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The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology

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Acknowledgements

"Believe you can and you are halfway there"
—Theodore Roosvelt

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Lastly, but not less important, I would like to thank my parents because of their unconditional support and because they have always given me opportunities to do wonderful things as this Master Thesis in Norway.

Preface

"The only way to do great work, is to love what you do"
—Steve Jobs

This master thesis has been performed at the Department of Production and Quality Engineering at the Norwegian University of Science and Technology (NTNU). It has been supervised by the Professor Kesheng Wang and the PhD student Haishu Ma.

Trondheim, 2016-05-31

Laura Domingo

Abstract

"Logic will take you from A to B. Imagination will take you everywhere"
—Albert Einstein

Internet has changed our life. It has brought a new way of communication, of transfer information and make businesses. The term already known as "*Internet of things*", give the idea of the digital connection of objects via internet, creating a network which enables this objects collect and exchange data. This concept has triggered a new industrial (r)evolution, where new technologies are developed bringing more automation and transparency to manufacturing.

This Master Thesis presents a framework of this new industrial (r)evolution applied to Logistics Processes, where Cyber-Physical System and technologies, which free humans to carry out activities which are repetitive and automatic, play an essential role. It is explained which are the technical components of Logistics 4.0, giving current examples of companies which are applying these technologies.

Parts of CPS as Radio Frequency Identification System are further developed in a Case Study, where is attempted to give a clear understanding of how Logistics 4.0 solutions can add value to the actual Logistics.

The outcome of this Master Thesis can be applied in manufacturing industry where Supply Chain Management is an important issue to optimize the production.

Contents

List of figures

Nomenclature

IT	Information Technology
IoT	Internet of Things
IoS	Internet of Services
RFID	Radio Frequency Identification
II-RFID	Intelligent Integrated RFID
CPS	Cyber-Physical System
GA	Genetic Algorithm
ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
WMS	Warehouse Management System
SCM	Supply Chain Management
CMM	Control-Monitoring Maintenance
RTLS	Real Time Locating System
KDL	Knowledge Discovery Lab
II-RFID	Intelligent Integrated Radio Frequency Identification
EPC	Electronic Product Code
RTLS	Real Time Locating System
TDOA	Time difference of arrival
AoA	Angle of arrival
EPC	Electronic Product Code

List of Tables

Chapter 1 Introduction

Industry is the part of the economy that carries out the production of materials and goods, which are highly mechanized and automatized. From the beginning of the industrialization technological changes have driven the paradigm shifts that are called "*industrial (re)evolutions*" (Lasi , Kemper, Fettke, Feld, & Hoffmann, 2014). Nowadays, the industrial production has reached the edge of a new industrial revolution and the factory of the future has been pictured (Schelechtendal, Keinert, Kretschmer, Lechler, & Verl, 2015).

According to experts from industry and research, the upcoming revolution will be triggered by the use of Internet that enables the communication between each other humans and machines in CPS throughout large networks (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

The increasing globalization and the way as the information and communication technologies (ITC) are growing and affecting all the parts of our life, is a daily reality. This makes that processes as supply chain or customer service, which are part from the logistics management or the supply chain management, have become essential things for a company, in order to be competent within the market.

We can understand logistics of a company as all the processes that make possible to have the right product at the right place, at the right moment in the right condition (Uckelmann, 2008).

Talking about the industrial changes over time, it can be understood how the technology in logistics has changed and its evolution over time. Therefore, it will be one of the aims of this thesis. The future logistics will be pictured under the term of "Logistics 4.0".

1.1 Objectives and motivation

There are many researches about the evolution of the technology within the industry and how is the new concept of "smart factory" which is called "Industry 4.0". However, the concept of this development applied to logistics processes within the manufacturing, is still a non-spread topic. Therefore, the aim of this Master's project is to talk about the evolution of logistics systems and towards this evolution is moving nowadays, making a framework of logistics and talking about this new evolution called "Logistics 4.0".

The objectives of this Master Thesis have agreed with Professor Keseng Wang (supervisor). These agreed objectives are:

1. To give a brief perspective of what Industry 4.0 is
2. To make a framework of Logistics 4.0
3. To explain the state of the art of Logistics 4.0 and towards this concept is moving
4. To give actual examples of the technology of Logistics 4.0
5. To make an implementation in the Lab of RFID technology which is an essential part of the technology applied for the development of Logistics 4.0
6. To explain a real implementation of a RFID system in a Norwegian company, which meets some of the concepts of "Logistics 4.0"

Currently Internet is an essential technology. It has changed our way of communicate with each other and the way we consume information. Furthermore, it enables to share and to communicate data in real time and to have access to information from whatever part of the world and whenever is wanted. This applied to logistics, can be seen as a revolutionary technology that can optimize the supply chain management and change the relationship between suppliers, companies and customers, creating a network and enabling the cooperation between them easily, as well as the communication between each other humans and machines.

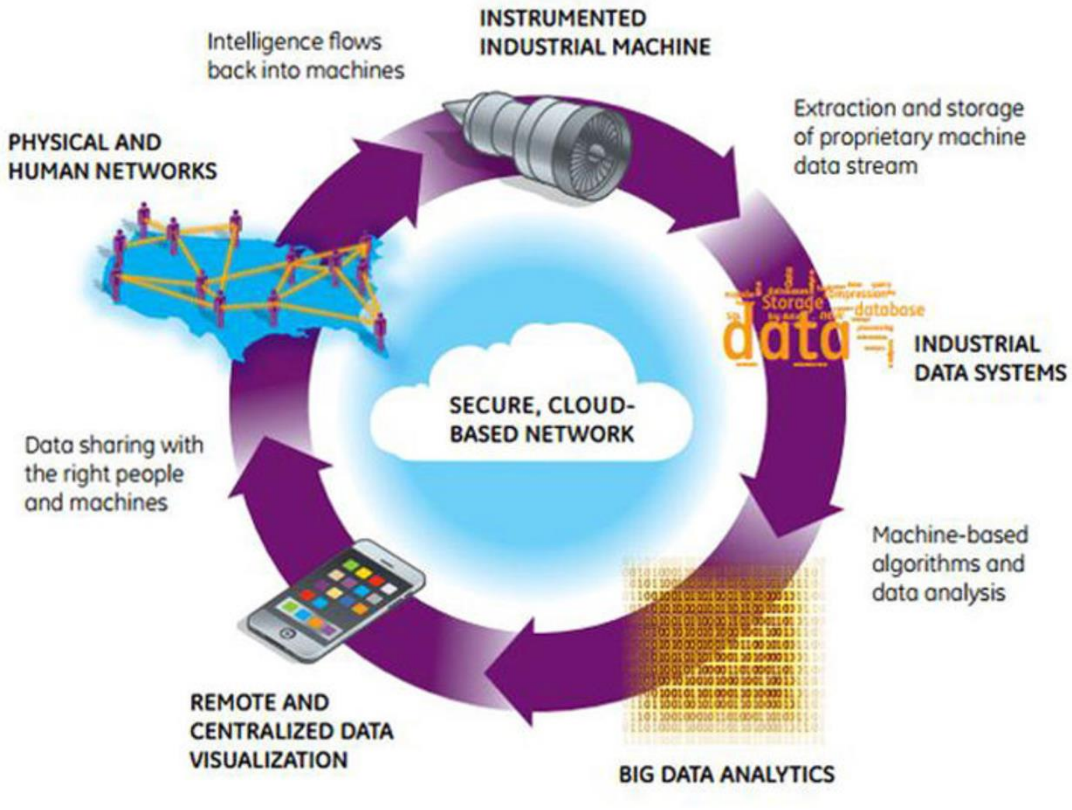

Figure 1.1 Internet of things in manufacturing ('Industrial Internet': M2M for planes, 2012)

As we can see in the figure 1.1, IoT enables to share information in real-time and to storage big amount of data in order to have access whenever and wherever is wanted, although it is essential a good security software in order to protect all this information. Therefore, by the use of Internet, a network can be created which connects factories and people as well as machines with each other, making a faster and more optimized logistics processes. systems, whichcollect and analyse data and

Hence, my main motivation is to finish my master's study knowing what can be understood nowadays as smart technology in logistics. As well as read and know about the actual logistics scenario and towards this scenario is moving, writing about:

1. How logistics have changed over time
2. How the IoT is being implemented for supply chain management
3. How IoT and the RFID systems can change the actual logistics scenario

1.2 Challenges and contribution

The main challenge writing this thesis has been the lack of information, since Logistics 4.0 is a non-spread term. It is easy to find information about Industry 4.0 and its components but it is not easy to find this information focused in the logistics part.

Furthermore, I have found a challenge in the fact that logistics is a broad term that encompasses many different processes, therefore it has been a challenge to include the right contents in order to give a clear understanding of the new evolution in logistics and make a proper framework of it.

My main contribution will be a framework of Logistics 4.0. It will be given a clear understanding of how the technology and the way of work in logistics have changed from the beginning of the industrialization to nowadays, and how the use of the IoT and RFID systems can trigger an evolution of the actual logistics.

1.3 Literature review

Manufacturing is an important part of the world's economy and the optimization of the production phases has always been an important issue. In order to reach this optimization, it is needed the use of new technologies that enables the production to adapt to the customer needs and to the market features.

Every market has different customer needs and market characteristics, but talking in a general way of the manufacturing, nowadays we find a need of flexibility, real time response to the changes in the market and a closer position to the customer preferences (Uckelmann, 2008).

Manufacturing companies have realised that customers do not want to pay large price premiums for incremental quality improvements; consequently, many manufacturing companies have adjusted their production focusing on customized products and fast time to market.

Due to novel manufacturing strategies such as Agile Manufacturing and Mass Customization, manufacturing enterprises are transformed into integrated networks, in which they join their core competences. Therefore, virtualization of processes and supply chain ensure smooth inter-company operations giving real time access to important production and product information for all participants by internet. This makes that companies' boundaries deteriorate as autonomous systems exchanging data, gained by embedded systems throughout the entire value chain (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

Consequently, the industrial production is moving towards a globalization, open supply chain network, short-term business connections and cooperation between the stakeholders. The technology needed to cover this new requirements, is already available and all encompassed in the concept called Industry 4.0, with the main issue of the high cost (Schelechtendal, Keinert, Kretschmer, Lechler, & Verl, 2015).

Hence, the main problem of applying the last technology is the price, it is necessary that the optimization of production has enough benefits. Even having enough benefit the investment is such high that is needed different pricing schemes as the concept of the *Billing Integrated Internet-of-Things* that allows multi-directional cost sharing and profit generation across supply chains. Nowadays there is no comprehensive approach for an open and integrated billing solution (Uckelmann, 2008).

Thus, it will be necessary leave clear the concept of Logistic 4.0 and how it can be implemented in order to achieve a clear understanding of how it can add value to the existing logistic processes. Once the future is clear it will appear new pricing schemes where this technology can be developed. As further research we could have these new pricing schemes, but it is not the aim of this thesis. The objective of this master thesis is the description of Logistics 4.0 and the technology that it involves as well as explain some examples of the application of this technology applied to the intralogistics processes.

It is important to understand what processes of the manufacturing the logistics includes, in order to know in what part of the production system this master thesis is focused.

1.3.1 Logistics and supply chain management

Early references to logistics as a word are found preliminary in military applications. It is found in 1898 that logistics is discussed as, "S*trategy is art of handling troops in the theatre of war; tactics that of handling them on the field of battle… The French have a third process, which they call logistics, the art of moving and quartering troops…*" (Lummus, Krumwiede, & Vokurka, 2001).

Nowadays, the term logistics means, in a broad sense, the process of managing and controlling the flows of goods, energy, information and other resources as facilities, services and people. It involves the integration of information, transportation, inventory, warehousing, material handling and packing (Gen, Cheng, & Lin, 2008).

Supply chain management is a term that emerged later from the textile industry and grocery industry, and it is used to define the integration of all inbound logistics processes with the outbound logistics, linking all of the partners in the chain including departments within an organization and external partners including suppliers, carriers, third party companies and information system providers (Lummus, Krumwiede, & Vokurka, 2001).

Therefore, we will refer in this thesis to the logistics management as the governance of supply chain functions and intralogistics functions, as an integrated logistics. Logistics management activities typically will include inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of third party logistics services providers. To varying degrees, the logistics function will also include customer service, sourcing and procurement, production planning and scheduling, packaging and assembly. It is part of all levels of planning and execution (strategic, operational and tactical) (Tseng, Yue, & Taylor, 2005).

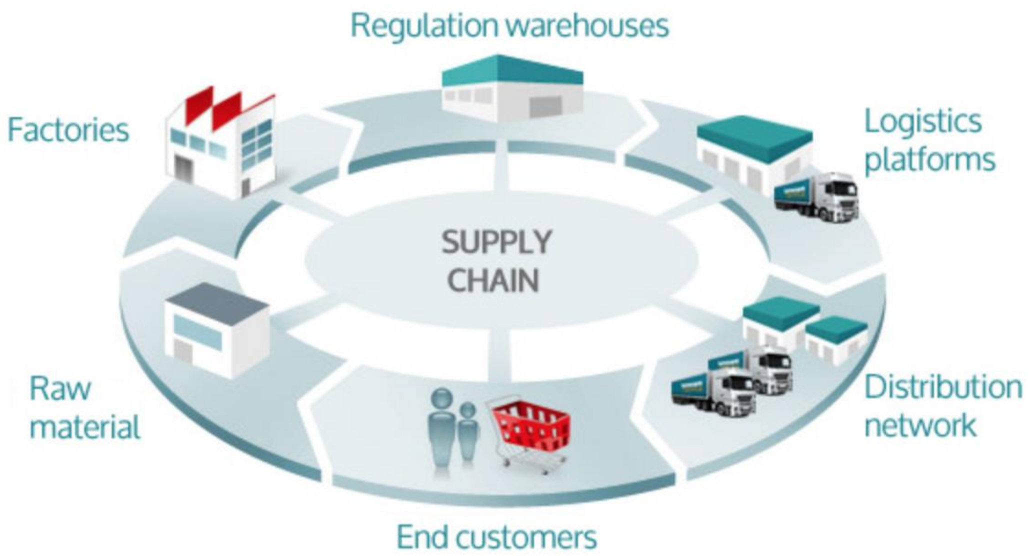

Figure 1.2 Logistics Management (Supply chain functions) (Salvesen Logístca, 2014)

Hence, the logistics responsibilities are the geographical repositioning of raw materials, work in process and inventories to where required the lowest possible cost (Gen, Cheng, & Lin, 2008).

As we can see in the figure 1.2, supply chain seen as integrated logistics, encompasses logistics inbound and the logistics outbound as well as all the management processes needed to distribute products and reach a proper delivery to customers (in the right moment, in the right place to the right customer).

For industries, logistics helps to optimize the existing production and distribution processes based on the same resources through management techniques for promoting the efficiency and competitiveness of enterprises (Tseng, Yue, & Taylor, 2005).

The closely linked components of the logistics system are:

1. Logistics services

   Logistics services support the movement of materials and products from inputs through production to consumers, as well as associated waste disposal and reverse flows. They include activities undertaken in-house by the users of the services (e.g. storage or inventory control at a manufacturer's plant) and the operations of external service providers. They comprise physical and non-physical activities (e.g. transport, storage and supply chain design, selection of contractors, freightage negotiations respectively). Most activities of logistics services are bi-direction.

2. Information systems

   Information systems include modelling and management of decision-making, and issues that are more important as tracking and tracing. It provides essential data and consultation in each step of the interaction among logistics services and the target stations.

3. Infrastructure/resources

   Infrastructure comprises human resources, financial resources, packaging materials, warehouses, transport and communications. Most fixed capital is for building those infrastructures. They are concrete foundations and basements within logistics systems.

(Tseng, Yue, & Taylor, 2005)

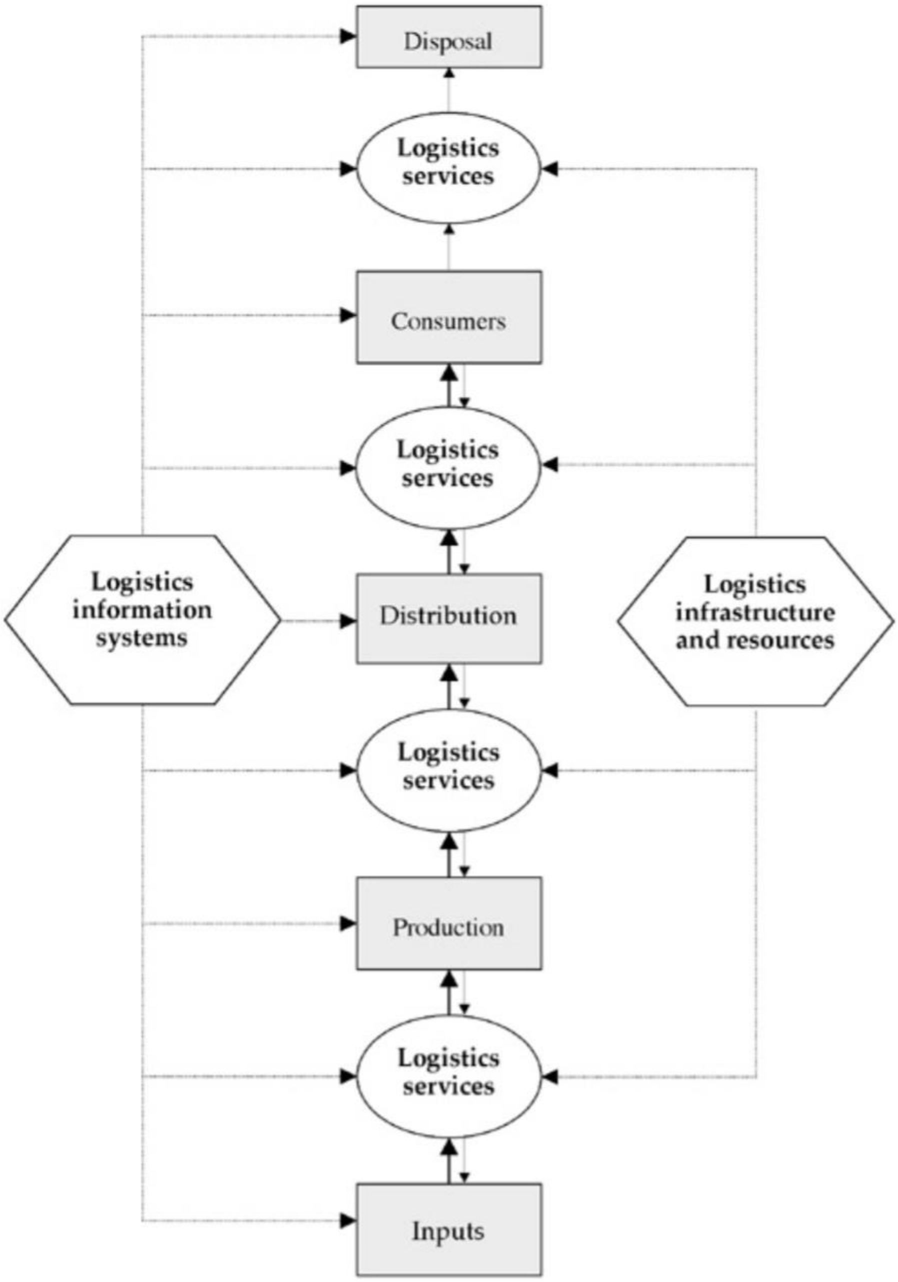

Figure 1.3 Overview logistics system (BTRE, 2001)

As a summary of the figure 1.3, can be said that the logistics system involves the entire process of shipping raw materials (inputs); the conversion of the goods into the final products at the plant (production); the transportation of the products to different warehouse and eventually the delivery of these products to the final customers (distribution and consumers). To manage all this system efficiently, the transportation and the storage of the goods are essential points in order to control the dynamic and the static material flows (Gen, Cheng, & Lin, 2008).

How to manage logistics system efficiently has become a very important point for almost all the companies, especially multinational enterprises in order to save costs in today's competitive environment (Gen, Cheng, & Lin, 2008). The optimization of logistics systems is fulfilled by the core processes of goods flow (transport, storage and transhipment), the supporting processes (packing, test processes) and the order transmission and processing processes (Premm & Kirn, 2015).

In short, there is a shift from traditional supply chains to open supply chain network, from long-lasting business relationships to short-term business connections, so it is needed new methods, products and services for the complexity of this supply chain network. As well as, more automation in order to optimise the movement of goods within the plant by giving the necessary information to the proper operator in the proper moment.

The globalization of the markets makes aspects as flexibility, adaptability and proactivity gain importance and these features just can be achieved integrating new technologies (Uckelmann, 2008).

1.3.2 Smart Logistics

Logistics 4.0 is related to the same conditions as Smart Services and Smart Products. So the technology driven approach used to define "Smart Products" and "Smart Services" is used to define "Smart Logistics".

We cannot fix something as smart since this is a term that can change over time and with the technological advances or the technology driven in that moment. Therefore, the term "smart" depend on the time and the advances. As Mark Weiser, man seen as the father of ubiquitous computing already criticized the change dependant of the term "Smart": "*The "Smart House" of 1935 had an electric light in every room. The "Smart House" of 1955 had a TV and telephone in every room. And the "Smart House" of 2005 will have computer in every room*".

