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IMPACT OF INDUSTRIAL INTERNET RELATED TECHNOLOGIES TO THE BUSINESS AND BUSINESS MODELS

Master of Science thesis

Examiner: prof. Hannu Kärkkäinen
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ABSTRACT

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Industrial Internet is one of the most talking topics in the recent years in both practical implications and literature reviews being a new paradigm for almost all industry sectors. It has been defined as the next industrial revolution since it opens a new and wide range of possibilities to the actual industry. This is possible through the latest advancements and trends of some key technologies such as sensors, actuators, RFID, communication technologies, cloud computing and big data analytics. Industrial Internet is supposed to revolutionize the business and the business models through new valuable information that was not available before due to the new huge amounts of accurate data that can be collected out of the machines, devices, processes and products.

This thesis aims to develop a better understanding of the impact of the major Industrial Internet technologies to the business and business models of mid-sized production line manufacturers. The current study started with a literature review, investigating the Industrial Internet concept and background as well as some other basic related concepts such as IoT, Industry 4.0, CPS and Smart Manufacturing. The differences between them were established and the opportunities and risks related to Industrial Internet among the literature were identified. The key Industrial Internet technologies were reviewed and categorized, and the basic functionalities, capabilities and optimization levels were defined. Finally, the BM literature was also reviewed and the Business Model Canvas framework was selected in order to carry out the last part of the interviews related to the impact of data and information to the business model components. Data was collected through semi-structured interviews with three mid-sized production line manufacturers' representatives. The interview structure was divided into three parts: risks and opportunities perception, perceived impact to the business model components and role of the data and information in the business and industry.

The results showed that Industrial Internet is perceived to have a big impact in the business and business model components and also that the opportunities of it, seem to be clearer that the risks which can be translated into the willingness of the companies to adopt Industrial Internet and to start offering innovative business models.

PREFACE

This thesis explores the impact of the Industrial Internet related technologies to the business and business models of mid-sized production line manufacturers.

I would like to thank in the first place Prof. Hannu Kärkkäinen for being such a good mentor, for giving me the opportunity to work in this amazing research topic and for welcoming me to Finland and to the university department as kindly as he did. In the second place, I would like to thank Karan Menon for his support and guidance through the whole research process, for being by my side all the time and helping me to overcome the difficulties. Finally, I would like to thank my parents, my brother and my friends for all their continuous support.

Barcelona, 20.02.17

Marta Minguell Montes

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LIST OF ABBREVIATIONS

BM	Business Model
BMC	Business Model Canvas
CPPS	Cyber-Physical Production System
CPS	Cyber-Physical System
GE	General Electrics
II	Industrial Internet
IIoT	Industrial Internet of Things
IoT	Internet of Things
NFC	Near Field Communication
RFID	Radio frequency Identification
SME	Small and Medium-sized Enterprises
WSN	Wireless Sensor Networks

1. INTRODUCTION

1.1 Research background

The adoption of Internet which started to happen in the early 90s and the technological advancements have been proliferating very fast until present times. The last evolution state of the Internet is called Internet of Things which is translated into a new world where all the big and small thigs can be connected and communicate between them. It didn't take much time to realize that IoT can also be applied to the industry and then it is referred to the so-called Industrial Internet.

The concept of Industrial Internet was first introduced by General Electrics (GE) in 2012 and together with Industry 4.0 has become one of the most talked about industrial business concepts in recent years. It is a new paradigm for the industry and opens a new world of possibilities and services.. Industrial internet promises to enhance decision making and data analytics to a level that was not possible before counting on huge numbers of connected devices and machines and gathering enormous amounts of reliable and accurate data to be afterwards transformed into high valuable information. Manufacturing industry is supposed to be one of the major application sectors for Industrial Internet making use of technologies such as sensor networks, RFID, cloud computing, and big data and analytics. However, the applications are not still clear (Belahcen et al., 2015) and literature often rely on new business model opportunities in general terms but the impact of Industrial Internet to the business and business models is still in its infancy. Business model has been one of the most talking topics within business research for at least the last two decades and some cases have been studied by literature research but it has been mainly from the large companies' perspective such as GE, Rolls-Royce, etc. (e.g. Agarwal and Brem, 2015; Porter and Heppelmann, 2015). This fact brings up a research gap related to the impact of the so-called Industrial Internet to SMEs business and business models and this is what the current study tries to address. Figure 1. below shows the research gap in dark green color making use of a Venn diagram.

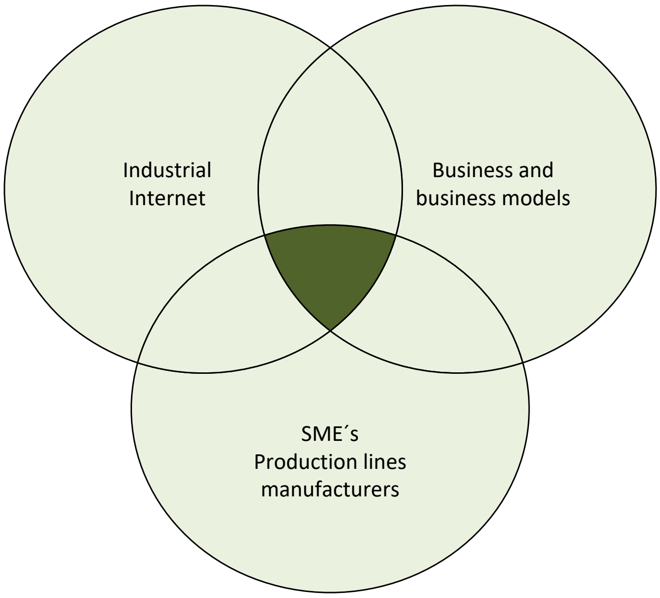

Figure 1. *Research gap this thesis addresses*

1.2 Research questions

In order to address the research gap in the current literature explained in the previous section, it has been formalized the following question which will be the primary ontological question of this thesis:

> *How major industrial internet related technologies are affecting the business and the business models of production line manufacturers?*

The primary ontological question comes from the previous explained background research and in order to answer it, it is necessary to split it into smaller and more specific questions, the research questions, which will be used as a guide during the study. These supporting questions are showed below:

Q0. What is II and differences between other concepts (II, IoT, Industry 4.0., CPS (CPPS), Smart Factories/Manufacturing, traditional automation?

