benefits RFID technology offers to the service business. It is assumed that servicing of the protective relays will be easier and more efficient when every PCB contains a RFID tag.

5. SUMMARY

This Master's Thesis was about researching the feasibility of RFID technology in case of ABB Medium Voltage Products. All the existing processes including inbound logistics, kanban, assembly and final and unit packing were described and current problems were presented at first. Then proposals of how RFID technology would be implemented were described and payback calculations were done related to every process. The type of this study was a case study and there were elements from both quantitative and qualitative research methods. Material for this study was collected from SAP, delivery error database, process descriptions and also by conducting interviews and making observations. Quantitative analysis was based on gathered data and payback time calculations and interviews and observations formed qualitative analysis. Literature review contained a large variety of technical description of RFID technology and also several real-life examples of RFID technology implementations. This study was able to find out answers to all three research question

Results of the payback time calculations showed that payback time in RFID technology investment can be under three year in case of certain supply chain processes. However there were a lot of processes where RFID technology couldn't achieve the three year payback time objective. It has to be noted that the investment calculations were divided in two different scenarios. The main difference between first and second scenario were that first scenario assumed that suppliers were willing to take care all investment and operating related costs. In case of second scenario ABB was responsible for all of the above-mentioned costs. Due to the nature of the assembly process the difference between first and second scenario were the amount of achieved savings. First scenario was more positive than second scenario related to the saving potential.

Supply chain processes, where the RFID technology investment paid itself back within three year target time, were inbound logistics' both scenarios, assembly's first scenario and unit & final packing's first scenario. Payback time in other supply chain processes was either too long or the investment couldn't achieve a payback time if the cumulative costs were constantly higher than achieved savings. Although other processes were infeasible solutions at the moment it didn't necessarily mean that the situation would remain unchanged in the future too. In addition alternative solutions were also presented because RFID technology wasn't able to offer feasible solutions for every process.

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