It is needed a more accurate definition than just "Smart Logistics" of what Logistics 4.0 is, since the "Smart Logistics" will change depending on the actual technology driven, so it has a time dependency and it is essential to define the state of the art of the technology in order to know what Logistics 4.0 involves. (Uckelmann, 2008)

Therefore, it is important to keep in mind that every time that is used the concept of smart in a definition, it has a temporal connotation and it will change with the technology driven in the actual moment.

What we can understand nowadays as "Smart Logistic", is a logistics system, which can improve the flexibility, the adaptation to the market changes and will make the company be closer to the customer needs. This will make possible to improve the level of customer service, the optimization of the production and make lower the prices of storage and production.

Recent technology developments that have resulted in high availability and affordability of sensors, data acquisition and computer networks, and the competiveness of today's industry has forced more factories to implement high-tech methodologies. The information from all related perspectives is closely monitored and synchronized between the physical factory floor and the cyber computational space, creating a network where all the information can be shared in real time (Lee, Bagheri, & Kao, 2014).

1.3.3 Smart products and smart services

Smart products and services are those who can carry out tasks that normally are carried out by people. In addition, they make possible to delegate activities so the employees can focus on the tasks that are needed more intelligence than automatic processes or the smartness that a simple Smart Product or Smart Service can provide.

Nowadays, the concept of smart products defines the products which have the ability to do computations, store data, communicate and interact with their environment. Starting from RFID technology that enables products to identify themselves. They are able to communicate information about not only the steps already passed through but also are able to define future steps. They are capable to interact with their environment, for example, sensors allow to capture physical measures, cameras to get visual information on the product and its environment in real time, as well as the actuators enable the products to impact physical entities in their environment without human intervention (Schmidt, Möhring, Härting, Reichstein, Neumaier, & Jozinović, 2015).

Some examples of smart products would be:

- Vending machine senses its inventory as well as its service needs and generates a message, if replenishment or service is required
- A printer that only works with original ink cartridges
- Packaging of cold chain goods indicates, if cold chain has been disrupted

Even the "*Internet of things*" is not required to offer a Smart product or Service, these last examples are based on machines that work without cooperation with others machines, but as many functionalities that the machine had as many means of communication it will be necessary to keep the concept of smart.

On the other hand, Smart Services offer the ability to measure what could not be measured before. They enable pricing, operating and trading. Examples of Smart Services would be:

- Control services, which make possible to delegate control tasks as tracing and tracking, theft protection, falsifications or reordering
- Risk services, that enable the insurance changes their pricing model based on estimates to usage based fees
- Information services, which enable instant online access to ubiquitous computing related information
- Leasing services, that with high visibility enables conversion of the basis of calculation from owner based information to usage based information

In short, the Smart Logistics frees humans from carry out logistics activities that can be delegated to Smart Products or Smart Services (Uckelmann, 2008).

1.4 Outline of thesis

The master thesis is structured in seven chapters. The first chapter includes an introduction of how important is the logistics part in manufacturing and the way of the globalization and the communication as well as information technology are growing and affecting the industry. In short, the first chapter explain which is the direction of the thesis. The second chapter will include an explanation of the term of Industry 4.0 and its main components, giving some examples of application. The third chapter will be the framework of Logistics 4.0. The fourth chapter will be about the technical components of Logistics 4.0, and afterwards the fifth chapter will be the implementation of II-RFID system in the Knowledge Discovery Lab (KDL). The sixth chapter will include a Norwegian perspective of Industry 4.0 where a real implementation of an II-RFID in a Norwegian company will be explained. At the end, the thesis will be concluded with the seventh chapter that will include the conclusions and proposes for further researches.

Chapter 2 Brief perspective about Industry 4.0

The aim of this chapter is to give a brief understanding of Industry 4.0 movement from where Logistics 4.0 has its roots.

2.1 State of art of Industry 4.0

The term Industry 4.0 appeared published for the first time in 2011, when an association of representative from business, politics and academia promoted the idea as an approach to strengthening the competiveness of the German manufacturing industry. The German Government supported the idea by announcing that it will be an integral part of its "*High-Tech Strategy 2020 for Germany*" initiative. The subsequently formed "*Industrie 4.0 Working Group*" which developed first recommendations for implementation, which were published in April 2013 (Herman, Pentek, & Otto, 2015) .

The concept of Industry 4.0 is used across Europe. In the United States and the English-speaking world more generally, also use terms as "'*The Internet of Things*" or the "*Internet of Everything*" (Deloitte, 2014).

The Figure 2.1 shows the environment of Industry 4.0. This thesis is focused in the smart logistics:

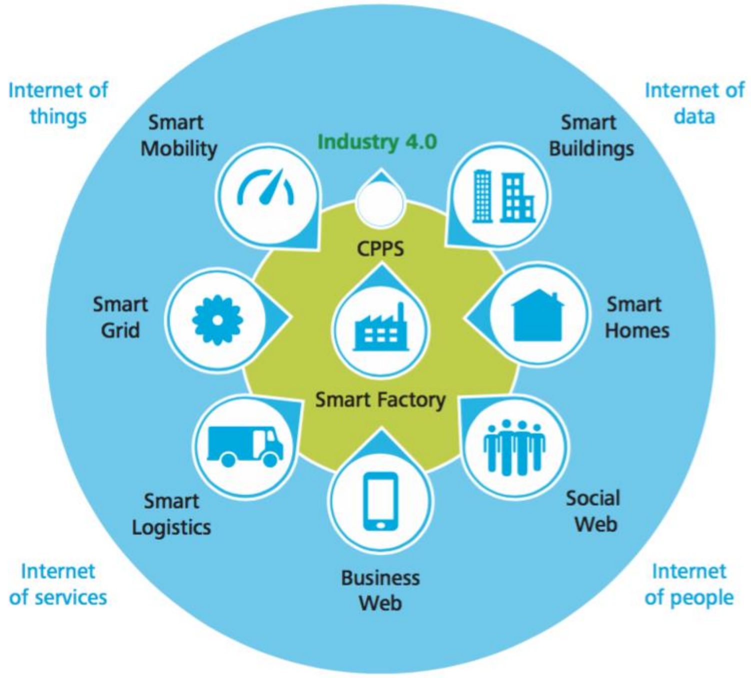

Figure 2.1 Industry 4.0 environment (Deloitte, 2014)

In short, the essence of Industry 4.0 is the Internet of things, which means the ubiquitous connection of machines, products, systems and people. In other words, machines and products can communicate so they can manage themselves and each other. Tools, products or means of transport are expected to negotiate within a virtual marketplace, creating a continuous link between the virtual and the physical world (Wegener, 2015).

Therefore, software-based systems and service platforms will play a major role in tomorrow's manufacturing, since they are the only way to bring connectivity, including data analysis, to machines and work pieces in production (Bosch, 2016).

Industry 4.0 is a term that facilitates the vision of the future "*smart factory*", and therefore "*the smart logistics*" as well. It might be defined as the embedding of smart products into digital and physical processes. Digital and physical processes interact with each other and cross-geographical and organizational boundaries (Schmidt, Möhring, Härting, Reichstein, Neumaier, & Jozinović, 2015).

This fourth industrial revolution describes a project as a basis for two fundamental development directions. On the one hand, an application pull that induces to a change in the operative framework conditions. Thus, this will mean social, economic and political changes. Those are in particular:

- Reduction of the development and innovation periods. High innovation capability is turning into an essential success factor for many companies
- Individualization sales. Over the time, the buyers have gained the chance to define the conditions of the trade. This trend leads to an increasing individualization of products. It is called "*batch size one*"
- Flexibility. Due to the characteristics of the markets is essential flexibility in the production
- Decentralization. To deal with the new framework requirements, faster decision making procedures will be necessary. This is why organizational hierarchies need to be reduced
- More sustainability. The aim is an economic and ecological efficiency in the production, due to the increase of the prices for resources as well as the social change in ecological aspects

On the other hand, there is a technological-push as the Smartphones, 3D-printers, the laptops, Apps, etc. that are affecting our life in the most of the contexts. However, in industrial practice these innovative technologies are not widely spread. Therefore, approaches of these technological innovations are:

- More technological aid used that support physical work as well as more automatic solutions adopted such as autonomous forklifts with their routes programmed or powered suits that will help the operators with the work load, both further developed in the next chapter
- Digitalization and networking. New technologies as simulation, digital protection or virtual representation are driven by the increasing digitalization of all manufacturing and manufacturing-supporting tools likewise the increased networking of technical components, as the software used to track goods within the factory or the database used to collect and analyse the RFID data read from the tags
- Miniaturization. While computers required much space some years ago, nowadays devices with better performance can be installed in a few cubic centimetres. This makes possible new fields of application, especially in logistics

In short, the term Industry 4.0 describes different, mainly IT driven, changes in manufacturing systems and especially in the logistics processes. These developments have technological as well as furthermore organizational implications (Lasi , Kemper, Fettke, Feld, & Hoffmann, 2014).

The figure 2.2 shows the investment in Industry 4.0 solutions from a study made by the companies PwC and Strategy& in 2015 in the German sector of manufacturing and engineering, automotive and process industries.

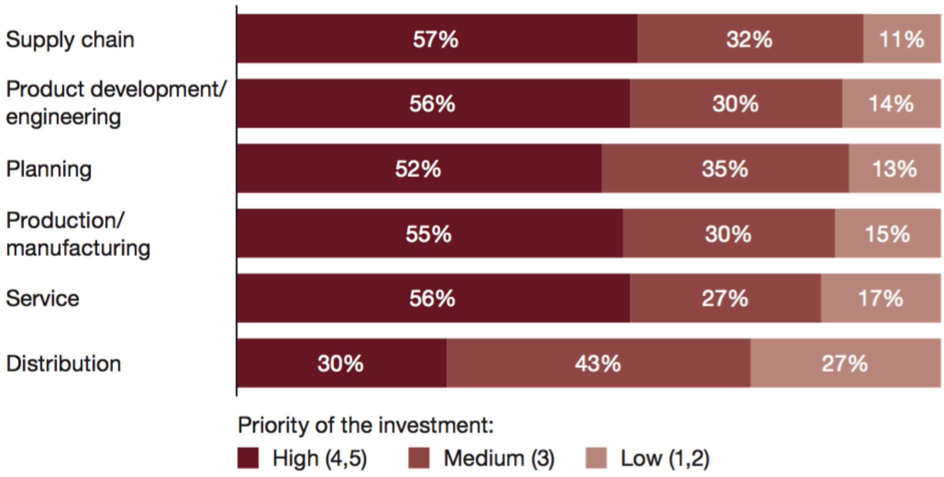

Figure 2.2 Investments in Industry 4.0 solutions from a survey study in the German industrial sector (Wegener, 2015)

It can be seen Industry 4.0 investments broken down by steps of the value chain. The conclusion is that companies (mainly in the information and communication industry) focus their investments on the optimisation of the logistics system, leaving clear the importance of the supply chain management in this fourth industrial revolution.

2.2 Main components

Industry 4.0 embraces a set of technologies enabling smart products as well as processes integrated into intertwined digital and physical processes. It will change business models, business processes and supply chains significantly (Schmidt, Möhring, Härting, Reichstein, Neumaier, & Jozinović).

The main components that form the concept of Industry 4.0 are:

- *Cyber-physical system* (CPS), the term that describes the unification of digital (cyber) with real (physical) workflows. In manufacturing, this means that the physical production steps are accompanied by computed-based processes, using the concept ubiquitous computing. CPS includes sensors and actuators by which can collect and send data. These CP systems are based on the Internet as a mean of communication. One example of a CPS would be the intelligent bin (*iBin*) by Würth. It contains a built-in infrared camera module for C-parts management, which determines the amount of C-parts within the iBin. If the quantity falls below the safety stock, the iBin automatically orders new parts via RFID. This allows consumption based C-parts management in real time

- *Internet of things* (IoT), part of the CPS that enables the communication with other Cyber-physical system and between the Cyber-physical system and users. It makes possible to create networks incorporating the entire manufacturing process, making possible the horizontal as well as the vertical integration
- *Big Data & Data Mining* (DM). Data mining and distribution of Big Data is a critical issue due to the variety, the volume and the speed needed to process the data from the CPS. Therefore, it is essential the appropriate computing system and software to manage this data
- *Internet of services* (IoS), which enables service vendors to offer their services via Internet. It consists of participants, infrastructure for services, business models and the services themselves

Talking about the components, when it is said horizontal integration, it refers to the integration of the IT systems in the different stages of the business planning processes as inbound logistics, outbound logistics, production and marketing and between different companies (value networks), as it can be seen in the figure 2.3 (Group, 2013). In this thesis, we focus in the supply chain management that implies the network suppliers (outbound logistics), the logistics (inbound logistics) as well as network of customers (outbound logistics).

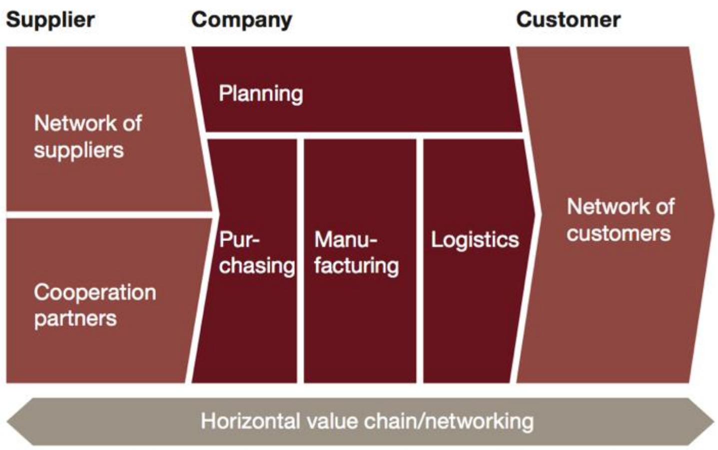

Figure 2.3 Horizontal integration stages (Group, 2013)

On the other hand, vertical integration refers to integration of different hierarchy levels as corporate planning levels, production management, manufacturing and execution, etc. as it is shown in the figure 2.4.

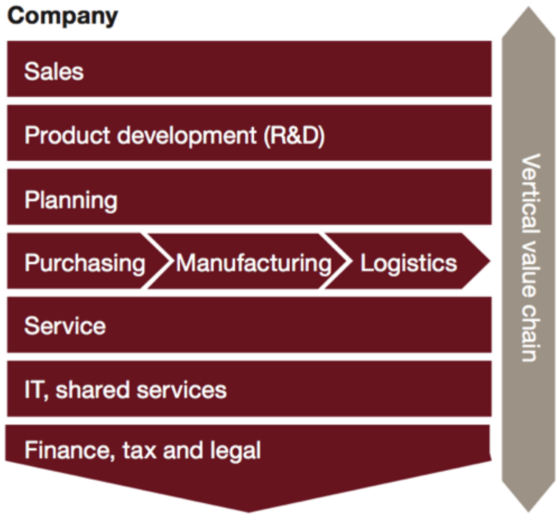

Figure 2.4 Vertical integration stages (Group, 2013)

2.3 Main challenges

The fourth industrial revolution- that is characterised by the increasing digitalization and the interconnection of products, value chains and business models- requires a significant investment.

The study made by the companies PwC and Strategy& in 2015 in the German sector of manufacturing and engineering, automotive and process industries, is based on surveys of 235 German companies. The respondents expected that regarding to the digital transition will lead to a significant transformation of their companies and they estimate that the share of investment will account for more than 50% of the planned capital investments for the next 5 years. Therefore, the first and the main challenge is the investment that means to apply Industry 4.0 solutions (Wegener, 2015).

Thus, the main challenges are the high investment levels and often the unclear business cases for the new industrial internet applications. As well as to have the sufficient skills to meet the needs of digital world.

Moreover, binding standards must also be defined and tasks in the field of IT security have to be solved. It is clearly needed that companies, trade unions, associations and policy-makers cooperate in order to spread this fourth industrial revolution.

2.4 Examples of Industry 4.0

Two examples of Industry 4.0 solutions can be seen in the two Siemens electronics plants in Amberg (Germany) and Chengdu (China). About 1,000 different products are manufactured in each plant. The plants use the latest software tools such as NX and Teamcenter, Product Lifecycle Management (PLM) programmes for production development, as well as a large of SIMATIC controllers and SIMATIC IT, Manufacturing Execution Systems (MES) for production processes. These products work together continuously and are connected through interfaces with the ERP systems. The use of this software tools has led to a significant increase in quality improvement (reduction from 550 to 12 defective steps out of a million process steps in total) over the past twenty years. Production has increased many times over the same period, while staff numbers remind almost the same, leaving clear the path to digitalization (Wegener, 2015).

Figure 2.5 Picture of Siemens electric plant in Amberg (Siemens, 2014)

In the previous picture shows the Siemens plant located in Amberg, which have the same machinery and technology used in the Chengdu plant.

Another example would be Arburg, which is a German machine construction company that makes injection-molding machines of small and medium clamping forces. They have already implemented Industry 4.0 solutions in his factory situated in Lossburg, Germany.

The process chain begins at the product design stage on a CAD workstation with a free former that produces prototypes in an additive manufacturing process. The order is entered in the system and the light switch rockers are produced on an ALLROUNDER injection-molding machine. The automated production cell incorporates a laser lettering process with a data matrix (DM) code and a quality control step. The free former turns the injection molded part into a unique item by applying an individual identifier during an additive process in the next step. Finally, the finished product is packaged in a robotic cell and printed with a QR code.

The individual code enables the process and quality parameters of each moulded part to be retrieved online. The ARBURG host computer system (ALS) is of central importance, recording all the parameters and transmitting them to a web server.

The figure 2.6 shows the part of the plant where the injection moulding machines are located:

Figure 2.6 Arburg factory (Wissen, 2014)

Chapter 3 Logistics 4.0

The first three industrial revolutions came as a result of the introduction of mechanization, electricity and IT. Nowadays, the introduction of the Internet of Things and Services into the industrial environment has triggered the fourth industrial revolution with the vision of "everything connected with everything else" (Group, 2013).

The demand for high-individualized products and services is continually increasing. Therefore, supply chain processes (inbound logistics and outbound logistics) have to adapt to this changing environment, since due to the increasing complexity, it cannot be handled with ordinary planning and control practices (Premm & Kirn, 2015).

The state of the art of Logistic 4.0 is the use of Cyber-Physical systems that monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. This CPS use RFID technology in order to identify, sensing and locate the item, and send the data to a computer which can collect and analyse this relevant information. These systems are able to communicate with other systems or with humans using the internet as a mean of communication, so that it can be shared data in real time and processes can be coordinated (Herman, Pentek, & Otto, 2015).

Many transportation and logistics companies are using RFID systems today to achieve near 100% shipping, receiving and order accuracy, 99,5% inventory accuracy and 30% faster order processing and reduction labour costs. RFID systems improve the visibility across the supply chain, since it is an automated way of knowing what you have and where it is. Nowadays, RFID systems are used for shipment and asset tracking and management, warehouse and distribution management and yard management, using internet in order to connect systems through the whole supply chain and exchange data in real time (Motorola, 2014).

3.1 Examples of Logistic 4.0

B&R

B&R is one of the world's most innovative Automation companies, being a leader in the field of industrial automation and process control. The company continues to invest in its people and services, and they believe that the distribution of automation logic throughout production systems -Industry 4.0- has created an urgent need for communication networks, which provide transparency and efficiency, without compromising reliability.

The latest B&R project was optimizing his production of industrial PCs. It consists on B&R customers configure PCs to their specifications using an online tool which after verifying the feasibility of the order, the ERP system generates a bill with a unique serial number.

"*Mathematically speaking, customer has more than 250 billion different hardware configurations to choose from. We can produce a one-off item with the same efficiency as a batch of 1000*" says Gerald Haas, head of global industrial management at B&R. Therefore, it can be concluded that they have achieved "*batch size one*" objective.

The ERP system plans an optimized order-processing schedule and ensures that the logistics works smoothly. Some parts that come from the warehouse are delivered just in time. The plant in Eggelsberg (Austria) is completely networked both horizontally and vertically.

"*What we have is a single, homogeneous network that incorporates every machine and every building automation component as well as ERP system*", says Haas. This is what allows the ERP system control the automated storage and retrieval vehicles in the bay warehouse.

Communication throughout the networked factory run in every direction. When a module reaches the fully automated station for assembly, testing and labelling, a real time SAP query determines which tests are required. This is possible because every product has a unique serial number read by the RFID system. B&R collects and evaluates all its production data using its own software of process control system.

"*For B&R, networked smart factory production has been a reality since 2006*", says Haas. "*What for us has been business as usual, has now been given a name: Industry 4.0*".