Q1. Which are the basic technologies that are related with II?

Q2. Which are the trends related to these basic technologies?

Q3. What is the impact of Industrial Internet related services (achieved by II related technologies) such as predictive maintenance to the BM´s of production line manufacturers?

Q4. How do the perceived risks and opportunities related to the predictive maintenance achieved by II technologies impact the business of production line manufacturers?

Q5. What is the role of the Data & Information in the development of BM's of production line manufacturers?

As it can be appreciated, they are formulated from more basic and theoretical questions to more specific and empirical ones. In the first place, this thesis is about Industrial Internet and thus, in order to carry out such study, it is necessary to define the concept and the concepts related to it in a clear way (Q0). Behind the Industrial Internet paradigm, there are important technologies that make it possible and it is also crucial to know which are these technologies and what kind of capabilities, functionalities and optimization levels allow and what have been the latest trends that have make possible the wide current adoption of some of them (Q1 and Q2). Q3 and Q4 are the two major research questions of this study. The first one is related to the business and business model impact generated by II services (predictive maintenance) and the second one about the risks and opportunities perception which obviously has an impact to the business and business models of the companies. Finally, since every application related to Industrial Internet relies in a direct or indirect form on the data and information, the las question (Q6) was found necessary.

1.3 Structure of thesis

This section explains the overall structure of the thesis. In a general categorization, this study can be divided into four differentiated parts: introduction, literature review, empirical part and conclusions (Figure 2.).

The first chapter is the introduction of the study, it presents and overall overview of the topic and the identified research gap as well as the primary ontological question of the thesis and its supporting or research questions.

The second part of the thesis starts in chapter 2 and provides the theory and literature review related to Industrial Internet and its related technologies. Chapter 3, embraces the Business Model (BM) related theory and frameworks of the study.

The third part of the thesis, chapters 4 and 5, constitute the empirical study of the research. Chapter 4 explains the case study selected approach, the companies' selection strategy, the data collection and the analysis method. Chapter 5 presents the results and findings of the interviews done as a part of the empirical study.

Finally, the last part of the thesis I chapter 6. It constitutes the discussion and the conclusions of the whole study. It provides the specific answers to the research questions and therefore it covers the answer of the outlined problem of the thesis, the primary ontological question. The chapter end by explaining the limitations of the thesis and proposing further directions for future research.

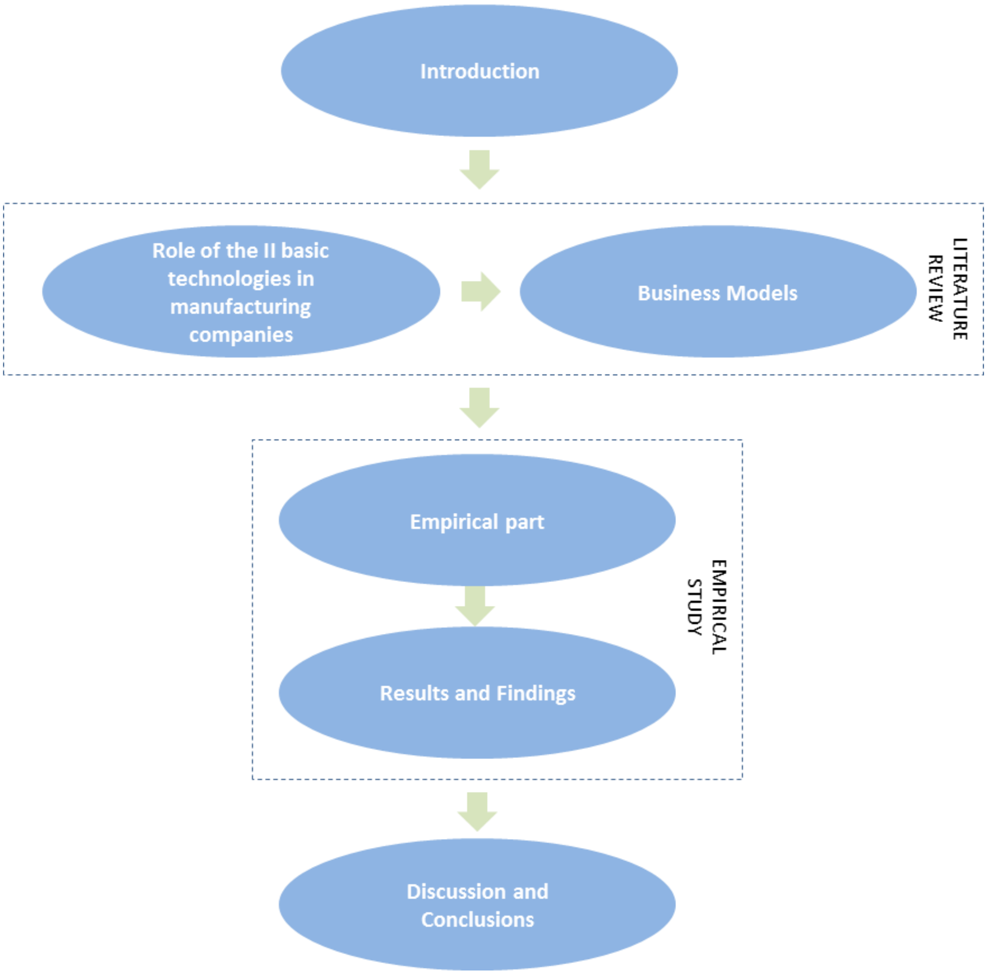

Figure 2. *Structure of the thesis*

2. ROLE OF THE INDUSTRIAL INTERNET BASIC TECHNOLOGIES IN MANUFACTURING COMPANIES

2.1 Industrial Internet

The internet and information technology (IT) revolution in the late twentieth century has been the biggest game-changer in the history of business since the industrial revolution, which began almost two centuries ago (Agarwal and Brem, 2015). Industry 4.0 and the Industrial Internet of Things (IIoT) have become one of the most talked about industrial business concepts in recent years (Gilchrist, 2016).

In this thesis, the terms Industrial Internet (II) and Industrial Internet of Things (IIoT) will be used indistinctly. There are different terminologies in the literature to refer to Industrial Internet of Things (IIoT). GE (General Electric) coined the name “Industrial Internet” in 2012, others such as Cisco termed it the Internet of Everything and some others called it Internet 4.0 (Gilchrist, 2016; Kagermann et al., 2013).