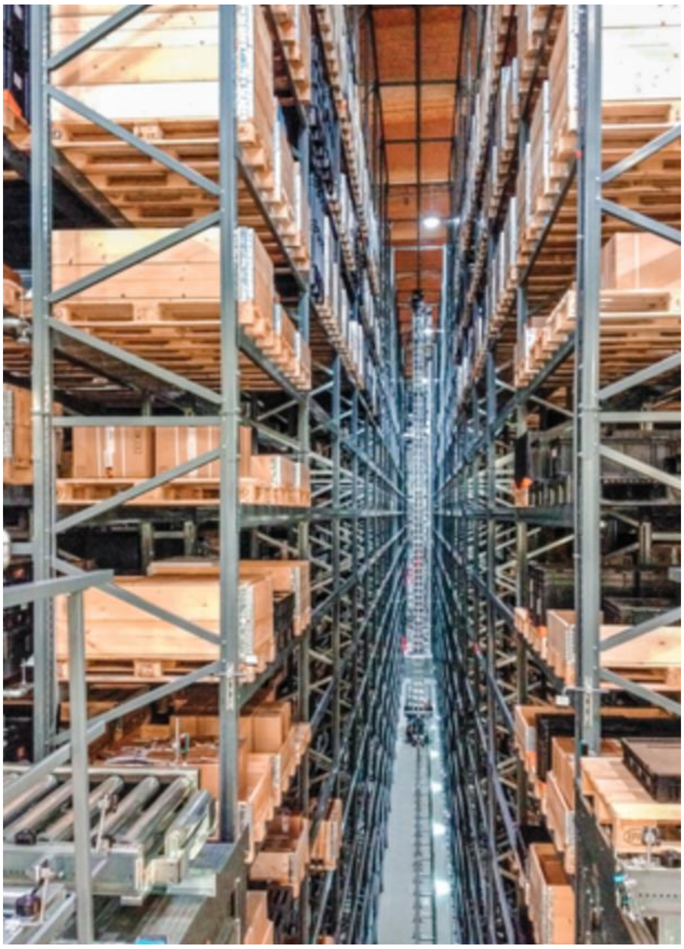

Figure 3.1 Picture of the high bay warehouse from a B&R factory (B&R, 2014)

Figure 3.1 shows a high bay warehouse in a plant from the company. B&R's production halls are fully networked. The ERP system has direct control of the storage and retrieval vehicles in the high bay warehouse and automatically optimizes production logistics. (B&R, 2014)

Toll Group

Toll Global Logistics needed more efficiently track goods and shipments at its Singapore facility. With goals including reducing person-hours by decreasing reliance on manual procedures and increasing visibility for the company and its customers, the organization deployed a system that tagged each of the location's 150,000 pallets with UHF passive RFID tags. When shipments arrive, staff members scan the barcodes on the boxes, and then use a portal to read RFID tags on the pallets these boxes are loaded into (or taken out of). The pallet identification data are then linked and sent via Wi-Fi to software that stores the data and makes it available to both internal users and customers. Toll Global

Logistics estimates that the system will save about six minutes of staff time per pallet, resulting in more than 600 person-days per year (Motorola, 2014).

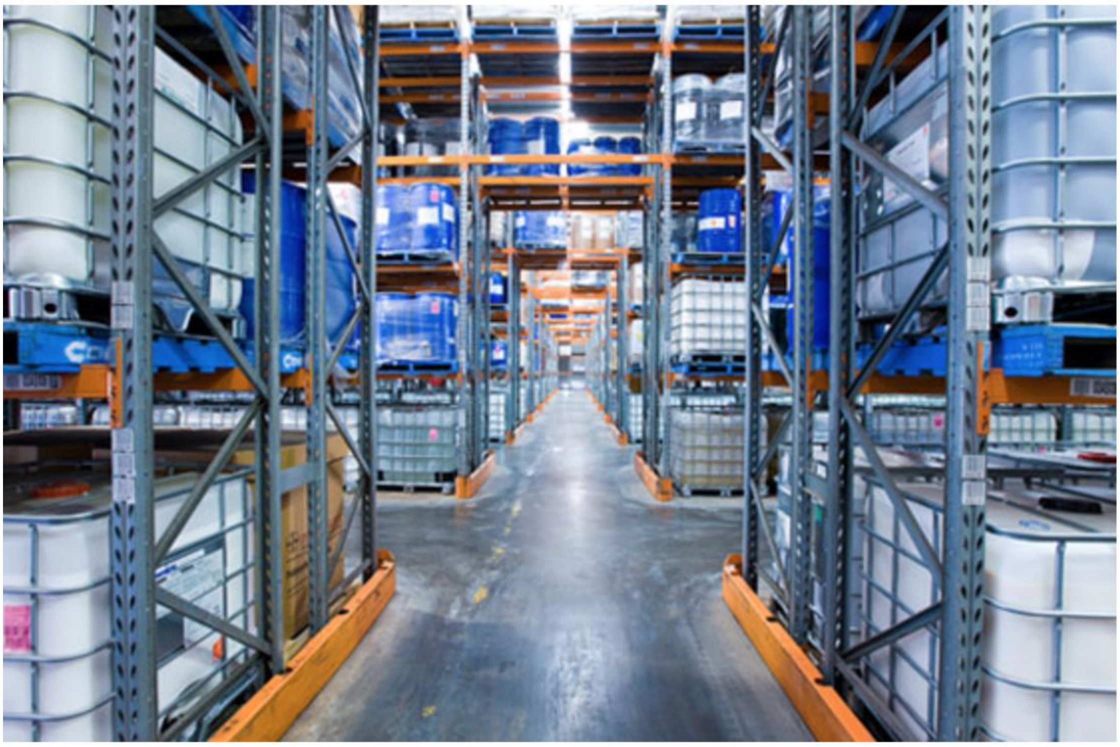

Figure 3.2 Toll Warehouse facility in Singapore (Motorola, 2014)

South-eastern Container

South-eastern Container manufactures plastic bottle pre-forms in three injection-molding facilities in the eastern United States. Pre-forms are then shipped to bottle manufacturing plants in cardboard containers and plastic bins, with empty containers being returned to the molding facility to repeat the cycle. However, problems in the return process were costing thousands of dollars a year due to loss and damage. The company replaced existing containers, returnable folding plastic bins designed to increase efficiency and reduce cost. Since these new containers cost nearly ten times the cost of a cardboard container, Southeast Container introduced an RFID-driven end-to-end cycle counting system to track container lifetimes against the number of cycles guaranteed by the manufacturer. Each container is permanently identified with a passive RFID tag for locating and tracking each unit in real time, enhancing visibility and extracting maximum business value from each container. The company expects to achieve payback on this project in less than two years (Motorola, 2014).

Figure 3.3 South-eastern Container injection molding plant (Container, 2016)

3.2 Background

The industrial production has experienced an evolution over the time. We can divide these changes of the industry in three main periods. Sometimes has been an abrupt change and sometimes just an improvement of the way of work. It is not an accepted way of design these periods of advances, but in order to simplify it versions of the industry and its logistics (1.0, 2.0, 3.0 and the coming 4.0) will be designed.

It can be observed in the figure 3.4 when and how the industrial logistics has evolved until becoming the actual logistics and towards this actual logistics is moving in the coming years.

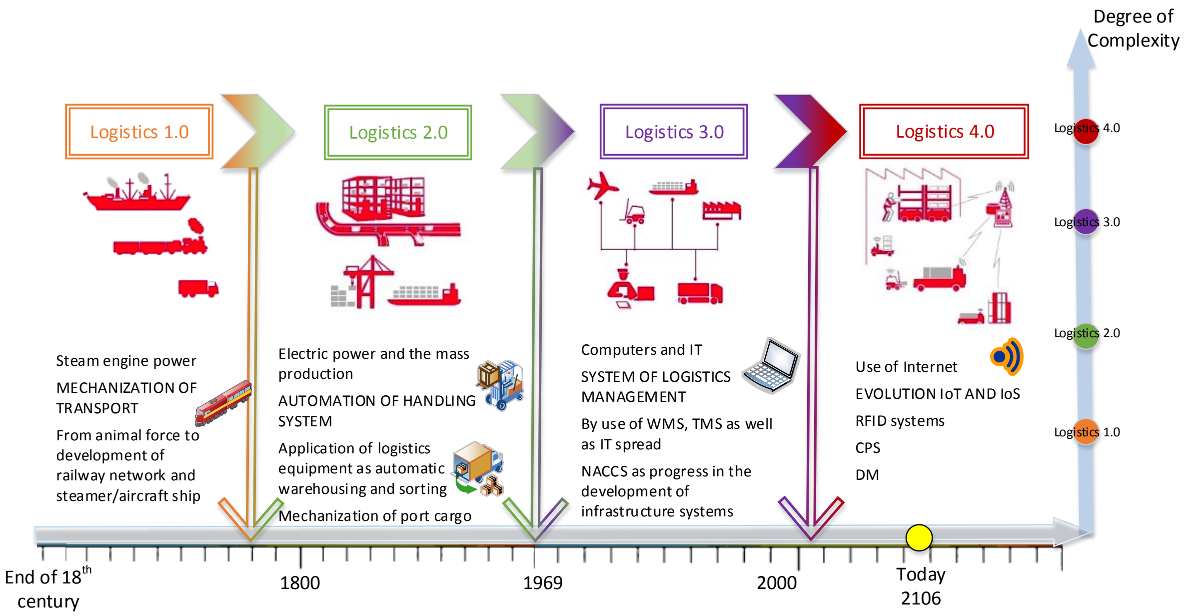

Figure 3.4 Evolution of Logistics

3.2.1 First industrial (r)evolution. Logistics 1.0

The first change that we can perceived in the industry was such an abrupt change that can be understood as revolution. It was the change from the manual work to the machine production. There is no a precise start or end, but we could say that it began in United Kingdom the second half of the 17th century and was spread to Occidental Europe and North America after some decades.

From this moment, the rural life turned into an industrialisation life, from working with manual tools and animal force to work with machinery of industrial manufacturing and transportation of goods and people (Revolution I. , 2009).

The ultimate success of this revolution was the introduction steam machine by James Watt in 1782 who made possible to achieve a significant increase of the capacity production by using supplied energy at any location. Later the development of ships and the railways networks along with the spread of the steamer/ aircraft ship in the second half of 19th century implied an evolution without precedents that enhanced significantly the transportation capacity. It can be said that was the beginning of the mass transit era.

Therefore, this period meant for logistics the "mechanization of transport".

The figure 3.5 shows a summary of the technology used in this period, what has been named in this thesis as Logistics 1.0:

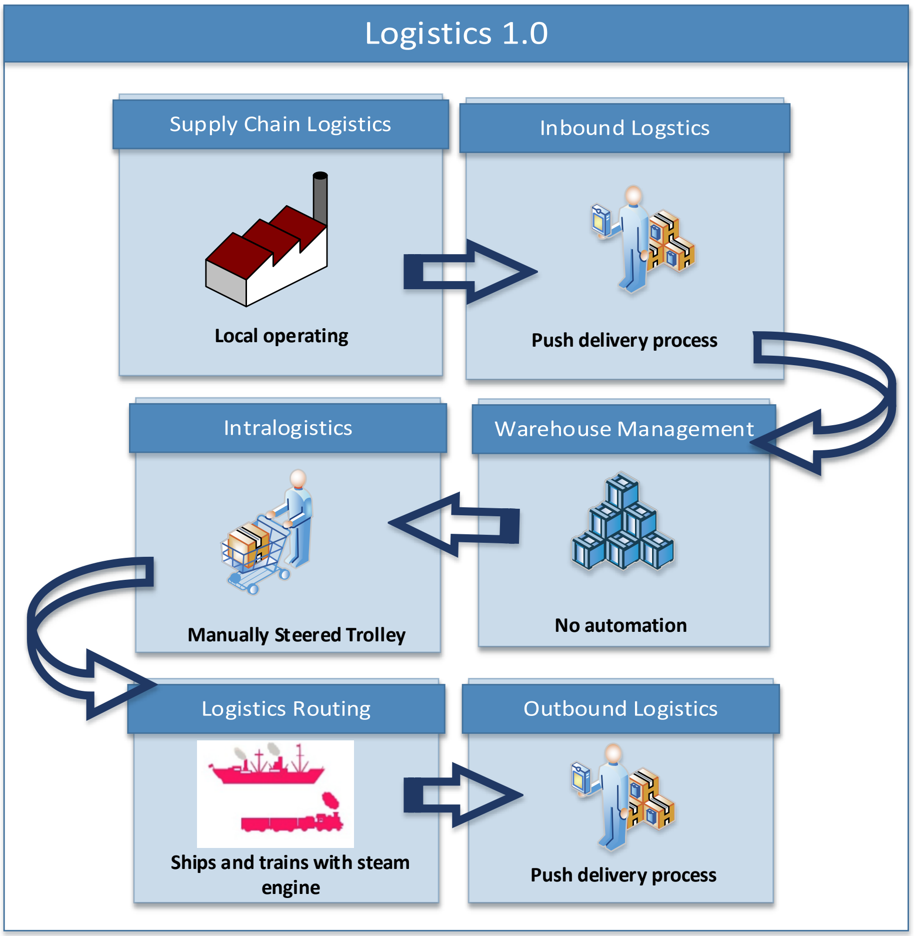

Figure 3.5 Supply Chain Management Process of Logistics 1.0

The supply chain management was local operating, where did not exist networks and the business tended to be with closer location suppliers. Most businesses were managed by individual owners or by partners, some of whom often had little daily hands on operations responsibility.

Push delivery process was used for the inbound as well as the outbound logistics. Products were pushed through the market, from the production side up to the retailer. The manufacturer sets production at a level according to historical ordering patterns from retailers. It takes longer for a push-based supply chain to respond to changes in demand, which can result in overstocking or bottlenecks and delays, unacceptable service levels and product obsolescence.

The warehouse was simply a room where storage the materials or the finished products. The intralogistics or the movement of goods inside the factory was manual work with trolley steered by humans. Trains and ships working with steam engines carried out the logistics routing or transportation of goods.

3.2.2 Second industrial (r)evolution. Logistics 2.0

This second period of changes is considered more as an evolution than a revolution from technology point of view.

There were findings about new materials as steel, copper or aluminium, which gained much importance in order to develop the machinery. In addition, the chemical industry suffered an expansion unprecedented and resources of power as electricity and petroleum made possible the advances in communication and transportation (Revolution T. S., 2000).

Although, was the globalization of the industry that makes a clear need of mass production. This is the way that was introduced the division of labour that finally meant a revolution in the industry allowing the mass production. This principles of rationalization were introduced by firstly Adam Smith in the 18th century and then it was Frederick W. Taylor early in 20th century who made a real advance in labour’s theory introducing what we understand today for the division of labour that set the pattern for the workshop of today (The Second Industrial Revolution, 2000).

Regarding the advances in logistics, we can find the “automation of cargo handling” from the 1960s. The transportation by railways and aircraft ships was already spread and with the electric power, the mass production was already a reality, therefore was the beginning of use of logistics equipment such as automatic sorting and automatic warehouses. In addition, the spread of the container ship made the mechanization of port cargo an important innovation.

In figure 3.6 can be seen a summary of the technology used in this period, what has been named in this thesis as Logistics 2.0:

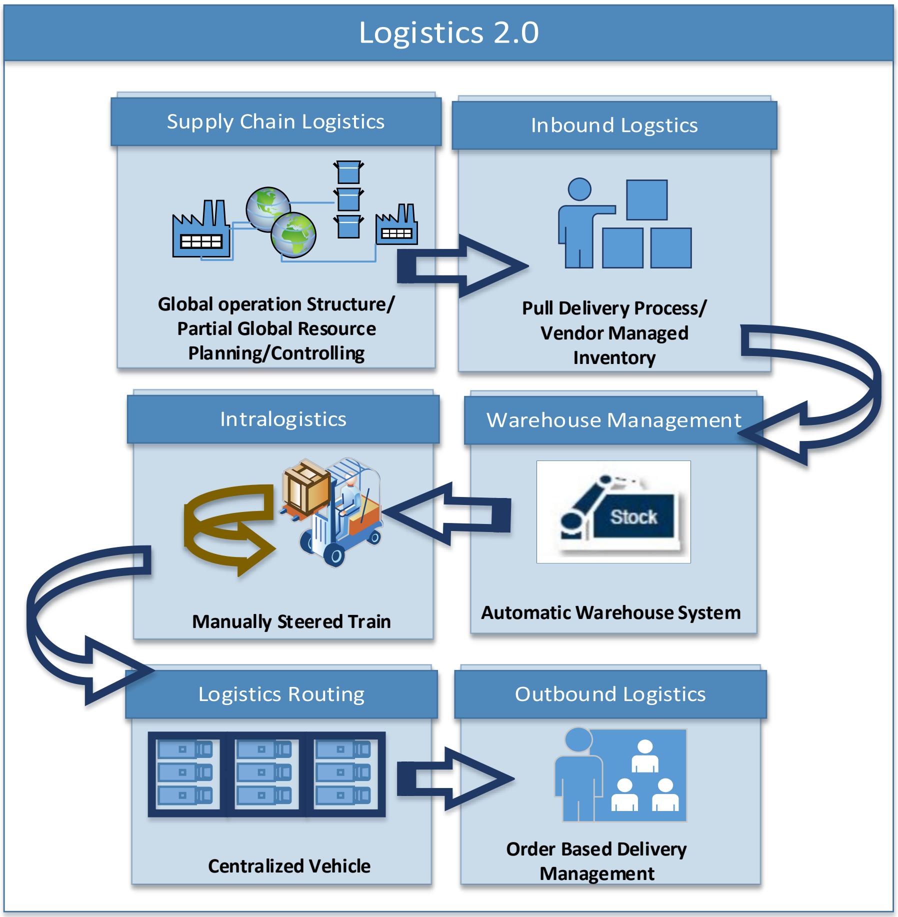

Figure 3.6 Supply Chain Management Process of Logistics 2.0

The supply chain management started to be global, where more than one supplier was taken into account and lasting supply relations were settled. With new types of industry requiring expertise in mechanics or engineering, business began hiring professional managers with the necessary expertise.

Pull delivery process was used for the inbound where the materials were replenished when they were consumed.

The warehouse starts to be automatic and operated by moving a transfer apparatus along a rack in a warehouse such that a container is stored in, or retrieved from the rack. The intralogistics or the movement of goods inside the factory changed to forklifts with electric motors steered by humans. Fleet vehicles already coordinated, carried out the transportation of the finished goods and raw material. In addition, the delivery process of items were managed according to demand forecast made before the production.

3.2.3 Third industrial (r)evolution. Logistics 3.0

The third industrial revolution took place with two technological breakthroughs:

- The numerically controlled machines, that provided the flexibility needed for an optimized mass production and made possible to finish with the rigidity in the production. These machines have computers with built-in memory and are operationally programmed, therefore it is just needed to change the programme in order to change the labour of the machine, being much faster than conventional mechanical automated machines which are the predecessors of this NC machines
- The industrial robots. The first industrial robot was manufactured in USA in 1961 by Joseph F. Engleberger. Towards 1968, the company Kawasaki, from Japan, created a more refined model and started to manufacture its own robots. And it was in the 70s when took place an improvement of the computers embedded in the robots and its cost was reduced, making more profitable to employ robots in the manufacture than human labour (Roal, 2001).

In short, this industrial evolution took place with the introduction of computers in manufacturing.

Regarding the logistics, it was developed the “system of logistics management”. It was the beginning of important software that nowadays are very spread as WMS (Warehouse Management System) and TMS (Transport Management System), and IT system, all this made a significant progress by the use of computers in order to manage and control the logistics processes.

The figure 3.7 shows a summary of the logistics technology used in the period that has been designed as the third industrial revolution:

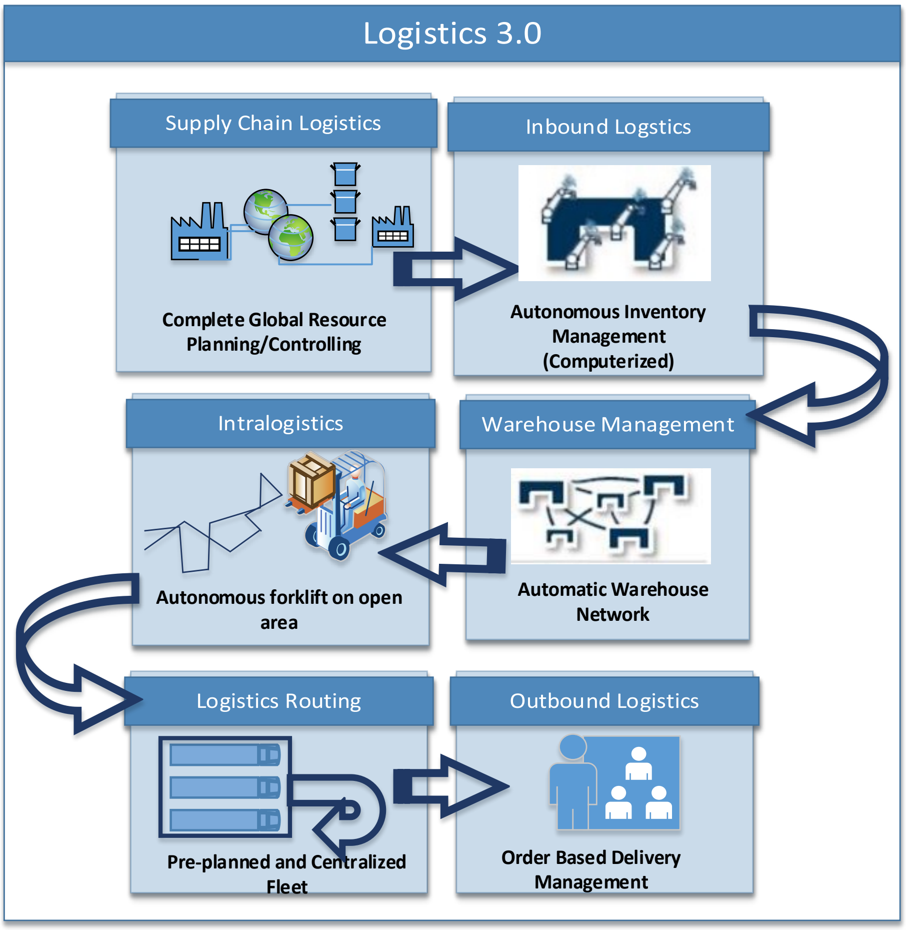

Figure 3.7 Supply Chain Management Process of Logistics 3.0

The supply chain management is completely global, where the best supplier inside a global market is hired and shorter relations are settled.