(Agarwal and Brem, 2015) describes the industrial internet as a phenomenon that involves the merging of the digital world with the world of machines. It is the convergence of the global industrial systems with the power of advanced computing, analytics, low-cost sensing, and new levels of connectivity provided by the internet (Agarwal and Brem, 2015; Annunziata and Evans, 2012). Integrating those technologies, the Industrial Internet allows companies to have a greater visibility of their operations and assets providing a method of transforming business operational processes by using as feedback the result gained from interrogating large data sets through advanced analytics (Gilchrist, 2016).

The essence of the Industrial Internet can be defined as the combination of the next three elements (Annunziata and Evans, 2012; Posada et al., 2015):

- Intelligent machines: Connecting the world’s machines and fleet of machines and networks with advanced sensors, controls and software applications.
- Advanced analytics: In order to understand how machines and systems operate it is required the combination of physic-based analytics, predictive algorithms, automation and deep domain expertise in key disciplines (i.e. material science, electrical engineering, etc.)

- People at work: Connecting people wherever they are, anytime to support more intelligent design, operations, maintenance, and enable higher quality service and safety.

The Industrial Internet is seen as the next industrial revolution and the technologies for such revolution exist, however the applications are not still clear (Belahcen et al., 2015) and literature often rely on new business model opportunities. Condition monitoring, with its traditions, advances and explicit need could offer a fertile background to start the implementation of such a technological jump. Currently with the Industrial Internet and cloud computing application, it is shifting towards remote monitoring with new requirements through the communication and analysis of big data. Condition monitoring should enable the prediction of incipient faults as to avoid loss in production, by taking appropriate measures before the complete degradation of the machine happens and thus provide a method for predictive maintenance (Belahcen et al., 2015).

There is a lot of literature pointing the opportunities and benefits and as well as the risks and threats that companies might face when it comes to of the Industrial Internet application (Annunziata and Evans, 2012; Gilchrist, 2016; Kagermann et al., 2013). Some of the most relevant and repeated opportunities in the literature are collected in Table 1 and Table 2 offers an overview of the main risks associated with the IIoT application. Taking advantage of the opportunities and overcoming the threats that brings the Industrial Internet, will have large impacts on business models of established manufacturing companies within several industries (Arnold et al., 2016; Ehret and Wirtz, 2017).

Table 1. *Opportunities associated with the IIoT application (Adapted from Arnold et al., 2016)*

Opportunities	**Main Sources**
Efficiency gains in material usage, energy consumption and human work (optimization of manufacturing processes)	Evans & Annunziata, 2012; Kaufmann, 2015; Rehage et al., 2013; Wildemann, 2014; Gilchrist, 2016
Accelerating productivity growth	Evans & Annunziata, 2012; Gilchrist, 2016
Increasing flexibility	Kagermann et al., 2013; Hinrichsen and Jasperneite, 2013
Optimized decision making	Kagermann et al., 2013; Ganiyusufoglu, 2013; Gilchrist, 2016
Customization	Kagermann et al., 2013; VDMA, 2014
Highly profitable business models	Kagermann et al., 2013; Gilchrist, 2016
Demography-sensitive job design and improved work-life balance	Hirsch-Kreinsen and Weyer, 2014; Spath et al., 2013; Kagermann et al., 2013
Delivery of better customer service	Gilchrist, 2016

Table 2. *Risks and threats associated with the IIoT application (Adapted from Ehrent & Wirtz,, 2016)*

Risks / Threats	Main Sources
Increase system uncertainty by connecting hitherto isolated systems	Geisberger & Broy, 2015, pp. 77–79 Sicari, Rizzardi, Grieco, & Coen-Porisini, 2015
Challenge of data and information reliability	Geisberger & Broy, 2015, pp. 77–79 Sicari, Rizzardi, Grieco, & Coen-Porisini, 2015; Belachen, Gyftakis, Martinez, Climente and Vaimann, 2015
Potential industry disruption by disintermediation and new competition through start-ups and Internet-driven businesses	Anderson, 2012, Brynjolfsson & MacAfee, 2012
Threatens intellectual property, know-how and intelligence	Geisberger & Broy, 2015, pp. 84–85
Safety and security of manufacturing information, for example, protecting against sabotage	Geisberger & Broy, 2015, pp. 82–84; Belachen, Gyftakis, Martinez, Climente and Vaimann, 2015
Privacy and know-how protection against unauthorized use of data	Geisberger & Broy, 2015, pp. 84–85

2.2 Basic concepts related to Industrial Internet

When talking about the industrial Internet, it is frequent to find a range of concepts (e.g. IoT, Industry 4.0, CPS, CPPS, etc.) that are brought up and repeated throughout the academic literature and to better understand this phenomenon in depth, it is necessary to define them and explain the differences between these concepts related to it. In this subsection, the main concepts related to Industrial Internet as well as the existing differences between them will be explained.

In Table 3, the basic concepts have been summarized including the main sources in order to give a global and easy first-view before explaining them in depth and pinpointing the differences.

Table 3. *Basic concepts summary*

Concept	Definition	Main Sources
Internet of Things (IoT)	Is the vision where physical objects become smart and connected with radio-frequency identification (RFID) and sensor technology so that they can send and receive data from/to other objects or the environment	(Atzori et al., 2010; Gubbi et al., 2013; Xu et al., 2014)

Industrial Internet (II)	It is the convergence of the global industrial systems with the power of advanced computing, analytics, low-cost sensing, and new levels of connectivity provided by the internet. It is a short-hand for industrial applications of IoT	(Agarwal and Brem, 2015; Annunziata and Evans, 2012; Posada et al., 2015)
Industry 4.0	Refers to the forth industrial revolution via the IoT and the internet of services becoming integrated with the manufacturing environment to achieve highly flexible production models of personalized and digital products and services, having real-time interactions between all the agents	(Kagermann et al., 2013)
Cyber-Physical Systems (CPS)	Cyber-Physical Systems (CPS) are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa	(Kagermann et al., 2013; Lee, 2008; Lee et al., 2015)
Cyber-Physical Production Systems (CPPS)	This concept is often used to remark the manufacturing environment. It includes smart machines, storage systems and production facilities capable of autonomously ex-changing information, triggering actions and control-ling each other independently	(Kagermann et al., 2013)
Smart Factories	The core of the Industry 4.0 is the Smart Factory. They are the new approach for industry where all its hosted assets will have smart capabilities, from machines to products or even the building	(Gilchrist, 2016; Kagermann et al., 2013)
Smart Manufacturing	It is a completely new approach to production as for example, using RFID or NFC technologies it is possible to identify each variety of product as they move through the line and not only identify them but also know all its characteristics (status, history, etc.) and which process is needed next	(Gilchrist, 2016; Kagermann et al., 2013)
Smart Products	A Smart product is a physical and information-based representation of a product which: (i) have a unique identification; (ii) is capable of communicating effectively with its environment; (iii) is able to retain or store data about itself; (iv) deploys language to display its features, production requirements, etc.; (v) is capable of participating in or making decision relevant to its own destiny.	(McFarlane et al., 2003; Meyer et al., 2009; Porter and Heppelmann, 2014)

2.2.1 Internet of Things

The Internet of Things (IoT) is a novel paradigm and an omnipresent vision that offers promising solutions and opportunities to transform businesses through the application of communication and information technologies to objects (Gubbi et al., 2013; Xu et al., 2014). IoT is a wide term used to refer to physical objects that are connected to the internet so that they can send and receive data.

The term was initially coined at the Auto-ID labs at the Massachusets Institute of Technology (MIT) in 1999 (Atzori et al., 2010; Weinberger et al., 2016) to refer to the vision where virtually all objects become smart and connected with radio-frequency identification (RFID) and sensor technology (Atzori et al., 2010; Xu et al., 2014). The definition of the word “Things” has suffered some modifications as technology evolved but the basis is still the same and it means making computers sense information from real objects without any human intervention. We are physical, and so is our environment, RFID and sensor technology enable computers to observe, identify and understand the world (Ashton, 2009) and many of the objects that surround us will be on the network in one form or another (Gubbi et al., 2013) communicating with each other, the Internet and humans (Weinberger et al., 2016).

As explained by (Atzori et al., 2010), IoT can be seen from three different perspectives (Figure 3). The very first emerging definitions of IoT were derived from a “Things-oriented” perspective, which includes mainly RFID and sensor technologies. The second perspective is the “Internet-oriented” one, referring to the middleware and finally, the “Semantic-oriented” view, which is related to the management of the potential knowledge available out of the very big amounts of data. In spite of being necessary to have those different perspectives due to the nature of the subject, IoT usefulness comes only when the three visions intersect (Atzori et al., 2010; Gubbi et al., 2013).

The key applications of the IoT are very broad and have been studied among academics and professionals during the last recent years. There is no doubt that IoT will affect several areas of the behavior and daily-life’s potential users in both working and domestic fields. On the one hand, domotics, e-health, assisted-living are examples of possible applications in the domestic context (Atzori et al., 2010) and on the other hand, automation, industrial manufacturing, logistics, business management and some others are suitable fields for the IoT application from the business users context. Many industries are suitable for the use of IoT technologies and a number of industrial IoT projects have been conducted in areas such as agriculture, food processing industry, environmental monitoring, healthcare, and others (Xu et al., 2014).

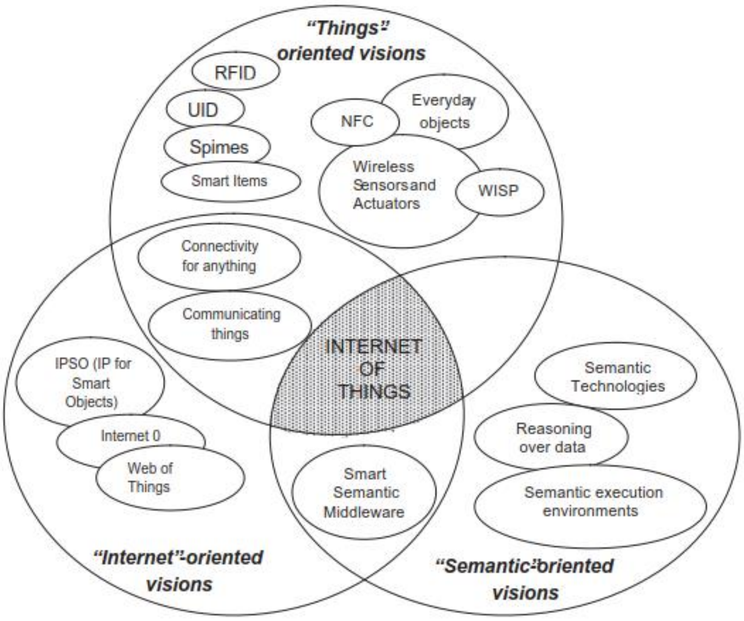

Figure 3. *Different visions for the Internet of things paradigm (Atzori et al., 2010)*

Because of these multiple applications and suitable fields for the IoT, when it comes to the industry application of IoT, other terms such as Industrial Internet (II), Industrial Internet of Things (IIoT) and Industry 4.0 are used. Due to the similarity of the concepts, it is not difficult to understand the frequent misconception of these terms but to sum up; Industrial Internet is no more than a short-hand for the industrial application of IoT(WEF, 2015).

2.2.2 Industry 4.0

The internet revolution in manufacturing domain is often referred to as Industry 4.0, which has a strong linkage to cyber-physical systems as well (Agarwal and Brem, 2015; Kagermann et al., 2013; Lee et al., 2015; Maier et al., 2015).

Industry 4.0's (Industrie 4.0 in German) provenance lies in the powerhouse of German manufacturing. However, the conceptual idea has since been widely adopted by other industrial nations within the European Union, and further afield in China, India, and other Asian countries. The name Industry 4.0 refers to the forth industrial revolution (Kagermann, 2015) with the first three coming about through mechanization, electricity, and IT. The forth industrial revolution, and hence the 4.0, will come about via the Internet of Things and the Internet of services becoming integrated with the manufacturing environment (Gilchrist, 2016).

Despite the terms Industrial Internet and Industry 4.0 are often used to refer to the same phenomenon, there is a slight difference in the concept and background. From generic IIoT concepts and principles, we can move forward Industry 4.0, which relates to industry in the context of manufacturing (Gilchrist, 2016) whereas II sectoral focus also includes others like energy, transportation, agriculture, etc. In addition, Industrial Internet emphasizes the vision of a future network of interconnected industrial assets and Industry 4.0 is more about the next revolution and state of the manufacturing industry. Despite this semantical and background differences, the main emerging technologies and principles can be both applied to II or Industry 4.0.