Software is used to elaborate a plan with all the orders to the suppliers and when it will be necessary to receive the orders. Therefore, the inbound logistics as well as warehouse management are preciously planned and controlled by software.

The intralogistics or the movement of goods inside the factory is carried out with automatic lines, forklift steered by humans and as a last technology, robots with their routes programmed.

Fleet vehicles with a pre-plan and a schedule with optimised routes computed by software, carried out the transportation of the finished goods and raw material. And the delivery process of the items is managed according to plan and the schedule planned before starting the production.

3.3 Framework of Logistics 4.0

Now, the introduction of the Internet of things and Services into the manufacturing environment has introduced the fourth industrial revolution (Kangermann, Wahlster, & Helbig, 2013).

Industry 4.0 has been always compared with proceeding disruptive increase in production such as the industrial (r)evolutions named before. They have in common that were initiated not by a single technology but by the interaction of numbers of technological advances whose effects created new ways of production (Schmidt, Möhring, Härting, Reichstein, Neumaier, & Jozinović, 2015).

This new paradigm shift in manufacturing is the result of the use of Internet that enables the communication between each other machines and humans in real time and the use of what is known as "smart products and smart services" as well as the advanced digitalization within the factories. This future "Smart factory" will enable to connect all elements involve in the manufacturing processes and will make possible the application of concepts as adaptability, interconnectivity, efficiency and ergonomics. (Lasi , Kemper, Fettke, Feld, & Hoffmann, 2014)

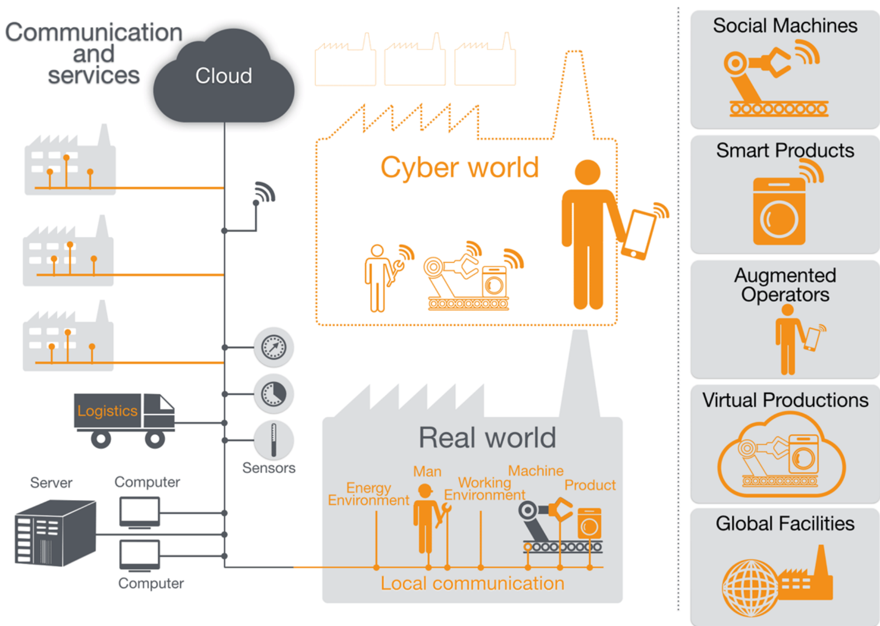

Figure 3.8 Combination of CPS and IoT to reach the concept of Industry 4.0 (4.0 W. w., 2016)

Regarding Logistics 4.0, it can be said that is the progress of "labour saving and standardization by the evolution of IoT". Technologies as warehouse robots and automatic driving are trying to replace processes that do not require operation and determination by human labour. The aim is the perfect equilibrium between the automation and the mechanization.

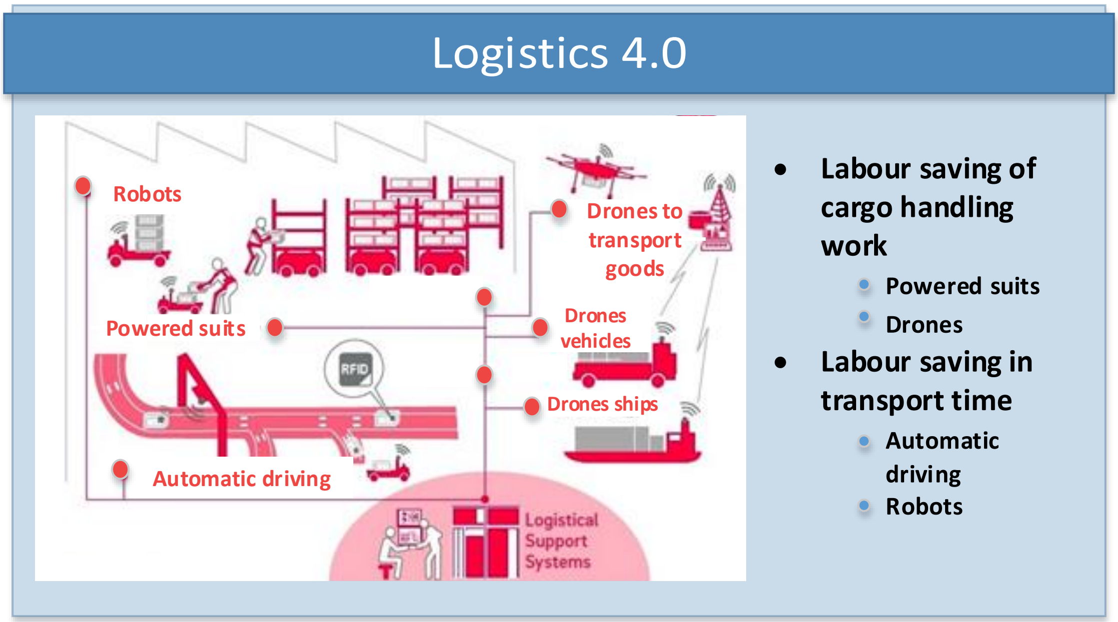

Figure 3.9 Technology involved in Logistics 4.0 so far

In order to implement the technology that will turn the factories into "*smart factory*" would not be needed a short period of time. It is essential an important investment and a special training, but it will be returned as improvement of cost performance of logistics and save of time.

Logistics equipment as automatic warehouses and automatic sorting is already widespread but its range of spread was limited since it becomes a dedicated system in line with the shape and characteristic of the pack of interest. Therefore, the aim is to introduce new technology that save labour of handling work and save time in transport, as it is shown in the figure 3.9.

3.3.1 Labour saving of cargo handling work

It is possible to facilitate the human labour by using warehouse robots which can carry the goods from the storage to the final mean of transport.

As an implementation example, we can find Amazon that from 2012 by the acquisition of Kiva Systems of robot manufacturer, promoted the automation of the picking process. They use a robot called "Kiva" which made "workers of walking" no longer needed and has succeeded in enhanced the labour productivity of each distribution centre.

Also, Hitachi, Ltd. has developed automated guided vehicle called "Racrew" that has been introduced in the logistics centre of Hitachi Transport System.

If the automatic operation and warehouses robots and similar autonomous control technology are established, can be solved the problems in the unmanned forklift such as low speed. In addition, the speed of recent technological innovation the moment of all the forklifts in the warehouse are autonomous is not far away.

Another implementation example would be the use of Powered suits of Cyberdyne which assist in the movement of the muscles of the wearer. This logistics equipment is attempting to reduce the work load of workers not to eliminate the "human intervention". This equipment is not really applied or spread.

3.3.2 Labour saving of transport process

The operation of transportation defines the efficiency of moving products. Figure 3.10 shows the components of logistics costs based on the estimation from Air Transportation Association (Logistical Management, 2000).

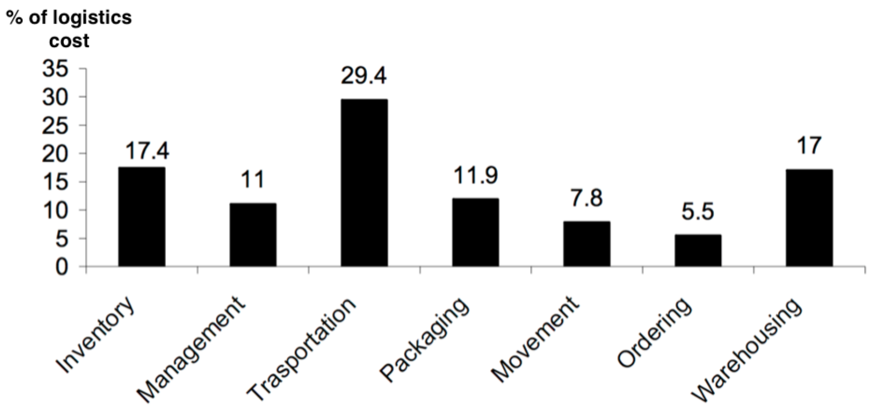

Figure 3.10 Components of logistics costs (Chang, Logistical Management, 2000)

Therefore, optimizing the transportation process will bring a big impact on the cost structure of logistics.

To achieve the "automation driving" is required to act in several parts of the transportation process. Firstly, is aimed the realization of the automatic highway. Furthermore, there will be not only technical considerations only, review of laws and car insurances system will be necessary. Thus, the full automatic operation will have to overcome various hurdles. However, with a partial automation of the highway will have a commensurate impact in the logistics cost since personnel expenses of truck drivers will go down.

Other implementation of new logistics technology, is the use of drones. The world's largest logistics company DHL is planning to use drones as an emergency means of transport. They developed "Parcelopter" that is a drone able to fly about 45 minutes. It is expected to expand the transport destination of this drone. Also, some companies are considering the use of it as a tool of campus transportation and equipment inspection. We can find an example in Chiyoda Corporation a leading engineering company which is working in materials management by using drones. It is expected that the use of drones in the inventory management, such as Chiyoda Corporation will keep increasing in the future.

The company Rolls-Royce is working on the development and commercialization of drone ship. It will mean an improvement in the fuel efficiency since it will not be needed residence space for the crew and of course the capacity of load since it could be occupied the whole ship with goods. However, problems as the risk of pirate attacks make as a requirement the development of a legal system and insurance system.

3.3.3 Logistics network

The base of this evolution 4.0 is the IoT that enables to connect all the functions and share information in real time, optimizing the logistics processes. It can be said that Logistics 4.0 is the standardization of logistics infrastructures.

For example, Bosch has introduced a virtual tracking in order to share information on the production, distribution and trading partners of the company. By using the RFID tags they automate the data management of the incoming goods and optimize the stock. Thereby, it enables flexible review of the production and logistics planning in response to changes in supply, transportation environment and demand fluctuations.

If several companies use this system, it can be shared the data in real time and reduced the differences between companies and industries.

In addition, DHL that is a vendor Agheera, has developed an integrated management that can open a platform data from logistics company. This platform has been connected to a plurality of logistics company of the data system, shipper is able to access the site of Agheera and take the necessary information in real time.

Therefore, the future smart factories will work as a "huge brain", sharing information in real time between all the stakeholders and making the logistics processes optimized and transparent. With this use of IoT in logistics will be necessary the development of a good safe system making sure that the data is protected and is in the right moment in the right place.

The figure 3.11 is a summary of the future in logistics technology, already named as Logistics 4.0:

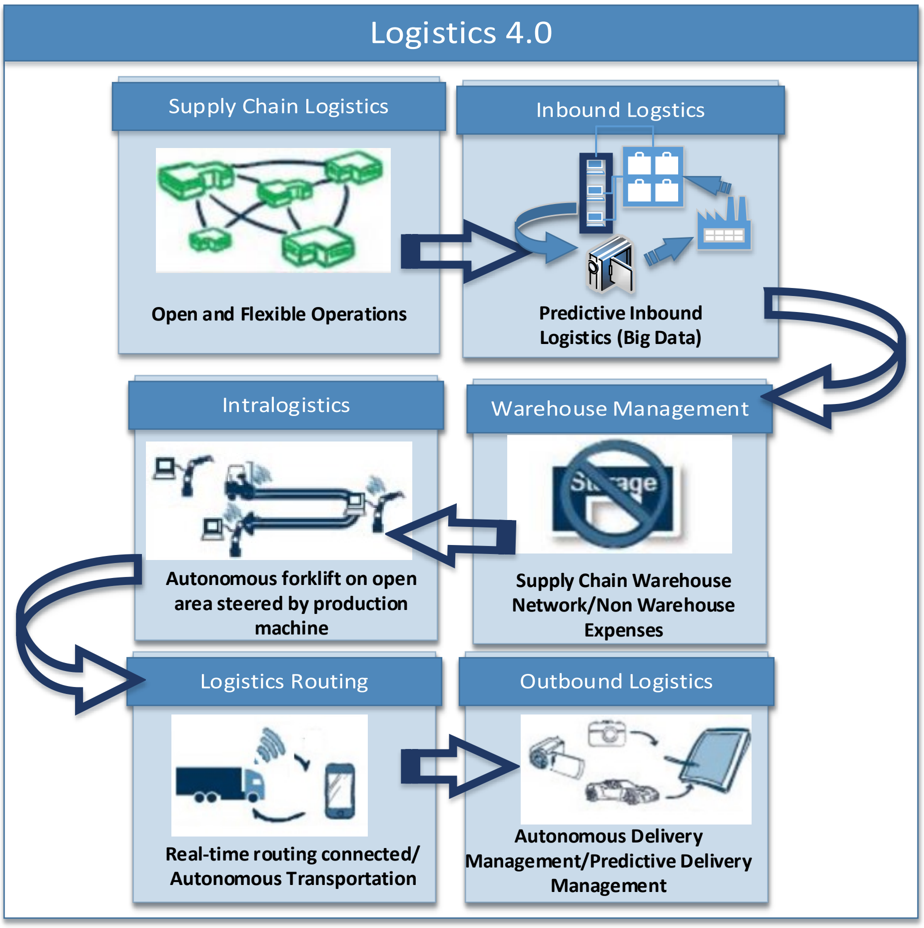

Figure 3.11 Supply Chain Management Process of Logistics 4.0

The supply chain management will be a big network where all the stakeholders in the supply chain (customers and suppliers) will have access to. An internet platform will be used and all the orders from the customers and to the suppliers will be managed in real time by it.

The intralogistics or the movement of goods inside the factory will be completely automated with autonomous forklift with his routes programmed according to the predictive inbound logistics that will come from the information received from the internet platform used by all the stakeholders.

Therefore, the warehouses expenses will be reduced to the minimum or will disappear completely because the customers' orders and the orders to the suppliers will be processed at the same time and the exactly dates to receive all the material necessary for the production in order to deliver the final product in time will be predicted.

Fleet vehicles will have a route programmed according to the internet platform from where will be taken the necessary information, and customers and suppliers will be able to track the vehicles which will have GPS in order to show their location in real-time.

However, it is essential to keep in mind that all the automation is not trying to replace humans in their works. It has the aim of aiding humans in their labours and provide a more secure work place for the workers.

Chapter 4 Technical components of Logistic 4.0

Logistics 4.0 can be defined as the Smart Logistics. As it has already said, the term smart denotes a temporal meaning, depending always on the technology driven. However, there are basic components that foster the Smart Logistics. These are the technologies used to identify, locate, sense, process and act. Thus, this chapter includes each function of Logistics 4.0 (focused in the intralogistics) with the technical component that carries out each task.

4.1 Identification (RFID systems)

The first step is the identification of the processing good. As virtual and real world are moving together, logistics items that are not identified are not existent and any action cannot be controlled until identification is enabled again.

It can be used RFID systems to identify logistics objects, due to the convergence of lower cost and increased capabilities of RFID tags. The object has attached a RFID tag and the reader identify the object and receive his information when it passes by it. Once the tag has sent the product information by radio waves, the reader can send this information to the computer which processes this data.

RFID is an important technology for revolutionizing a wide range of applications, including supply chain management. It offers a convenient way of identification of objects, and usually “right thing”, “right time” and “right place” are confirmed together with the identification number provide by the RFID tag (Uckelmann, 2008). The next chapter shows an implementation of a RFID system and this technology will be further explained.

Benefits of using RFID technology include the reduction of labour costs, the simplification of business processes and the reduction of inventory inaccuracies, as well as more transparency in logistics processes.

4.2 Locating (RTLS)

Identification used to be associated with locating or recording the place of identification, however in order to locate is used real time locating systems (RTLS).
RTLS combine the functions of identify objects in real time and to locate them. Some of the real time locating systems provide physical position (e.g. GPS) and others refer to a symbolic location such as goods issue.

For the indoor locating systems, radio frequency, infrared, ultrasound, magnetic or optical technologies are used, being the radio frequency technology (RFID systems) the most spread. We can find the next locating methods:

- Cell-of-origin (transponder-of-origin)
- Amplitude (received signal strength indicator) triangulation
- Time of flight ranging systems
- Time difference of arrival (TDOA)
- Angle of arrival (AoA)

The cell-of-origin only indicates that the transponder is within the read range. Basically every RFID reader or tag attached to a fixed locating represents a cell-of-origin locating system. For example, for pallets-tracking are used transponders in the floor that indicate the position, while the forklift passes them, which have low frequency readers hooked.

Another way of real time locating is the signal strength, where any hardware that offers the possibility to measure the received signal strength might be used. RFID systems offer this possibility, while a tag is within reading range of multiple antennas, amplitude trilateration may be used to locate the tag.

TDOA systems use triangulation algorithms and estimation of the location and a higher degree of synchronization between the readers is needed to measure exact timings.

AoA systems for locating are used at airports where rotating radar antennas locate planes. Antennas are rotated to find the direction of the highest strength signal and antennas arrays are also used to measure the angles.

Hybrid approaches combine any of the above mentioned technologies. One example of this would be the combination of GPS and passive RFID in a hybrid personal data terminal used for location tracking.

All these previous technologies are possible RTL systems, however RFID system with several antennas that locate the object depending on the frequency received for each antenna, is the one that will be analysed for the indoor locating in the implementation in KDL. For the outdoor locating system, the most used is the GPS.

High prices are hinder the diffusion of RTLS within the supply chains. But lower prices are not the only challenge, if potentials of RTLS can be achieved by multiple stakeholders within the supply chain, a billing across the supply chain for increased visibility will be possible (Uckelmann, 2008).

4.3 Sensing (CPS)

Sensing provide the function of the right condition to the logistics system. The condition of goods is essential in many fields as for example the cold chain and the fresh food logistics.

CPS are automated systems that enable connection of the operations of the physical reality with computing and communication structures. These systems consist of a control unit, usually one or more microcontroller(s), that control the sensors and actuators which interact with the environment and from where process data is taken. They need to exchange data with others CPS, requiring a communication interface. Therefore, CPS is an embedded system which is able to receive and send data over a network.

CPS consist of two main functional components:

- The advanced connectivity that ensures real time data acquisition from the physical world and feedback from the computational world (RFID system)
- Intelligent data management, analytics and computational capability that construct the cyber world (software).

Acquiring accurate and reliable data from machines and their components is the first step in developing a CPS. This data might be measured directly from sensors or obtained from controllers or enterprise manufacturing systems as ERP, MES, SCM and CMM. After this, the various type of data acquired, a continuous and fixed method to manage this data acquisition procedure and transferring data to a central server have to be considered. Furthermore, selecting proper sensors (type and specifications) is another main issue to develop a CPS (Lee, Bagheri, & Kao, 2014).

In short, the sensors and actuators together with the computer software form the CPS that enables sensing the product and compare the information from the sensors and actuators to the virtual model in order to know if the product adjust to the model and the right condition is achieved.

4.4 Networking (IoT)

With IoT enterprises can supervise their every product in real time, and manage their logistics architecture. They not only supervise the circulation in supply chain and share information, but also analyse the data generated from every procedure and forecast.

By forecasting the information from the current procedure of their products, the future trend or the probability that accident happens is estimated, remedy measures can be adopted or the warning can be given ahead. This improves enterprises’ ability of responding to the market.

The Internet of Things and Services make possible to create networks incorporating the entire supply chain process that convert it into a Smart Logistics. CPS comprise smart warehousing systems, machines and production facilities that have been developed digitally and with ICT-based integration, from inbounds logistics to production, marketing, service and outbound logistics (Group, 2013).

The IoT can be defined as a network of cyber-physical systems that are uniquely identified and can interact to achieve common goals, therefore IoT is understood as a one of main parts of the CPS.

The “things” in IoT are sensors, actuators (that form the CPS), communication modules, devices that can cooperate together with smart components to reach goals that could not be accomplish without this cooperation. Thus, IoT is a network where CPS can communicate and cooperate with each other through a common goal.

Often, CPS use man-machine interfaces to enable the communication between users and production plants in a networked environment (Creation, 2015).

In short, IoT affects the whole supply chain. Firstly, it optimizes the supply chain management; secondly it makes sources to be used effectively; thirdly it makes the whole supply chain to be visible so that it can improve the information of supply chain transparency; fourthly the supply chain is managed in real time; the lastly it makes the supply chain high agility and complete integration (Sun, 2012).