The vision of Industry 4.0 is that in the future, industrial businesses will build global networks to connect their machinery, factories, and warehousing facilities as cyber-physical systems, which will connect and control each other intelligently by sharing information that triggers actions (Gilchrist, 2016). The goal of Industry 4.0 is to achieve highly flexible production models of personalized and digital products and services, having real-time interactions between all the agents (people, machines and products) during the production process (Zhou et al., 2015).

Depending on the classification of the earlier industrial revolutions, it is also used the term of “Third Wave” or “Third Industrial Revolution” (Annunziata and Evans, 2012; Rifkin, 2011). While in the American context, the II is categorized as the third industrial revolution, in the German (Europe) context, it is called Industry 4.0 (see Figure 4). The Third Industrial Revolution predecessors are in first place, the Industrial Revolution, started in the mid-eighteenth century with the commercialization of the steam engine on a first stage and followed by the internal combustion engine in a second stage. In the second place, the Internet Revolution, started at the end of the 20th century with computing power and rise of distributed information networks (Annunziata and Evans, 2012). In the German categorization, the third revolution is attributed to electronics and information technology (IT) started during the early 1970s (Kagermann et al., 2013).

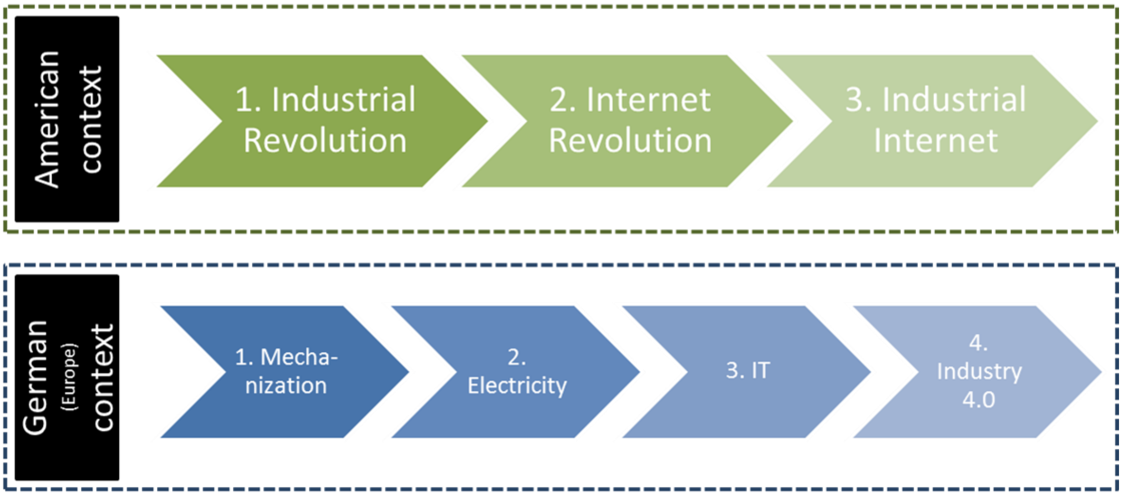

Figure 4. *Industrial waves depending on the context (Adapted from Gilchist 2016, Evans and Anunziata 2012 and Kagerman et al. 2013)*

2.2.3 Cyber-Physical Systems and Cyber-Physical Production Systems

Industry 4.0 requires the use of Cyber-Physical Systems (CPS), which can merge the physical and the virtual worlds (Kagermann et al., 2013; Lee, 2008; Zhou et al., 2015), to realize smart factories. When a system comprise physical, network and digital processing features, it is called a cyber-physical system (Gilchrist, 2016). (Lee et al., 2015) define CPS as transformative technologies for managing interconnected systems between its physical assets and computational capabilities.

CPS concept was introduced before than the Industry 4.0. An earlier concept for the integration of physical processes and computing is the “embedded systems”, information systems that are embedded into physical devices (e.g. aircraft control systems). However, this concept is a “closed box” that doesn’t show the computing capability to the outside (Lee, 2008). Differently, while traditional embedded systems are often standalone devices, CPS systems are networked, which allow remote access to the gathered data and which implies that software applications can interact with events of the physical world (Gilchrist, 2016).

Another term related to CPS is Cyber-Physical Production Systems (CPPS). This concept is often used to remark the manufacturing environment (Kagermann et al., 2013; Monostori, 2014; Posada et al., 2015). This CPPS include smart machines, storage systems and production facilities capable of autonomously ex-changing information, triggering actions and control-ling each other independently (Kagermann et al., 2013).CPPS will enable and support the communication between humans, machines and products alike. The elements of a CPPS are able to acquisition and process data, and can self-control certain tasks and interact with humans via interfaces (Figure 5) (Monostori, 2014).

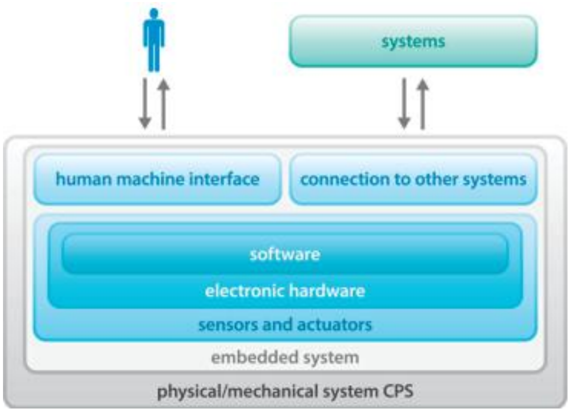

Figure 5. *Cyber-physical systems architecture (Monostori, 2014)*

Business will be able to set up global networks that collect their machinery, warehousing systems and production facilities in the shape of CPS. To sum up, Industry 4.0 will require the integration of CPS in manufacturing and logistics while introducing the Industrial Internet of Things due to the interaction between the designed product and the production systems (Gilchrist, 2016; Hehenberger et al., 2016). This will bring new ways to create value, business and downstream services for SME (Gilchrist, 2016).

2.2.4 Smart Factories, Smart Manufacturing and Smart Products

The core of the Industry 4.0 is the Smart Factory, from the theory, in Industry 4.0 everything from processes to supply chain to business models, are defined to create the Smart Factory (Gilchrist, 2016). Smart factories are the new approach for industry where all its hosted assets will have smart capabilities, from machines to products or even the building (Figure 6).

Smart factories are the ultimate stage of Smart Manufacturing (Kang et al., 2016) where people, machines and products communicate to each other in a natural way. While the traditional lean manufacturing goal was to reduce costs through the elimination of wastes, Smart Manufacturing focuses on the improvement of productivity, quality, delivery and flexibility using the convergence of the latest technologies such as RFID, NFC, sensors and actuators, cloud computing, etc.

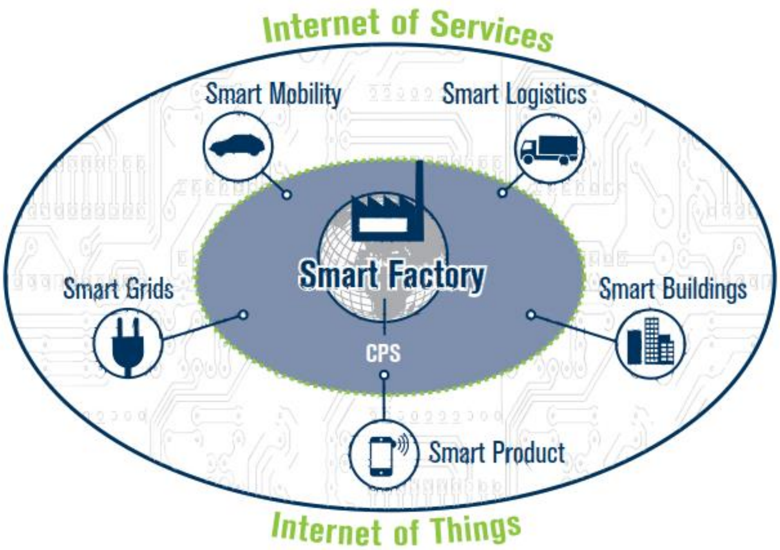

Figure 6. *Smart Factory (Kagermann et al., 2013)*

The terms “Smart Production”, “Smart Manufacturing” or “Smart Factory” are used in Europe, China and the US to refer specifically to digital networking of production to create smart manufacturing systems (Kagermann et al., 2013). Some literature considers Industry 4.0 and Smart Manufacturing as the same phenomenon responsible of the fourth industrial revolution (Lee et al., 2015).

Smart manufacturing gives a completely new approach to production as for example, using RFID or NFC technologies it is possible to identify each variety of product as they move through the line and not only identify them but also know all its characteristics (status, history, etc.) and which process is needed next. This is not a futuristic approach, General Electric counts already with IIoT technology in some of its manufacturing plants (Gilchrist, 2016). GE aims to transform their traditional plants by digitally connecting teams, designing products to the factory floor, other supply chain partners and, finally, to service operations (Gilchrist, 2016). Smart Factories are not only achievable and related to large companies but also are perfect for SME (Small and Medium Enterprises) because of the flexibility they provide (Gilchrist, 2016). The opportunities that this new version of the factories offers are enormous, for example, it is possible to make last minute changes in the design or a better decision-making. In summary, this entire new paradigm for the manufacturing industry will bring new ways to create value, new business models and downstream services for SME.

Smart Factories require smart or intelligent (Meyer et al., 2009) products. (McFarlane et al., 2003) defines formally an intelligent product as a physical and information-based representation of a product which:

(i) has a unique identification;
(ii) is capable of communicating effectively with its environment;
(iii) is able to retain or store data about itself;
(iv) deploys language to display its features, production requirements, etc.;
(v) is capable of participating in or making decision relevant to its own destiny.

In Figure 7 it is shown an example of such an intelligent product. The pallet is the physical product, the information-based representation of the product is stored through the network in the database and the decision-making agent provides the intelligence.

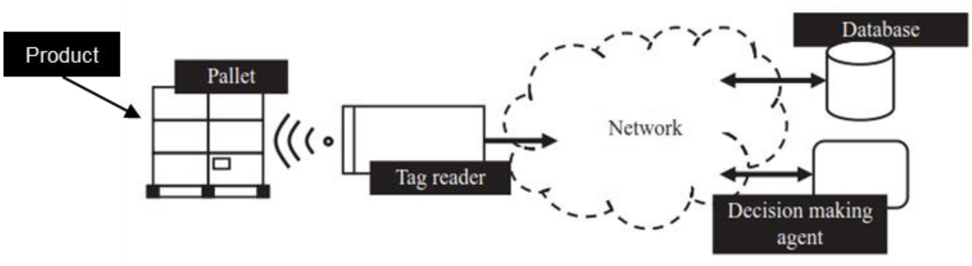

Figure 7. *Smart or Intelligent product (G. Meyer et al., 2014)*

(Porter and Heppelmann, 2014) refers to smart products as smart, connected products to emphasize that a product could be considered smart if it included embedded sensors and could show its performance on a screen for example, but it is not a really smart product until it is capable to communicate with other products or devices (connected). Smart, connected products core elements are: (i) physical components (e.g. the engine block, tires and batteries of a car); (ii) “smart” components such as sensors, microprocessors, data storage, software, embedded operating system and user interface (in the car e.g. it would be the engine control unit, rain-sensing windshields and so on); (iii) connectivity components including ports and connectivity protocols that could take three different forms: one-to-one, one-to-many or many-to-many. While smart components increase the value of the physical object, connectivity components enable smart components to exist out of the product itself (Porter and Heppelmann, 2014). Porter's vision of smart product despite being acknowledged and useful, is more focused on end products point of view (e.g. smart tractor, smart racket, smart wearables, etc.) and not on spare parts with RFID technology or other industrial applications for smart products.

Having defined and differenced the main concepts related to Industrial Internet, in Figure 8 it has been designed a graphic illustration to summarize in a visual form the hierarchy, connections and overlaps between them. As it can be seen, the most generic and broad concept that includes all the other is the IoT. Inside IoT, it is found the so-called Industrial Internet and the Industry 4.0. Due to the shared characteristics among them, it is represented an intersection between the two circles. Inside this intersection and also out of it, it is represented the Cyber-Physical Systems because they are not only representative of II and Industry 4.0. Finally, inside the CPS bubble intersection, there is the Smart Factory because this concept is not possible without having II or Industry 4.0 and CPS.