Regarding the supply chain management, IoT affects in manufacturing link, warehousing link, transportation link and selling link. It makes enterprises even all the whole supply chain response to the variation of the market quickly so that the adaptability is improved (Obitko & Jirkovsky, 2015).

Leading industrial companies are digitizing and connecting functions along the vertical value chain as well as horizontal. It encompasses the digital order process, customised product development and the automated transfer of product data to connected planning and manufacturing systems and further on integrated customer service, as well as the horizontal integration of inventory and planning data performed with suppliers, customers and other value chain partners. And it optimises the flow of information and products from the customer through their own company to the supplier and back (Wegener, 2015).

4.5 Data collection and analysis (Big Data and Data Mining)

Logistics 4.0 implies a huge increase of variety, volume and velocity of data creation. The type and amount of collected data has been increased because of the advances in sensor technology and the products contained computed capacities.

Before, only simple types of data as temperature measurement were collected, nowadays large data as images or real time videos are used (Schmidt, Möhring, Härting, Reichstein, Neumaier, & Jozinović, 2015).

Big Data is the term used for datasets that are growing and becoming difficult to manage with the existing database and tools. The difficulty come from the change of the volume, velocity and variety of data. This changes are:

- Regarding the volume, the systems are moving to processing petabytes and larger amount of data, due to the new opportunities to collect data from many sources together and also the IoT is bringing the necessity to gather and process larger amount of data
- Regarding the velocity, due to the need of the real time processing data by the use of internet. For example, the need of immediate reaction for proper serving web page or the need of the fraud credit card detection that has to be processed immediately as well
- Regarding the variety, is not surprising since computers process almost anything. Well-structured data in relational database are accompanied by images, texts, audios or videos. The challenges come when trying to integrate even well-structured data, and the data integration in general is a big research field. Several studies say that the main problem with the Big Data is not the "Big", if not the heterogeneity of the data

(Obitko & Jirkovsky, 2015)

In a study made by the companies PwC and Strategy& in 2015, based on surveys about application of Industry 4.0 solutions, one of the findings of these surveys was that already today the efficient analysis and use of data is a great significance for half of all the companies surveyed (235 companies from German sector of manufacturing and engineering, automotive and process industries surveyed).

In addition, 90% of these companies believe that the ability of analyse data will be decisive to their business model in five years (Wegener, 2015). This leaves clear that one of the basis of this industrial evolution of IoT is the Big Data and Data Mining, which enables the processing and analysing big amount of data.

4.6 Business Service (IoS, ERP, Billing, Marketing, CMS)

The IoS is the term used to name the concept of offering services over Internet so that they can combined into value-added services by various suppliers. The IoS is based on the service vendors providing the services themselves, infrastructure for services and business models. The formed services are, therefore, accessed by customers. An example would be the forming virtual production technologies and capabilities by combining individual services as necessary to carry out a complex task while combining different skills and observing time or financial restriction (Obitko & Jirkovsky, 2015).

The idea of IoS has been already implemented in a project called *Smart Face* under the "*Autonomics for Industrie 4.0*" program initiated by the German Federal Ministry for Economic Affairs and Energy. This project is based on a service-oriented architecture. It allows the use of modular assembly stations, which can be flexible, modified and expanded. Automated guided vehicles carry out the transportation between the stations. Both, assembly stations and automated vehicles offer their services through IoS. The vehicles know the customer specific configurations and they can decide autonomously which working steps are necessary. Therefore, they can individually compose the required processes through the IoS (Herman, Pentek, & Otto, 2015).

As conclusion, the technological components described above make possible the concept of Logistics 4.0. It consists of the intelligent identification (for example with RFID tags), intelligent sense and location of the good (with RFID antennas working as RTLS) and send the information collected in the tag (Big Data and Data Mining) to a database working as a network. This system forms a CPS, which makes possible that the item can track himself without human intervention by communicating with each other and with other CPS over internet, forming a network.

The main design or implementation principles for all the technical components presented are:

- Interoperability, where standardization and semantic descriptions are important, since means that companies, humans and CPS are connected by IoT and IoS. The German Commission for Electrical, Electronic & Information Technologies of DIN and VDE recognised this need of standards and published "German Standardization Roadmap" in 2013
- Virtualization, over CPS the physical world can be linked to the virtual. In other words, the data from sensors are linked to virtual and simulation models. Thus a virtual copy of the physical world is created and enables the CPS monitor physical processes
- Real time capability, the continuous data analysis is needed to react to any changes in the environment in real time, such as routing or handling failures
- Decentralization, that means giving autonomy, resources and responsibility to lower levels of the organizational hierarchy. Individual agents have to make decisions on their own and delegate the decisions to higher levels in the event

of failures or complex situations. Due to it is difficult to control inherently systems centrally. This requires enterprises to review the hierarchical planning and look for a more decentralized concept of coordination

- Modularity, in order to be flexible in this changing environment it is needed to be able to adjust or add modules and to utilize new modules
- Service orientation. Service-orientated architecture (SOA), which is an architectural pattern in computer software design in which application components provide services to other components via a communications protocol, typically over network; allows encapsulation of various services to combine them and to facilitate their utilization
- Security of the information and its privacy shall be emphasized in the data exchange using ICT technologies

(Obitko & Jirkovsky, 2015)

The next table shows the design principles needed to each technical component already described:

	Identification	Locating	Sensing	Networking	Data collection and analysis	Business services
Interoperability	X	X	X	X	X	X
Virtualization	X	X	X	X	X	-
Real-time capability	X	X	X	X	X	X
Decentralization	X	X	X	-	X	X
Modularity	-	-	-	-	-	X
Service Orientation	-	-	-	-	-	X
Security	-	-	-	X	X	X

Table 4.1 Design principles of each Logistics 4.0 technical component

4.7 Main challenges within the industry

The unclear economic benefits and the high investments are two of the most important challenges, due to the digital and the automation technologies will lead to a significant transformation of companies with an important investment in software and machinery.

There is another challenge in the insufficient qualification of employees regarding the digital change, this will alter requirements for employees across all the steps of the value chain. Through the IoT and the growing digitalization, the need for employees with a foundation in data science and information technology in particular will increase. Policy-makers should create the basis for the education needed. They need to encourage enthusiasm for technology from the early stage.

The lack of agreed standards, due to the broad range of the numerous and complex challenges cannot be faced by companies alone, but also demand joint efforts by industrial associations, trade unions and employer's associations. Policy-makers can provide support promoting uniform industrial standards and regulations.

The figure 4.1 shows the main challenges that the companies face with integration of the technology and the business model that the fourth industrial revolution means.

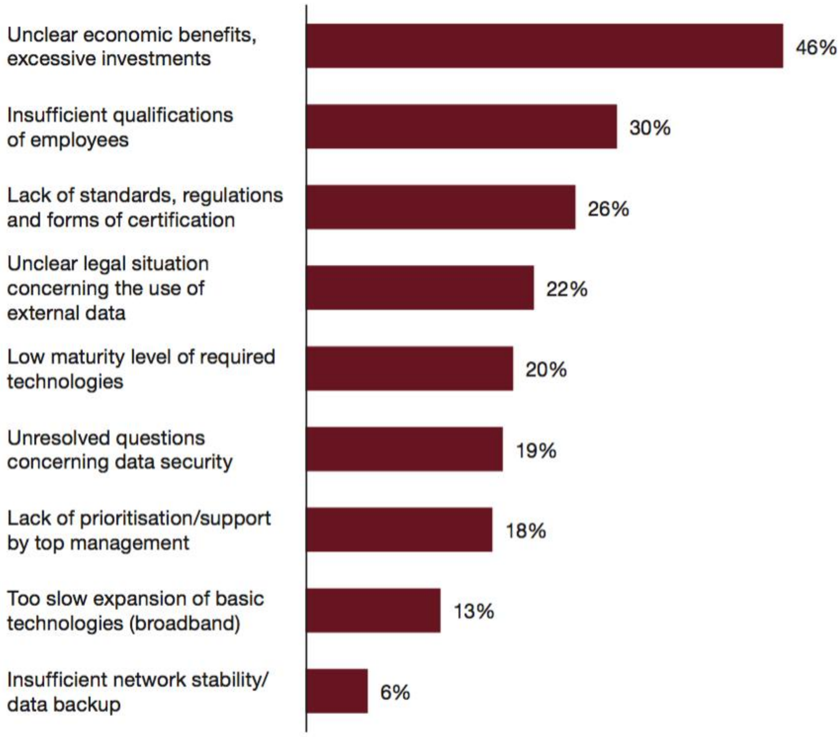

Figure 4.1 Challenges for the successful implementation of the technology and business model of the fourth industrial revolution

The data from the figure 4.1 has been computed based on the study from PwC and Strategy& already mentioned before (Wegener, 2015).

Chapter 5 Case study in KDL

This chapter is a case study make that has been performed in the Knowledge Discovery Lab (KDL). A scenario is described and the lab facilities are used in order to perform a simulation of a real factory with an Intelligent Integrated RFID system implemented to control intralogistics processes such as tracking objects and inventory management.

5.1 Radio frequency identification (RFID) technique

Radio frequency identification (RFID) is a non-contact automatic identification technology, that sends signals through radio waves. It does not need for manual intervention and it can work in harsh environment. It is a revolutionary technology used in wide range of application as aircraft maintenance, baggage handling, healthcare, supply chain management and retail (Sun, 2012).

This increasingly technology is used in supply chain management and is a perfect support to logistics processes due to their ability to identify, trace and track information. RFID systems can deliver real time information about the products to suppliers, manufacturers, distributors and retailers. Many companies have already exploited it in their main operations taking benefits of the high potential of more automation, more inventory visibility and efficient business processes.

It used for identifying and tracking containers and goods, in warehouses and on the entire shipping route. Therefore, this accurate inventory information can turn into a lower labour cost, improvement of the supply chain and more simplified business processes (Zhu, Mukhopadhyay, & Kurata, 2012).

The simplest RFID system consists of a RFID tag, an antenna and a RFID reader linked to a computer system, as the figure 5.1 shows:

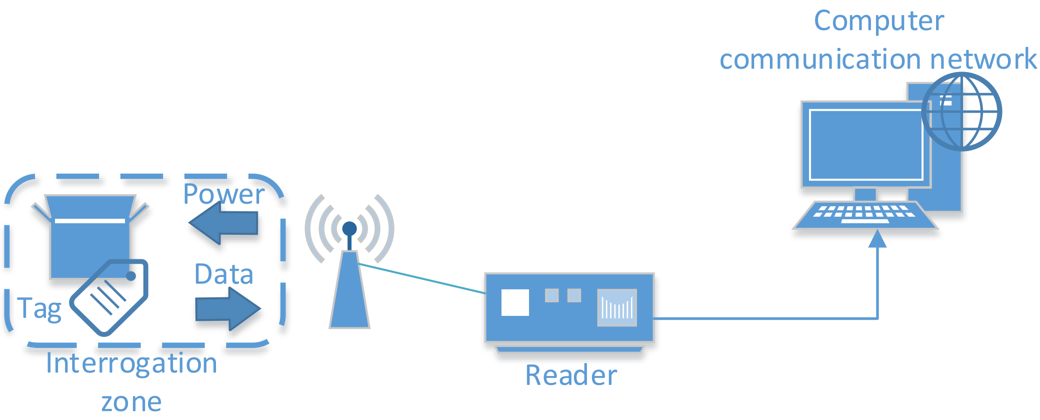

Figure 5.1 Components of RFID system

The tag is attached to the object. This tag consists of a digital memory chip to process and storage the information about the product and an antenna which transmits the information by radio waves to the other antenna.

The antenna that detects and receives the tag information, is powered by the reader, and the reader packaged with a transceiver and decoder, emits a signal that activates the RFID tag so it can be received and transmits data.

The RFID reader receives this information from the antenna when the tag passes by the interrogation zone. The reader decoder the data encoded from the tag and it is sent to the host computer.

Therefore, RFID describes a system that transmit the identification of an object or a person wirelessly using radio waves in the form of a unique serial number (Sun, 2012).

When RFID techniques are implemented, multiple antennas and readers are used to constitute a complex system. If it is used multiple readers in order to expand the data detectable area, a Middleware is required as a platform to manage the RFID data acquired from different readers. In addition, the use of Ethernet makes the system accessible anywhere.

The structure is shown in the figure 5.2:

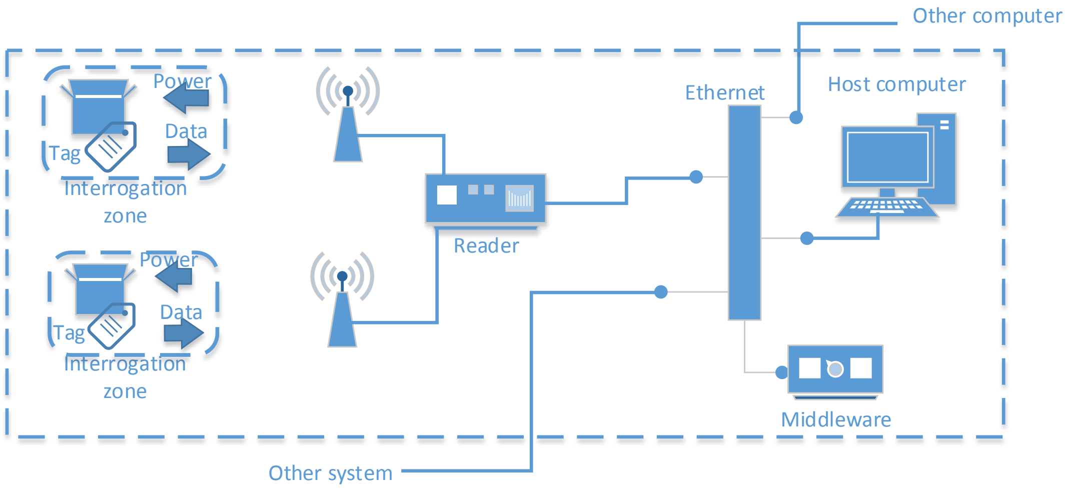

Figure 5.2 RFID system with several antennas

RFID system with the IoT enables enterprises supervise their every product in real time and manage their logistics architecture as well as the information can be shared and analysed obtaining future trends and current procedures. This makes possible to adopt measures, to estimate and to avoid unwanted situations. It improves enterprises' ability of responding to the market.

In this chapter is introduced a RFID system installed in the KDL. Afterwards a scenario is described and performed in lab using its II-RFID system in order to implement how would be the real situation in this imaginary scenario.

5.2 Intelligent Integrated RFID (II-RFID) system

When RFID system is linked to a database there is a high potential for improvements in the logistics processes within the plant. The physical objects with the tag attached turn into traceable within the RFID system. This system carries out the data acquisition, do the track and query, but this is not enough for having an intelligent system. The RFID database decision making is an essential part to take real advantages of this system. Thus, an Intelligent Integrated RFID system is suggested, which includes the RFID data acquisition and the database on the basis of data mining.

5.2.1 II-RFID System architecture

II-RFID has the aim of discover knowledge from the RFID data in order to optimise processes and take the best possible advantage of the manufacturing process. It comprises six levels of the manufacturing. The figure 5.3 shows the levels:

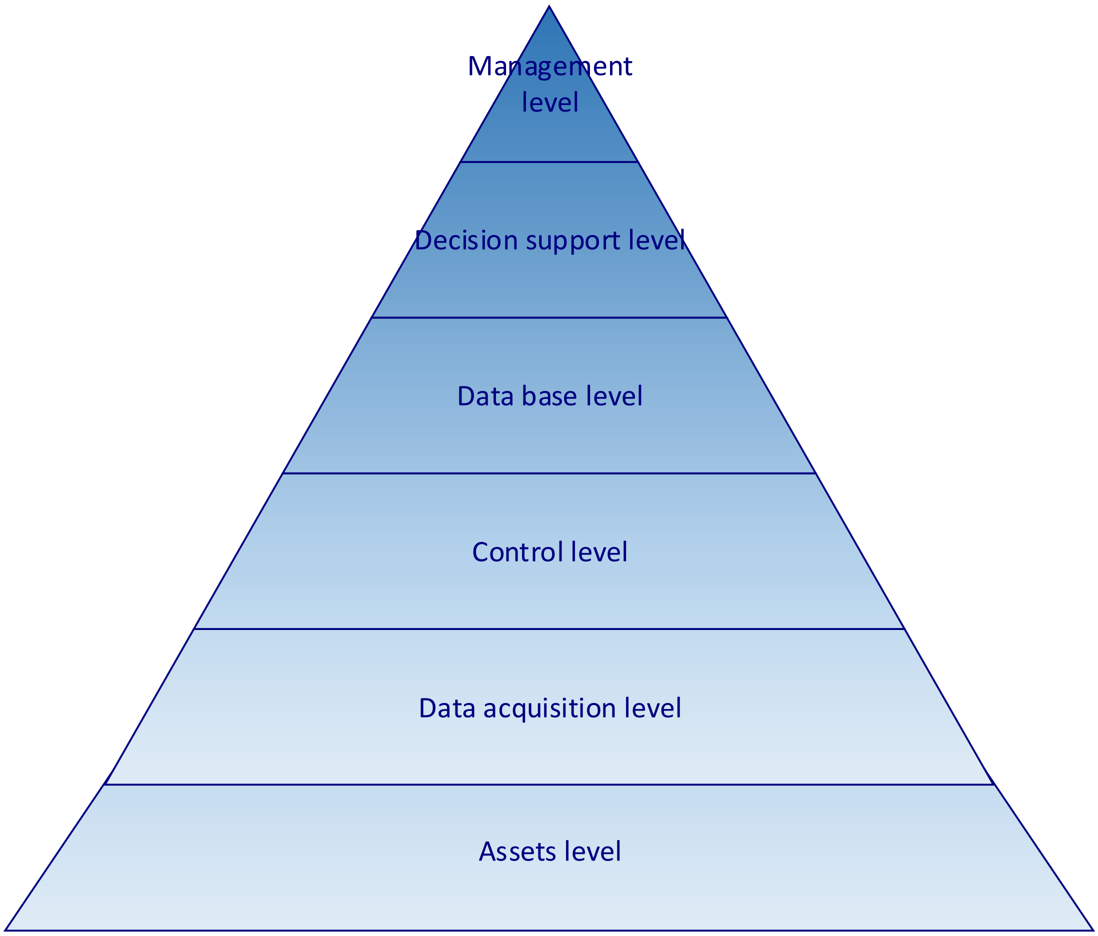

Figure 5.3 II-RFID compromised levels

- Assets level, from where products belong (from materials to finish goods) as pallets, box, packages, etc.
- Data acquisition level, which includes all the RFID system hardware (tags, antennas, readers…).
- Control level, which contains middleware, PCs and the network devices used to connect equipment.
- Data base level, that consists of RFID database and other high level databases as WMS, MES and ERP included in the application software.
- Decision support level, which includes computational intelligent for decision making and data mining approaches as for example, Decision Tree for the

Production Management, Artificial Neuronal Network for the Warehouse Management, Support Vector Machine for the Resource Planning and Swarm Intelligent for the Supply Chain Management.

- Management level, where the decisions are taken by the manager according to the information available. The Production Management, the Warehouse Management, the Resource Planning Management and the Supply Chain Management are included. This is the final object of installing a RFID system. (Yu, 2015)

5.2.2 II-RFID System functions

The input of the II-RFID system is the information collected by the RFID tag. The main tasks based on RFID data acquisition are:

- Online data collection
- Online processing progress statistics
- Daily processing statistics per work station
- Processing time of each working process and total processing time for a batch of product
- Production progress visualization and remaining processing time prediction
- Quality statistics

(Yu, 2015).

5.3 Implementation in Knowledge Discovery Lab

In Knowledge Discovery Lab (KDL), the II-RFID system is installed with both RFID hardware and software. The aim of this section is to explain the facilities and the software and hardware used in this factory prototype.

The figure 5.4 shows the II-RFID lab architecture according to the architecture explained above. It is written components included in each level:

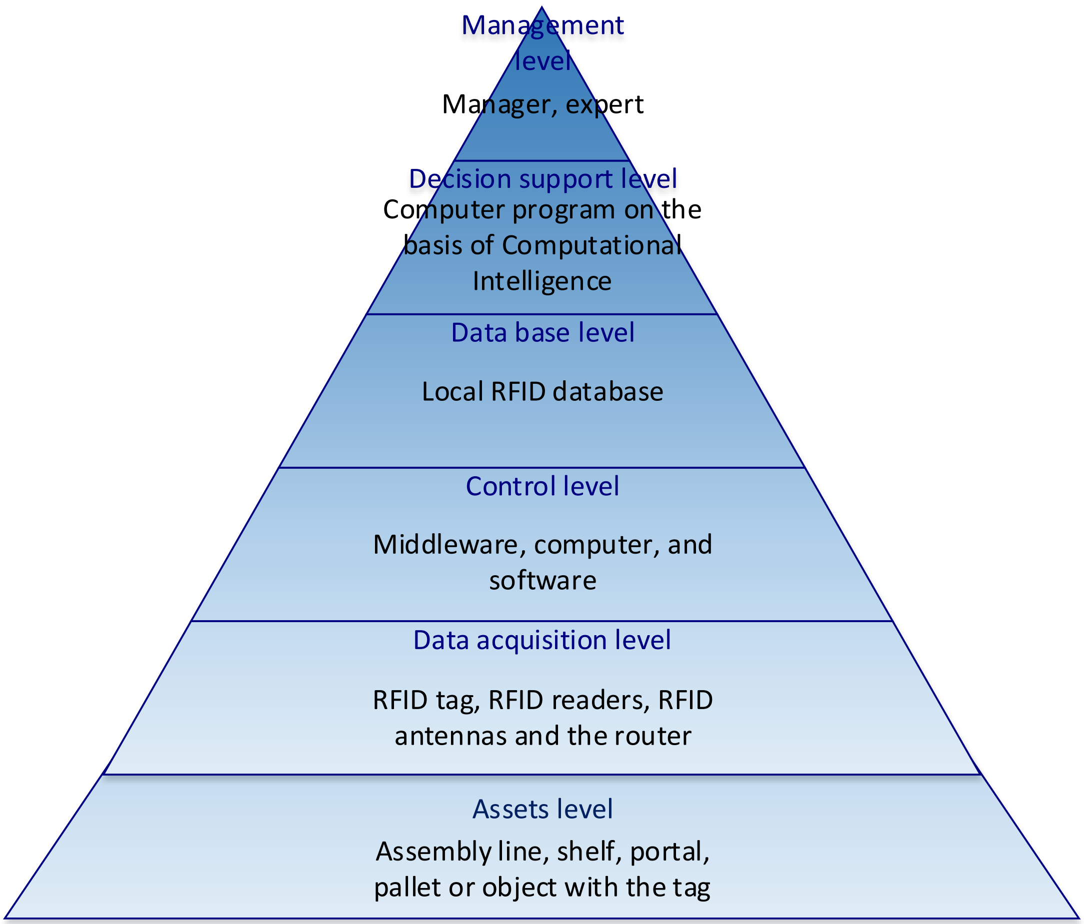

Figure 5.4 II-RFID Lab architecture

The experiment equipment includes infrastructures of warehouse and production line, RFID data acquisition system and production management software. The figure 5.5 shows the lab layout:

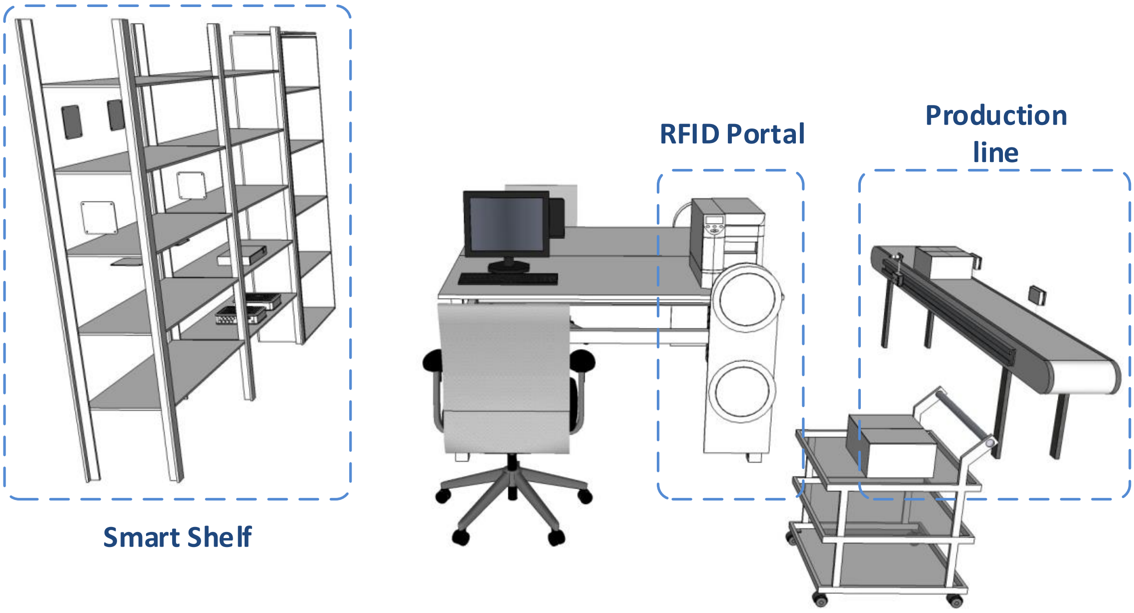

Figure 5.5 KDL layout (Yu, 2015)

All the functional areas are equipped with several RFID antennas creating a one read point in order to represent the location of the item with the tag attached. The conveyor belt showed in the figure 5.6 represents the assembly line and two antennas are located along the conveyor line representing two working stations.

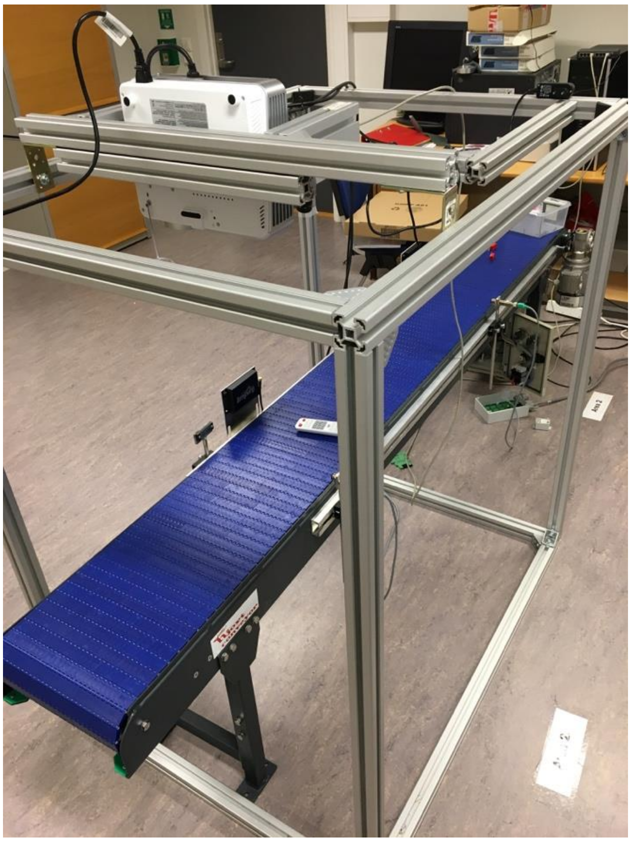

Figure 5.6 Conveyor belt

The RFID portal area is showed in the figure 5.7. It has the entrance and the exit, and each portal is equipped with two antennas to control the tagged items passing by.

Figure 5.7 Desk with the RFID Portal area

The warehouse showed in the figure 5.8, consists of the three shelves that is designed as the Smart Shelf area.

Figure 5.8 Shelf simulating the warehouse

Thus, the KDL simulates RFID data collection in the production line and in the warehouse. This case study will focus on the tracking objects and the inventory management.

5.3.1 RFID Hardware

RFID hardware comprises the physical components of the II-RFID, therefore it includes the assets, the data acquisition and part of the control level. These physical components are RFID antennas, fixed RFID reader, Middleware, Computer, Router/Switch, handheld RFID reader and RFID printer as is shown in the figure 5.9:

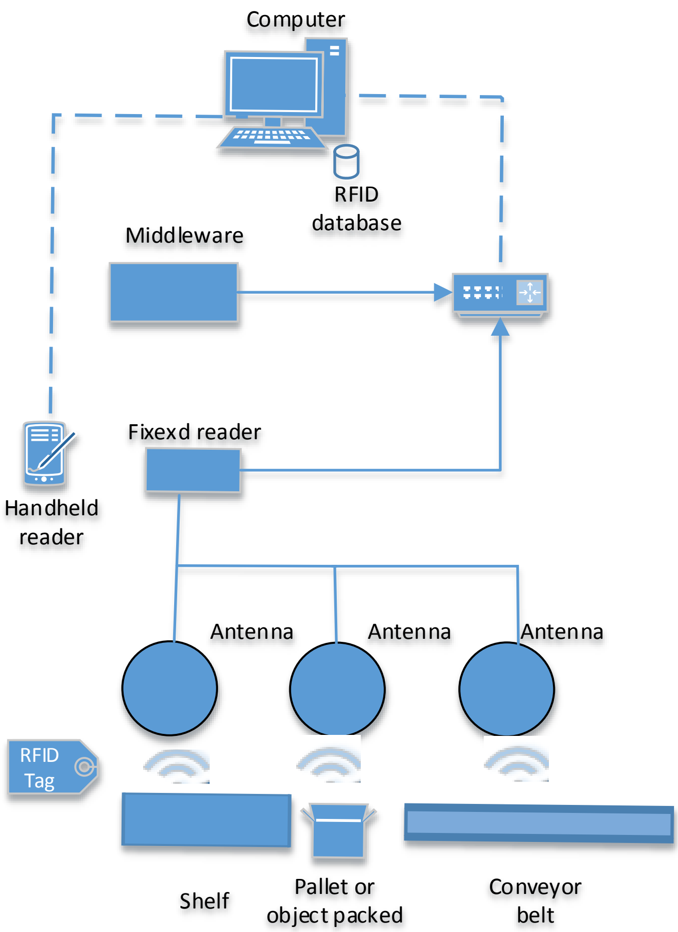

Figure 5.9 Hardware of the II-RFID lab (Yu, 2015)

These components are:

- RFID Tag:

Figure 5.10 Different kind of tags from KDL

There are different kind of tags in order to meet different requirements. It has to be considered carefully the applicability of the tag before choosing one. For example, some tags are just compatible with either plastic or metal while others are compatible with both materials, or the maximum distance for reading the tag differs from one to other. In the lab we can find tags with different size, different maximum distance reading, mounting way and material compatibility as the tags showed in the figure 5.10.

The need for interoperability is very clear in end-to-end supply chain applications where goods move through dozens of different trading partners and businesses, each with potentially unique implementation of RFID system and application requirements. Thus, EPCglobal has created a EPC that addresses the needs to have a common data formatting, processing and exchanging. This Electronic Product Code (EPC) is a numbering scheme embedded in the tag, that allows assignment a unique identifier to any physical object. The figure 5.11 shows this EPC format:

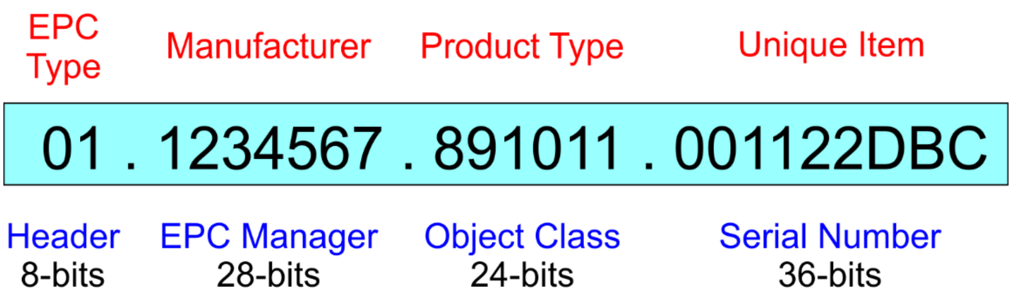

Figure 5.11 EPC format

The header identifies the EPC's version number, the Manager number identifies the enterprise, the Object Class is the part which identifies the class or category of the product and the Serial Number identifies a unique instanced of the item tagged (Bhuptani & Moradpour, 2005).
This 96-bit EPC specification gives unique identifier for 268 million companies. Each company can have 16 million object classes, with 68 billion serial numbers in each class.

- RFID antenna:

Figure 5.12 RFID antennas from KDL

There are five different types of antennas in the KDL as we can see in the figure 5.12. Every antenna represents a read point, for example the round antennas which are located in the portal area (see figure 5.5 and 5.7), can read the entrance to the warehouse and the exit from the warehouse of any item.

- RFID reader:
There are fixed RFID readers and handheld readers. The fixed RFID reader powers the antenna, detects the tag and receives remote tag operating command. It has wire connections that enables the reader send the tag information to the host computer. The figure 5.13 shows the three different fixed readers:

Figure 5.13 Fixed RFID readers from KDL

Regarding the handheld RFID readers there are three different used in the lab. Each handheld reader has different reading distance. They have integrated the antenna and the reader in the same device and both are powered by the same battery.

Figure 5.14 Handheld RFID readers from KDL

- RFID middleware

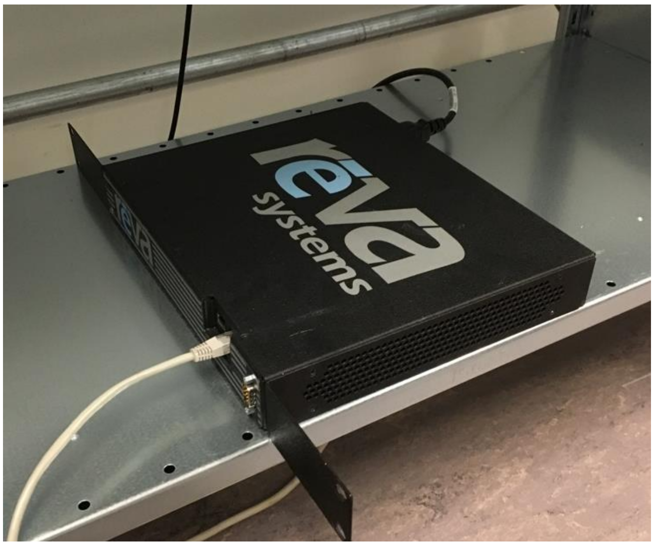

Figure 5.15 Middleware from KDL

The middleware is part of the RFID hardware and the software. The middleware as part of the hardware is the device that enables to process the tag data from different readers. It organises and remit the tag data collected by multiple readers to the database. Therefore, the middleware is used to RFID data processing and combine real time control of RFID readers, other devices and other sensor management.

5.3.2 RFID Software

Characteristics and functionalities of the software part of a RFID system vary depending on the application and requirements. The software components are:

- RFID system software

  It collects the functions necessary to allow the basic interaction between the tag and the reader.

  The software installed in the lab has two applications which enables the configure and control the reader. These two application are:

  - *Reader Startup Tool (RST)*

    It is a Microsoft Windows application from where it can be seen all the readers on your network. After selecting a reader, it can be modified its communication, network and operational parameters, and also it can read tags, review tag data, perform diagnostics and upload new software. RST is mainly intended for initially configuring a reader prior to deployment. After deployment, the RCT application has to be used. Figure 5.16 shows RST interface:

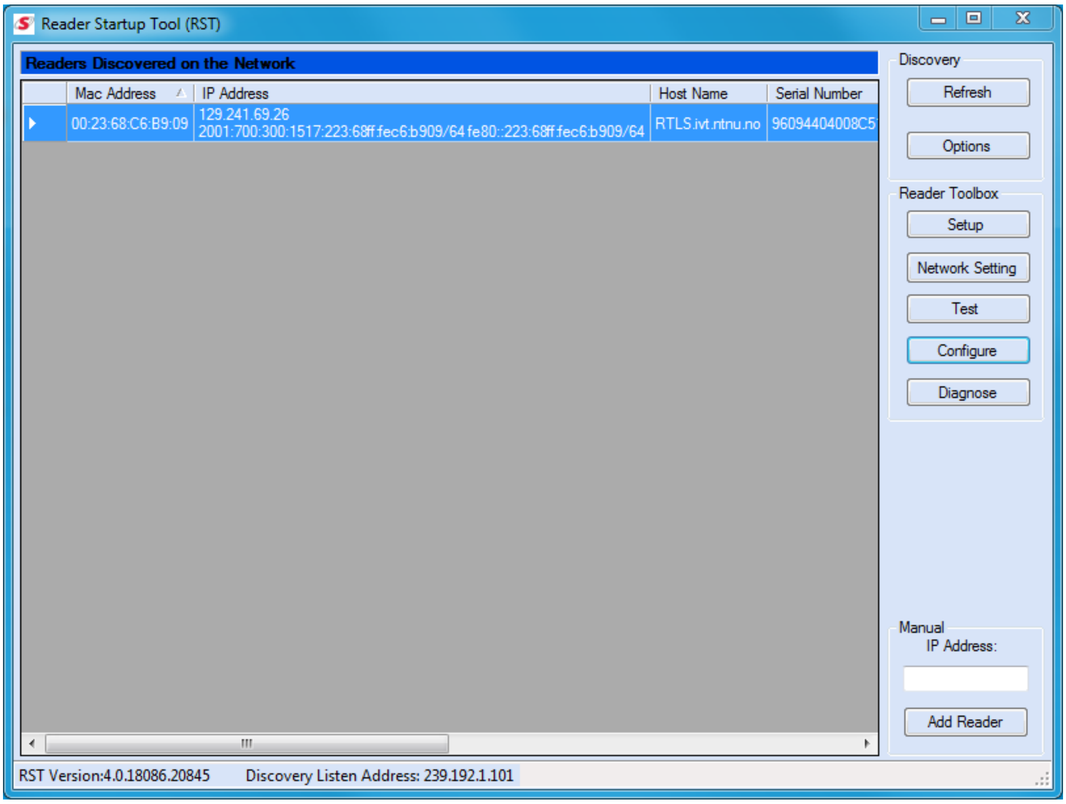

Figure 5.16 RST interface

It can be seen in the figure 5.16 that there is just a reader connected.

- *Embedded Reader Configuration Tool (RCT)*

  RCT is an application that allows the access to the readers across internet. It enables to fully modify and operate the reader. With the same functionality as RST, it allows to modify the reader's communication, network and operational parameters as well as read tags, review tag data, perform diagnostics and upload new software. But it is intended for configuring and managing deployed readers. Figure 5.17 shows the RCT interface:

Figure 5.17 RCT interface

- Middleware Management Console
  The middleware as a part of the software, is the application which enables to manage and coordinate the readers. It combines device and sensor management, RFID data processing and real time adaptive control of RFID readers. Figure 5.18 shows the interface of Middleware Management Console:

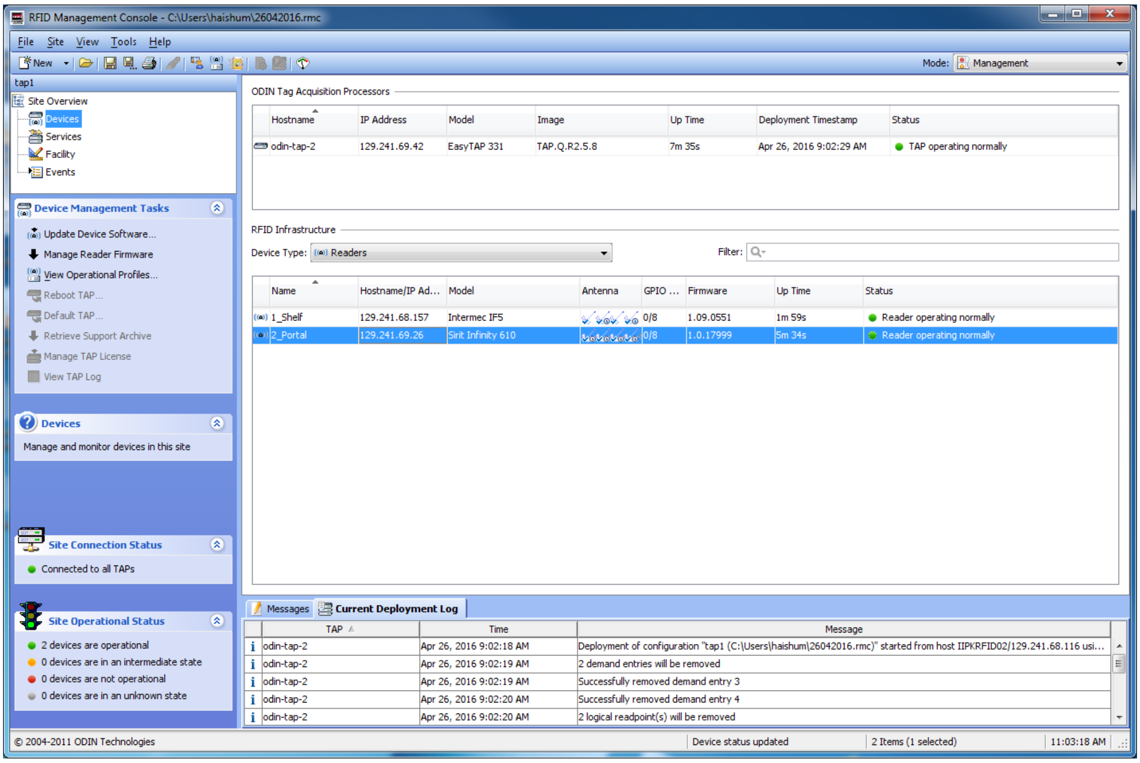

Figure 5.18 Middleware Management Console interface

- Application software or Host application
  The host application is normally an existing software program in an enterprise, such as inventory control or warehouse management system. It receives processed and normalized data sent from the tag, via the reader and the RFID middleware software. Therefore, the input data of the host application can be the RFID data, enabling the system help to make decisions in the management level.