Taking into account all the definitions and clarifications of the different concepts above in this section, in this thesis, the work is related to Industrial Internet concept and not to the Internet of Things.

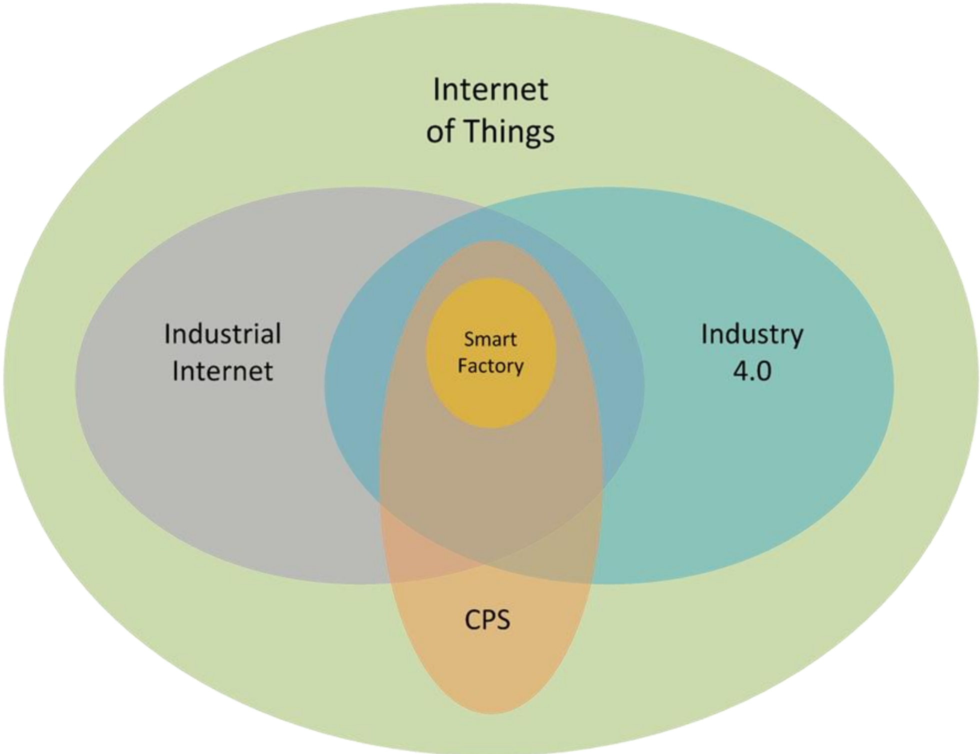

Figure 8. *Hierarchy, connections and overlaps between II related concepts*

2.3 Major basic technologies related to II

The application or use of Industrial Internet in the real world is possible due to the integration of several enabling or key technologies. Many different classifications are present in the academic literature varying depending on the nature of the research or the author (communication protocols in IT, sensors and actuators in things or hardware-oriented research, identification technologies in the supply chain research, etc.).

In order to address this subsection, and answer the RQ1 and RQ2, it has been developed in the first place, three general categories and subcategories where the main Industrial Internet related technologies should fit in. These categories are: (i) Physical Product/Asset; (ii) Connectivity; (iii) Product/Asset Cloud. Secondly, the major basic technologies related to Industrial Internet have been classified in this categories (or subcategories). Further in the section, it will be explained the functionalities, capabilities and dimension levels allowed by the implementation of Industrial Internet related technologies and the trends of some of these technologies (e.g. trends in sensoring).

2.3.1 Categories of the basic technologies

There is no agreement for a right or wrong categorization of the Industrial Internet related technologies, even there is no agreement for the right key enabling technologies or what should be considered as a technology and what not. For example, some academic literature, presents CPS as an enabling technology (Kagermann, 2015; Kang et al., 2016; Zhou et al., 2015) while some others see it as a global or basic concept related to Industrial Internet without whom the phenomenon would not be possible (Atzori et al., 2010; Ehret and Wirtz, 2017; Gubbi et al., 2013; Xu et al., 2014). After reviewing the most relevant literature and also following our own understanding, in this thesis, CPS will not be treated as a key enabling technology but will be considered as a main and basic concept related to Industrial Internet.

Depending on the background (computer science, information science, supply chain, etc.) of the academic researchers or publications, the categories for the key Industrial Internet technologies can vary or directly do not exist and they focus on different technologies (e.g. computer science is more concerned about RFID and middleware, information science on big data analytics, etc.). (Atzori et al., 2010) presented just two categories: (i) identification, sensing and communication technologies and (ii) middleware. (Whitmore et al., 2015) proposed three categories for technology: (i) hardware (e.g. RFID, NFC, sensor networks); (ii) software (e.g. middleware, search/browsing); and (iii) Architecture (e.g. software and process architectures). (Porter and Heppelmann, 2014) offered an interesting approach for what they called “the new technology stack”. Starting from *smart connected products’* three core elements: physical components, smart components and connectivity components, (Porter and Heppelmann, 2014), developed the already mentioned *new technology stack.* It is divided into main three categories: product, connectivity and product cloud with multiple layers on them. This approach also takes into account the "boundaries" of smart connected products such as identity and security and external information sources but in this thesis, we will focus on the direct related technologies in Industrial Internet. This framework have been used as a reference in order to define and elaborate a possible categorization for the Industrial Internet related technologies (Figure 9). Despite (Porter and Heppelmann, 2014) defined it mainly based on smart consumer-products (e.g. wearables), it also suits (with some modifications and additions) for our interest in this thesis. Industrial Internet refers to the application of IoT to the industry so in this case the so-called *smart connected products* could be machines, robots, tools, spare parts or by-products among others.