After seeing the hardware and the software parts, the figure 5.19 summarizes all these components and its interdependencies:

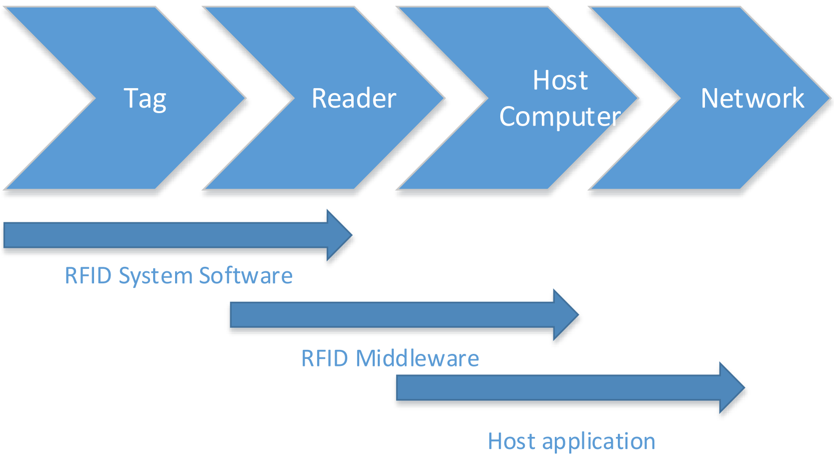

Figure 5.19 Components and interdependencies (Bhuptani & Moradpour, 2005)

As the interdependencies show, the RFID software enables configure the reader and take the tag data from it, while the middleware remit and organise the data from different readers in order to send it to the host computer. The host application, which is typically an existing software program in the enterprise such as ERP, it receives processed and normalized data from the middleware and readers and after analysing this data in order to support the decision making process in the management level.

5.3.3 Implementation scenario

The implementation scenario will be a factory, which produces bicycles according to customer's preferences. Customers can order specific features of the bicycle such as size, colour, if they want something printed on the bicycle such as their names, a sticker, etc. These customer's orders could be processed via an internet platform, where the customers could enter and configure the bicycle according to their preferences and after finishing the configuration, this internet platform could generate the price of the bicycle and let the customer pays the order. Afterwards, these orders would be sent to the production plant that in this case will be simulated by the KDL.

The figure 5.20 shows the lab layout with the parts of the II-RFID system:

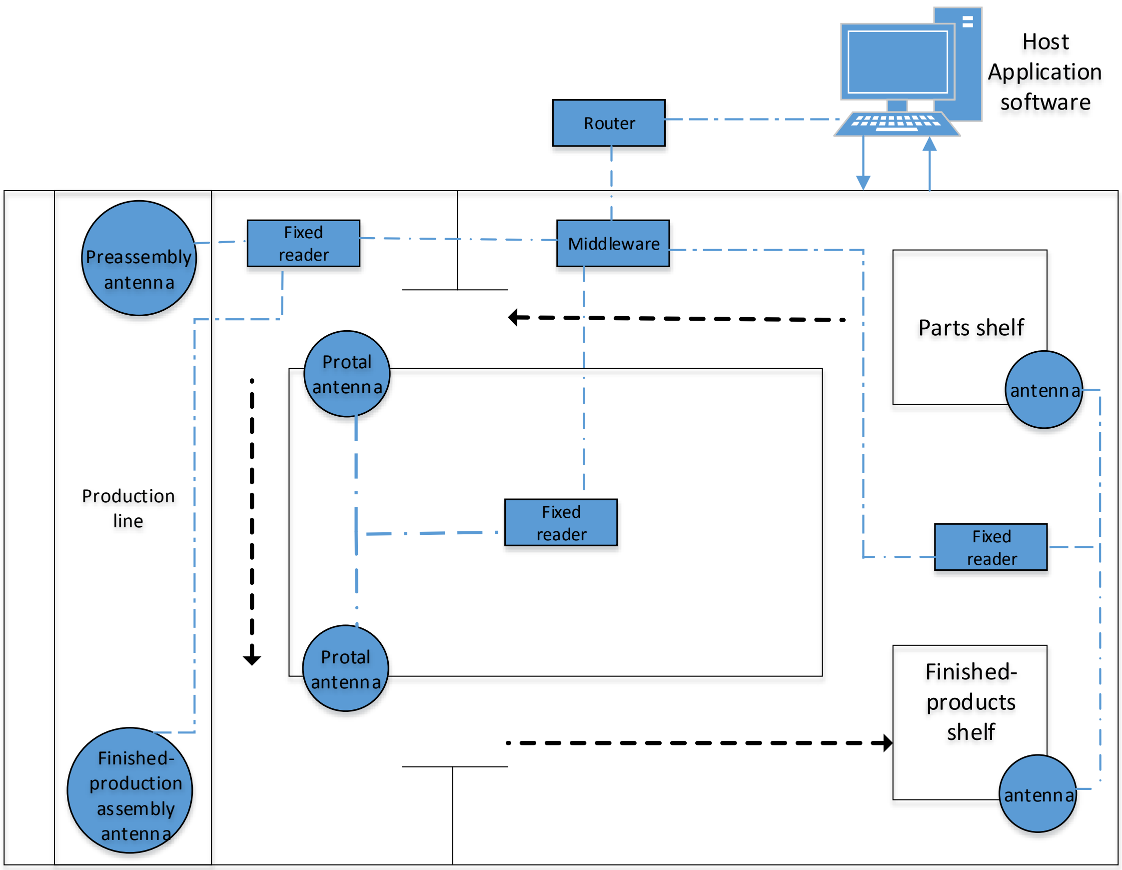

Figure 5.20 Lab layout simulating the bicycle factory

The black dashed arrows are pointing out the object route within the lab according to the production process. The blue dashed lines are showing which fixed reader control each antenna and all the hardware connections.

The right part of the smart shelf from the lab will be the "Parts shelf" which will simulate a warehouse with the bicycle parts. The conveyor belt is simulating the "Production line" and the left part of smart shelf will be the "Finished-product shelf" which will simulate the warehouse with the bicycles finished.

The figure 5.21 shows production process structure within the factory:

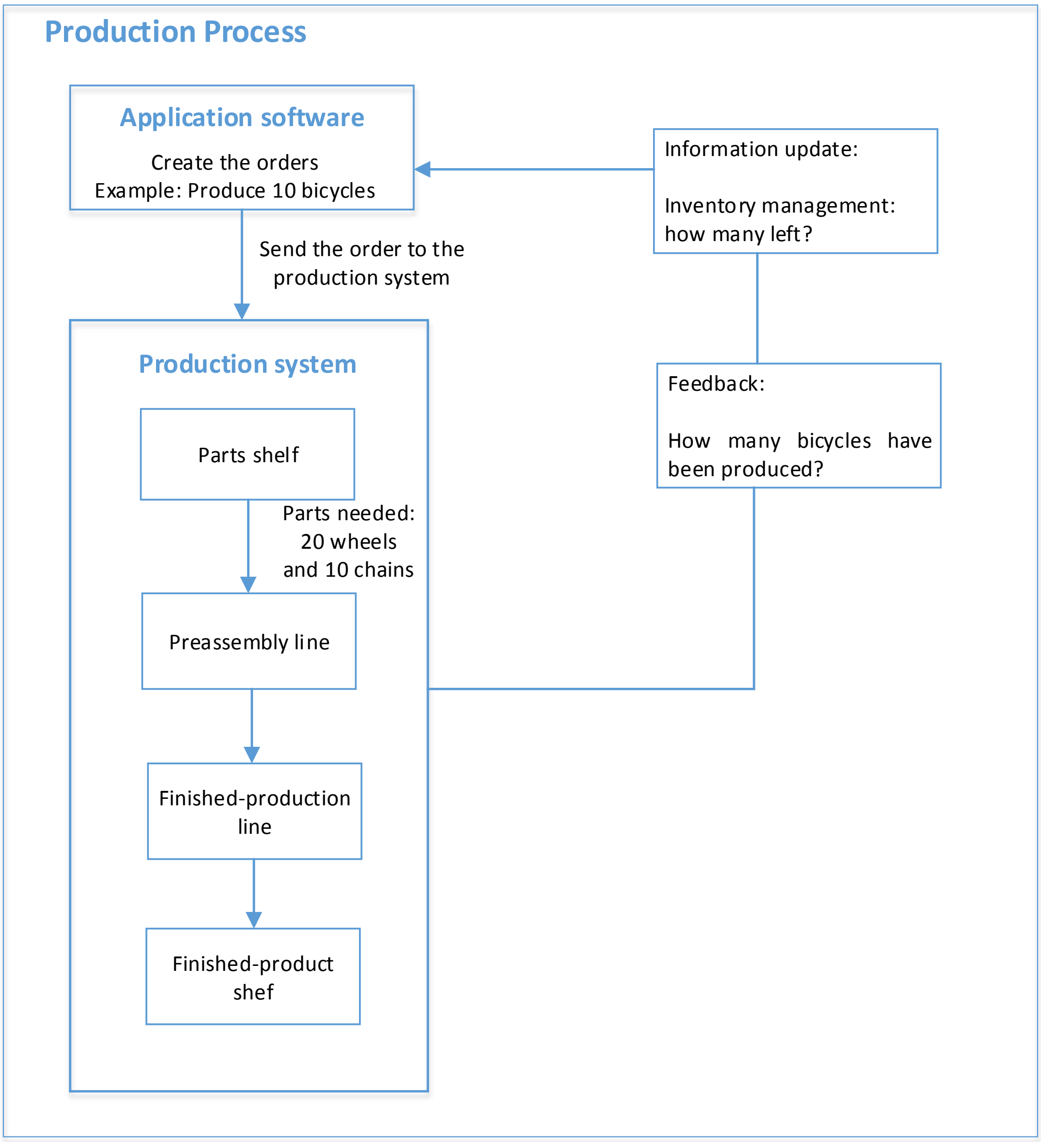

Figure 5.21 Production process

The production process will start when the host application software sends to the production system the customer's orders to produce, which have been received before from the internet platform.

According to these orders the operator receive a message in the forklift screen with the number and what parts he has to pick up from the "Parts Shelf" and where these parts are located. All the parts stored in the warehouses, have a tag attached with its specific information such as the colour that has to be painted, the special features as it has a sticker or something written on it. This information is written in the tag when the customer order is processed by the host application.

Once the operator has taken the parts needed, the antenna located in each shelf can send the information of the material left in the warehouse to the host application software and the new inventory can be updated. When the inventory arrives to certain level a message can be generated with the replenishment needed.

The forklift has attached a tag, and once it passes by the portal antenna is detected, therefore the forklift can be tracked as well. When the order has delivered to the "Preassembly line", the antennas can detect the parts and the operator can start the program assembly if all the parts are in the preassembly line.

Each antenna situated along the "Preassembly line", the "Finished-product line" are simulating a workstation, and they are updating the information about the bicycles progress, sending the information from the tag and the location to the software, making the production process more visible and transparent. In addition, each work station can read the tag information and carry out the specific production program to produce the specific order.

Once all the parts are assembled and have had the different production steps needed for that specific order, a new tag is printed with the information of that specific bicycle. After the order of for example 10 bicycles is completed, and therefore all bicycles are detected by the last antenna in the "Finished-product line", an automatic message can be generated to the operator, who can pick the order up.

When the forklift passes by the portal antenna, the tags are detected and the information is sent. After leaving the bicycles in the proper shelf, the antenna detects it and the information of the inventory in the finished product warehouse is updated in the application software.

This is how the materials and the finished products can be tracked and inventory information can be updated in real time. The Intelligent Integrated RFID system makes possible more automation, information updated in real time and enables to detect any problem before it occurs since the production process is controlled by intelligent software which receives real time information.

5.3.4 Tracking

In this section is showed how the tracking process can be carried out by the RFID software. An object with a tag attached has been located in every step of the object route explained in the production process, simulating the tracking process in the factory.

The figures from 5.22 to 5.26, show first the location of the object within the lab and after the software interface where can be seen the sequence of the object location:

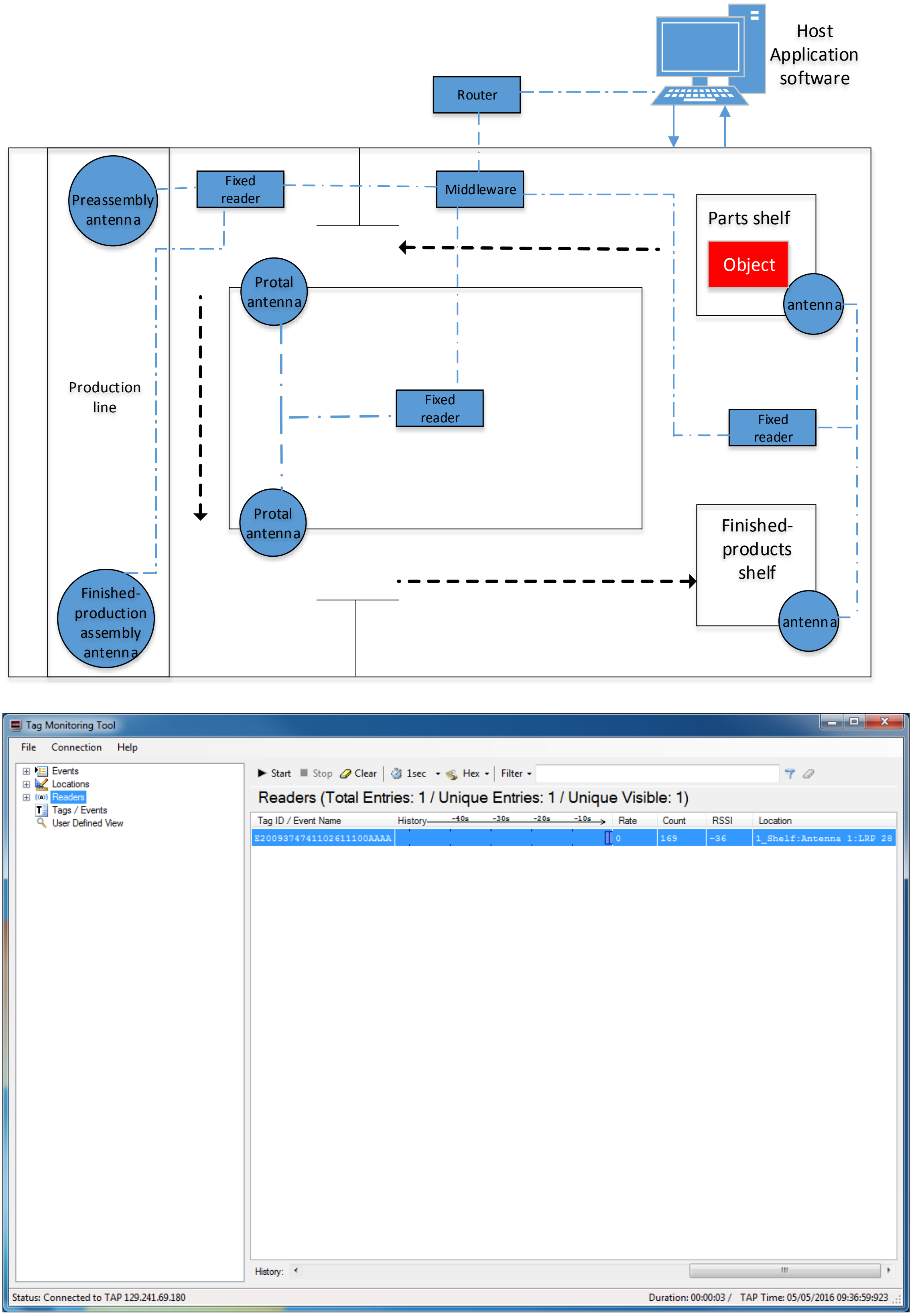

Figure 5.22 Object in the “Parts Shelf” and software interface

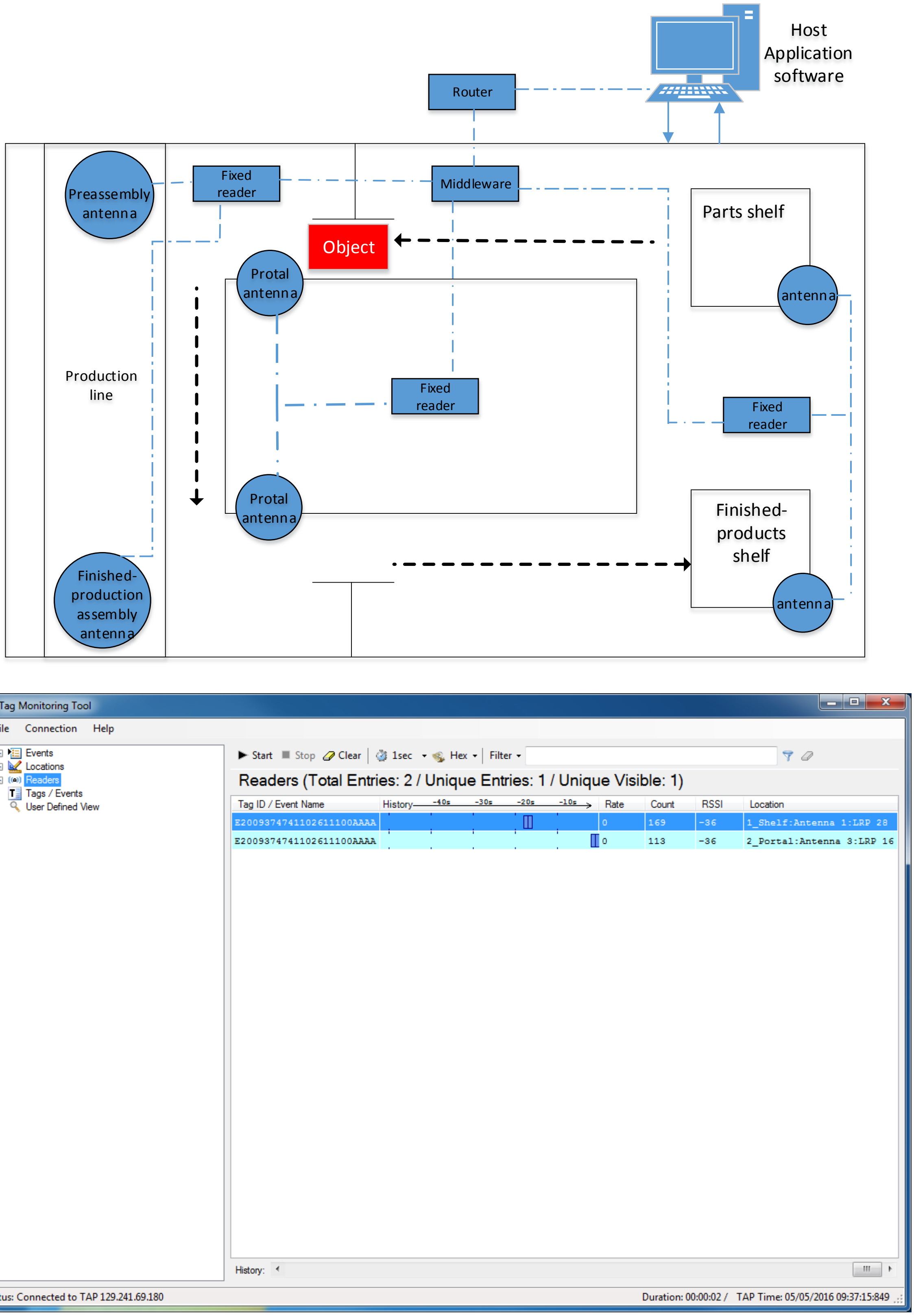

Figure 5.23 Object passing by the portal entrance and software interface

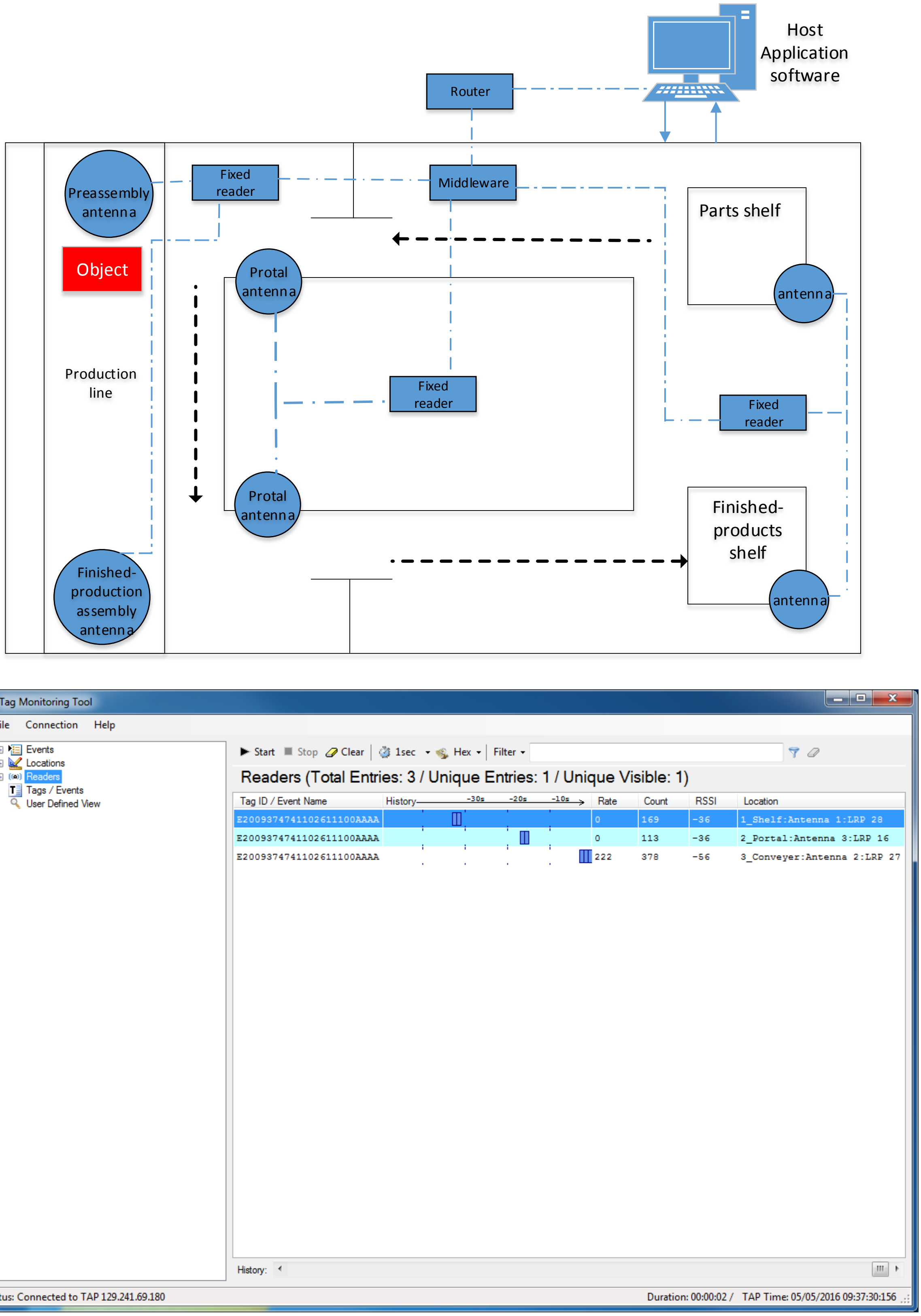

Figure 5.24 Object on the conveyor belt and the software interface

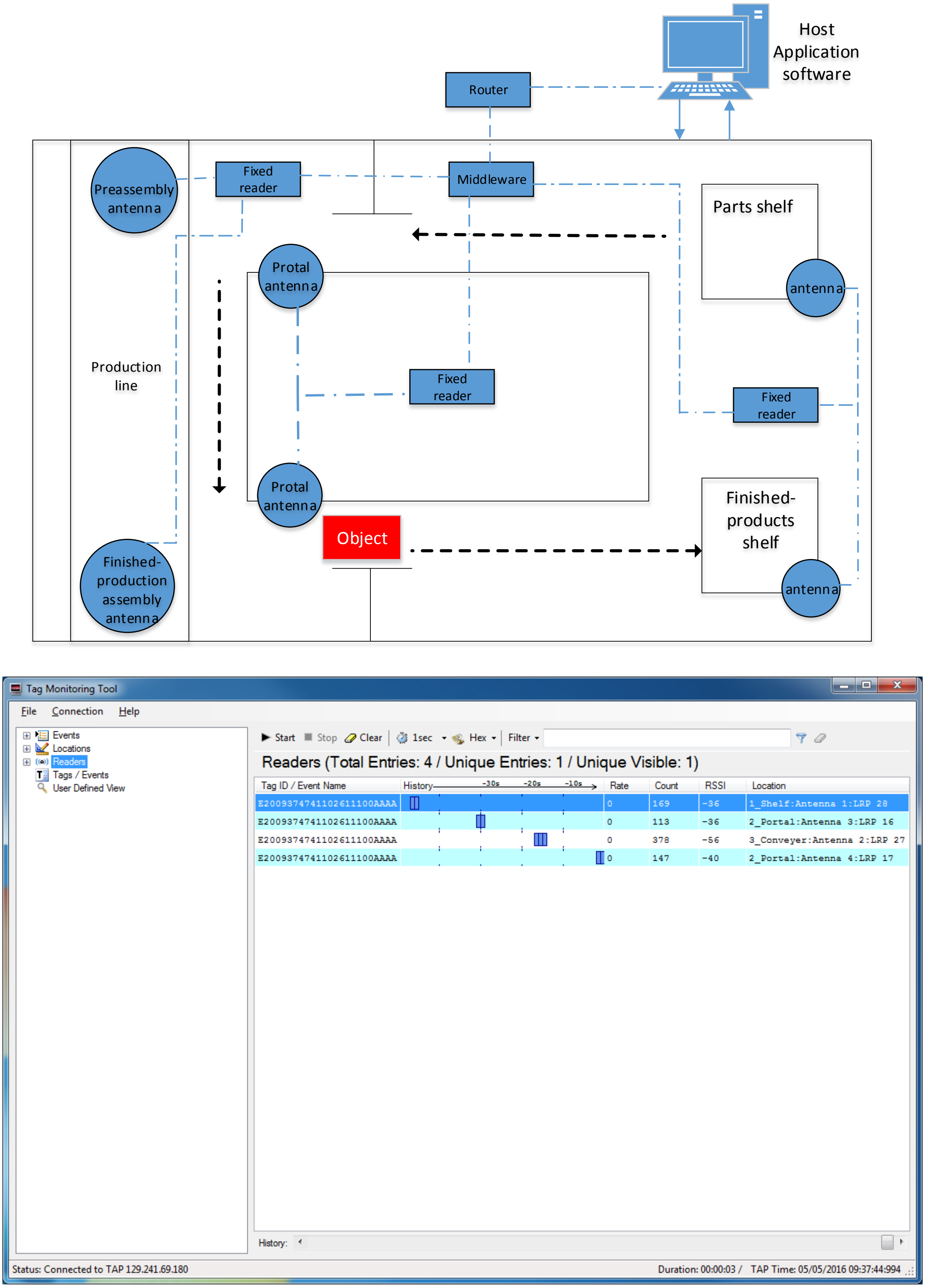

Figure 5.25 Object passing by the portal exit and the software interface

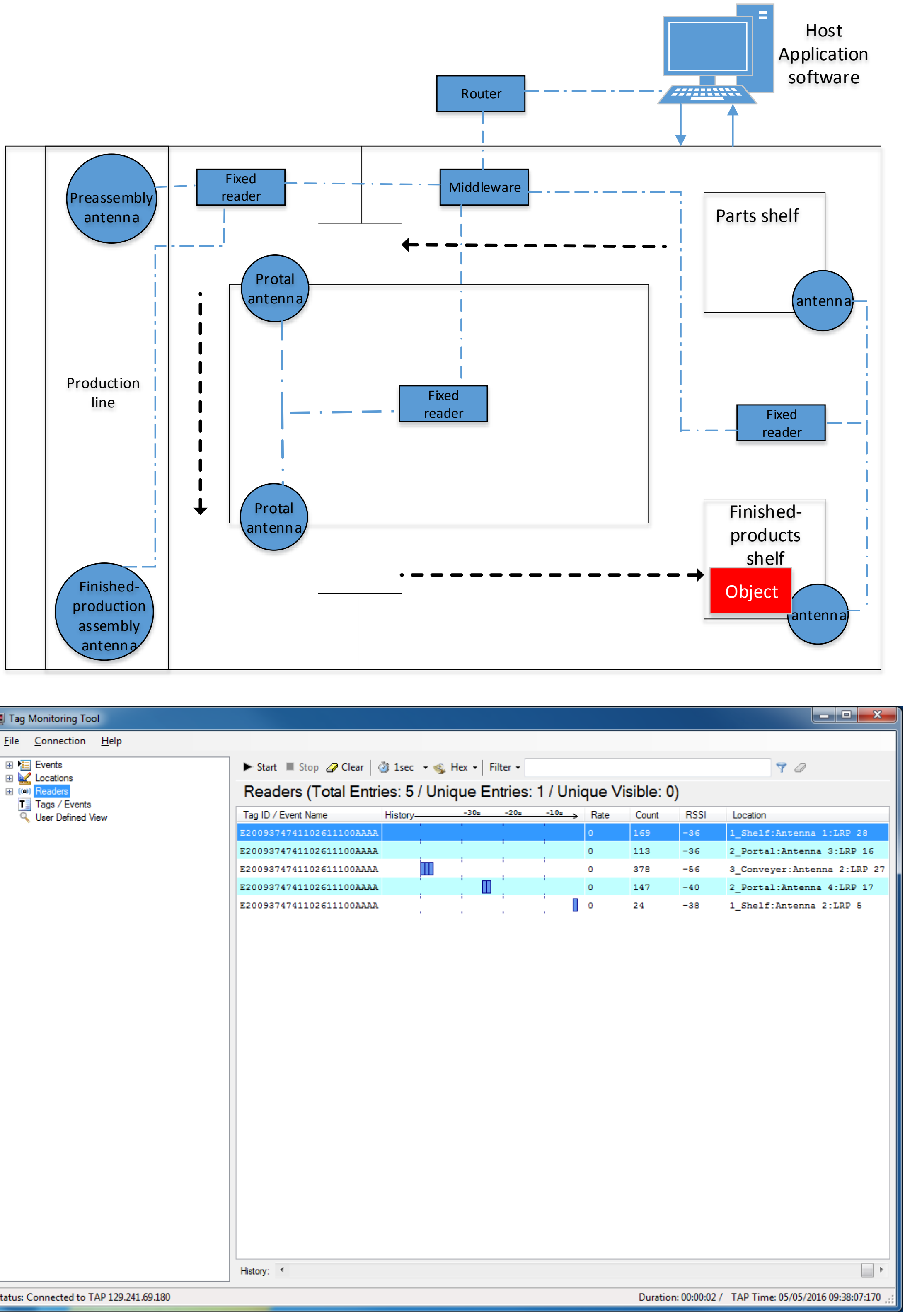

Figure 5.26 Object in the Finished-Product shelf and software interface

This process has been done with an object in order to show the tracking easily, but normally it will read several items at once and it will be generated a big amount of data, which will be processed and stored by the software.

5.3.5 Inventory management

The inventory is carried out by the host application, which includes an ERP system. The information is sent by the reader which detects the tags from the objects located in every shelf and update the inventory in real time.

Other way of reading the inventory is with the handheld reader. By pointing with the handheld reader to the shelf, it can detect the tags and show the tag number identification and the number of items. The figure 5.27 shows the handheld reader screen with the tag identification number and the quantity of items located in the shelf:

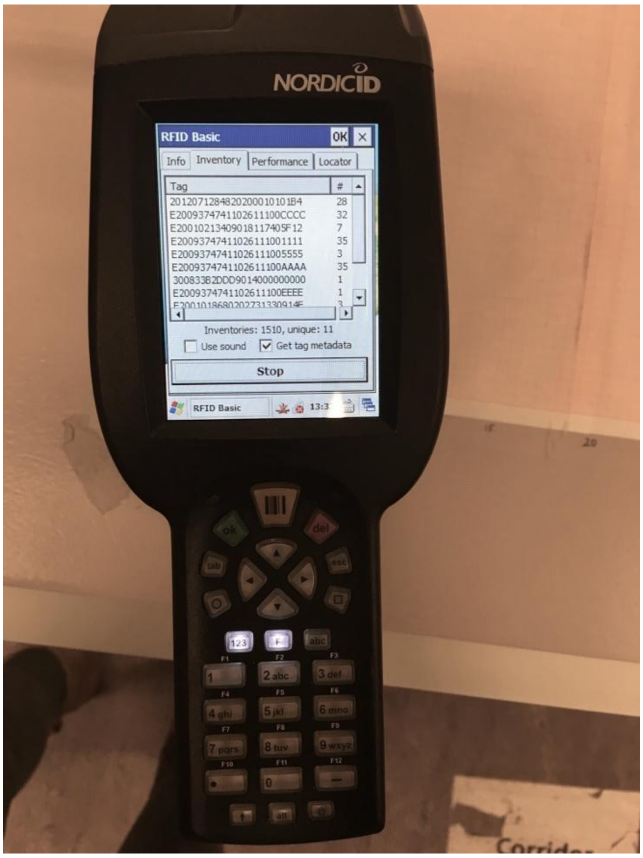

Figure 5.27 Handheld reader screen showing the inventory read

By the host application there is a more automatic way of control the inventory than with the handheld reader since it is needed an operator going to every shelf in the warehouse to record the inventory, while with the fixed reader the inventory is directly send to the computer and the operator can be just controlling the computer. However, the handheld reader is a good tool to use in a specific moment to control and contrast the inventory with the ERP system if it is detected any anomaly.

5.4 Summary

The RFID systems provide the possibility to make completely visible the logistics processes by giving an accurate information about the inventory level and removing the discrepancy between the inventory recorded and the physical inventory.

It is a spread technology, which is gaining importance over the time. Nowadays, it has established as an important asset to inventory systems due to his benefits as the reduction of labour costs, reduction of inventory inaccuracies and the simplification of businesses processes.

The Integrated Intelligent RFID systems give the possibility to achieve an "smart logistics" where the processes are automated and the same products can give his information which can be collected and analysed by a database which will provide support to the managers in the decision making process.

The aim of having more automated processes is not to replace humans in their works, it is to avoid inaccuracies and to have faster processes where the information can be shared wireless and in real time. It will be always needed people in the plant supervising and controlling the processes and taking control of any system failure.

Chapter 6 Norwegian perspective

This chapter is focused in a Norwegian company that have implemented an Intelligent Integrated RFID system, which can be understood as an approach of Logistics 4.0.

6.1 Norwegian Approach to the Logistic 4.0

Minera Skifer is a Norwegian slate supplier. They have their own quarries and long appointments, unique access to good resources from slate quarries in Oppdal and Otta in Norway and in Offerdal in Sweden. His corporate headquarters is located in Oppdal. It is an international company that sells annually slates in over 25 countries. In 2010, they won the “Best RFID Implementation” for its high-tech customer solution, and nowadays they use the database from APX systems for both intralogistics (RFID system software and host application) and supply chain management (GPS in order to track the final product until it is delivered).

Figure 6.1 Minera Skifer plant in Oppdal

The plant has four-ways forklift steered by an operator to carry the raw material indoors and loaders steered by an operator in order to carry the raw material situated outdoors. Once the raw material is available in the plant, the automated process begins. The steps are:

1. By the database is selected the product for manufacturing and order its raw materials

Figure 6.2 Operator selecting the product to produce

2. The order of raw material goes to the four-way forklift which is steered by the operator

Figure 6.3 Forklift steered by an operator and window generated with the process information

If the raw material is located outdoors a message is generated and the order can be sent by one click to the loaders. A loader driver picks the job up while the others drivers receive automatic updates

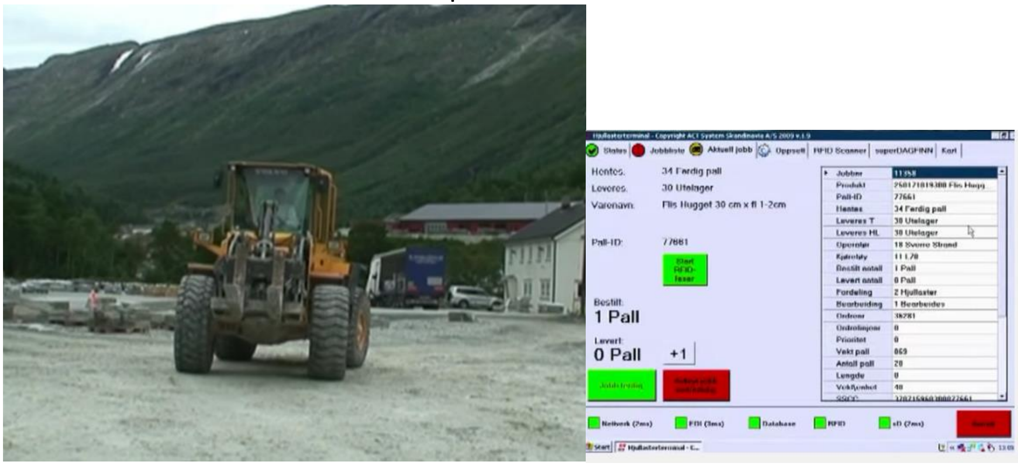

Figure 6.4 Loader steered by an operator and window generated with the process information

3. Once the job has been completed the driver clicks to confirm it and the four-way forklift driver receives an automatic message to pick the raw material indoor

Figure 6.5 Window generated when the loader driver confirms that the raw material is located indoor and the forklift can pick it up

4. Once the raw material has been placed on the production line the forklift driver clicks to confirm the delivery

5. After the treatment of the stones a software which is called POPP, is used to sort by quality each stone at different pallet stations. The pallets are loaded either with finished products or sales orders

Figure 6.6 An operator using POPP to sort each stone

6. An RFID tag is used in every pallet. The RFID reader is located in the conveyor belt. Once the pallet passes by the reader his ID number is read at the same time as his weight and the number of squares meter or consecutive metres is computed

Figure 6.7 RFID tag attached to the pallet

7. Afterwards the pallet is wrapped in plastic and transported to superDAGFINN (the software installed in the KDL) with another RFID tag attached

Figure 6.8 Pallet wrapped in plastic

8. The superDAGFINN software now requests orders or product information from the ERP system. A new RFID tag is printed and the pallet is labelled with this new RFID label

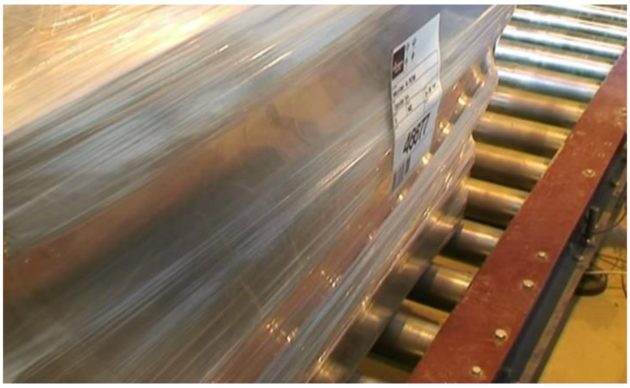

Figure 6.9 New tag with the product information generated by superDRAGFINN

9. At the same time the ERP is updated with the pallet data and the APX solution has now a good amount of data about the pallet stored
10. Afterwards the loaders receive an automatic message that the pallet has been completed and the drive can see all the pallets wrapped in plastic and transported outdoors
11. As the loader have been fitted with an RFID reader and two antennas, the pallet can be read and can send the information

Figure 6.10 Loader that transports the final pallet with the product

12. The shipment will be stored according to GPS coordinates-LAT-LONG and can be tracked during all its way

Figure 6.11 Window from the program with location of the product in real time

This is how the logistics processes of Minera Skifer are carried out. As it can be seen, the APX software supports logistics processes generating automated messages, collecting the data and sending it to the correct place. Furthermore, once the final product has leaved the plant, it can be tracked by internet and using GPS technology.

This implementation has the basic components and it uses technologies (as RFID systems and database, IoT) explained as Logistics 4.0 technical components. Thus, it is a good application of Logistics 4.0 solutions (Minera Norge, 2010).

Chapter 7 Conclusions and further research

7.1 Summary and conclusions

This paper presents a framework of the “smart logistics” referred as “Logistics 4.0”. Under the same principal statements of Industry 4.0, Logistics 4.0 encompass a range of technical components as Cyber-physical systems, which include RFID systems, software and database support. Over these Cyber-physical systems can be collected, analysed and shared essential product information with internet as a mean of communication.

Thus, Logistics 4.0 is a wide term that can be summarized as logistics and supply chain processes which are supported by intelligent sensors (RFID systems), embedded software and databases from which relevant product information is provided and shared over internet (IoT), so that a major automation degree can be achieved and logistics can be seen as a network where all the machinery can communicate each other and with humans.

The technical theory has been supported by current application of what could be understood as Logistics 4.0 solutions, since these examples meet some or the most of the technical components and technology explained as part of the new industrial evolution focused in logistics processes.

Regarding the supply chain, the digital transformation and the use of internet will trigger the use of a single database, making supply chains smarter, more transparent and more efficient in every stage. There will be a particular focus in new models which will be more closely to individual customer needs, thus the most successful companies will use better communications to integrate supplier’s and customer’s needs into their activities.

Regarding the intralogistics, the integration of autonomous technologies such as automatic driving or drones and smart systems as II-RFID systems will mean a way of optimizing logistics processes and facilitating human labour.

These technologies are not intended to replace humans in their jobs with machines or lead to job losses; they have the aim of serving human, improve the quality of human work and provide more secure jobs. esconcluded

1. The important investments in software-based systems and intelligent sensors as RFID systems
2. The need for employees with foundation in data science and information technology
3. The lack of agreed standards, due to the broad range of the numerous and complex challenges

7.2 The fear of the new technology that means a high investment which long period of returnFor further researches

The concept of Logistics 4.0 has been pictured in this thesis. It implies software applications, internet platforms and sensors installed in the plant facilities. All of this means a high investment, therefore future work would be the feasibility study within a real environment of the implementation of Intelligent Integrated RFID systems in order to manage logistics processes.

Furthermore, this thesis has focused mainly in the intralogistics processes where the objects movements are tacked and the inventory can be updated automatically in real time. Supply Chain Management is a term which includes all the management processes needed to distribute products within a plant (intralogistics) and reach a proper delivery of the raw material (inbound logistics) and the final product to customers (outbound logistics). Thus, another future work would be the development of Logistics 4.0 focused in the inbound and outbound logistics with the basis of internet platforms where all the stakeholders can have access and the information can be updated and available for everyone. As well as standards procedures and regulations regarding the access and the use of the data.

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