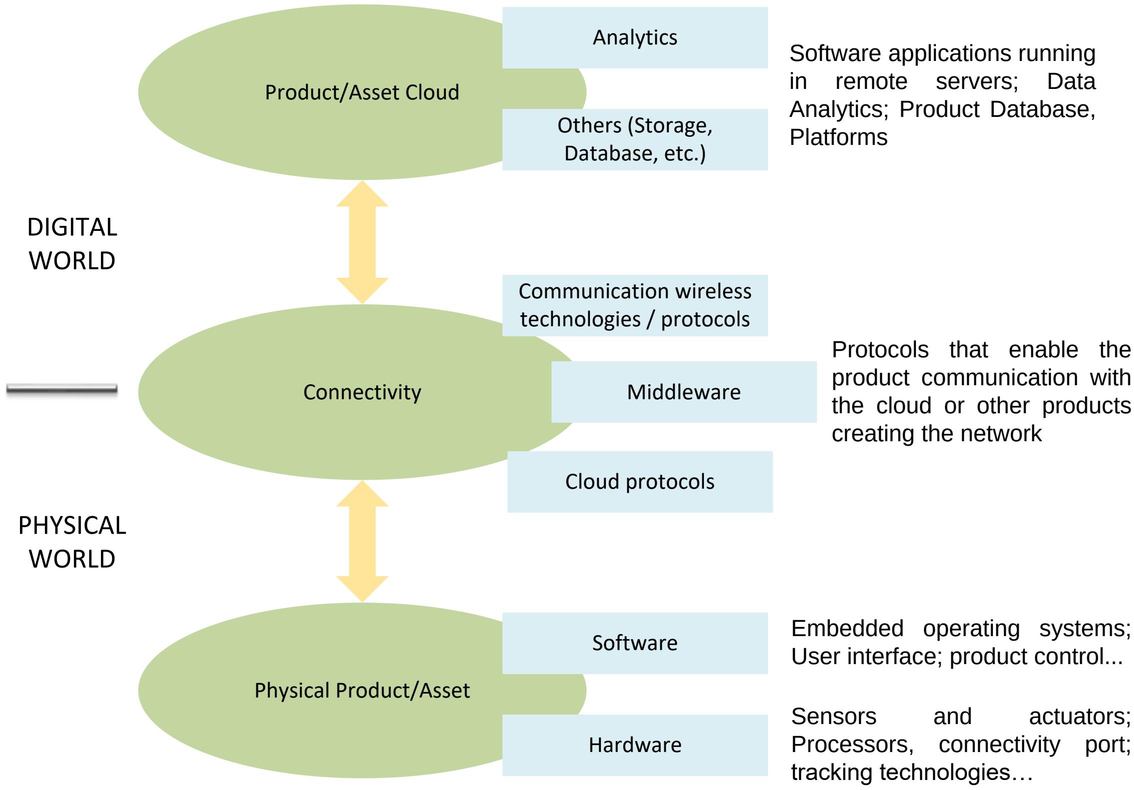

Figure 9. *Industrial Internet technology stack. Adapted from Porter and Heppelmann, (2014)*

A general categorization to sum up the different key enabling technologies for IIoT is shown in Figure 9. The three main categories are Physical Product/Asset, Connectivity and Product/Asset Cloud. The first one, Physical product/asset, is divided into two subcategories, Software and Hardware which contain technologies such as sensors and actuators, and embedded operating systems respectively. Connectivity category refers to protocols and technologies that enable the product communication with the cloud or other products creating the network (Porter and Heppelmann, 2014) and connecting the physical with the digital world. It has been divided into three subcategories: Internet protocols (e.g. IPv4 and IPv6), Middleware and Communication technologies and protocols such as RFID, NFC among others. Finally, the Product/Asset Cloud category refers mainly to software applications running in remote servers, data analytics, platforms, etc. It has been split into two subcategories: Analytics and a generic one named Others conformed by technologies for storage, database, etc.

2.3.2 Categorization of the basic technologies

Industrial Internet related technologies are numerous among the academic literature. Wireless Sensor Networks (WSN) and Radio-Frequency Identification (RFID) are considered foundational technologies for IoT (Xu et al., 2014). Despite being two important enabling Industrial Internet technologies, there are some others that play an important role and should be explained in order to have a broader perspective of what is behind Industrial Internet and which technologies and trends are emerging because of or enabling this phenomenon. Explaining in depth all the Industrial Internet related technologies is not suitable and neither relevant for this thesis but a general view and categorization and the main literature sources is shown in Table 4. The categorization of the technologies follows the framework proposed and explained in the previous section. The main and basic technologies will be explained in further detail below in this section.

Table 4. *Industrial Internet enabling technologies classification*

Category	**Sub- Category**	**Technology**	**Source**
Physical Product/Asset	Hardware	WSN (Wireless Sensor Networks)/Smart sensors	(Atzori et al., 2010; Ehret and Wirtz, 2017; Gilchrist, 2016; Gubbi et al., 2013; Kagermann, 2015; Kang et al., 2016; Whitmore et al., 2015; Xu et al., 2014)
		Actuators	(Ehret and Wirtz, 2017; Whitmore et al., 2015)
		RFID tag	(Atzori et al., 2010; Gilchrist, 2016; Gubbi et al., 2013; Whitmore et al., 2015; Xu et al., 2014)
		NFC tag (Near Field Communication)	(Gilchrist, 2016; Whitmore et al., 2015; Xu et al., 2014)
	Software	RFID, NFC and sensor software	(Atzori et al., 2010; Gilchrist, 2016; Gubbi et al., 2013; Whitmore et al., 2015; Xu et al., 2014)
Connectivity	Middleware	Platforms (SOA (Service Oriented Architecture))	(Atzori et al., 2010; Gilchrist, 2016; Gubbi et al., 2013; Whitmore et al., 2015; Xu et al., 2014)
	Cloud protocol		

	Communication wireless technologies / protocols	IPv4, IPv6	(Atzori et al., 2010; Gilchrist, 2016; Gubbi et al., 2013; Kagermann, 2015; Xu et al., 2014)
		3G/4G	(Xu et al., 2014)
		WiFi	(Gilchrist, 2016; Xu et al., 2014)
		ZigBee	(Gilchrist, 2016; Li et al., 2015; Xu et al., 2014)
		Bluethooth (low-power)	(Gilchrist, 2016; Li et al., 2015; Xu et al., 2014)
		WiMax	(Gilchrist, 2016; Li et al., 2015; Xu et al., 2014)
		Other wireless communication technologies: Thread, Digimesh, WirelessHart, 802.I5.4, LoHoWAN, HaLow, , DASH7, UWB, UMTS/CDMA/EDGE/MBWA	(Gilchrist, 2016; Li et al., 2015; Xu et al., 2014)
Product/Asset Cloud	Analytics	Big Data & Advanced Analytics (Big Data Analytics)	(Ehret and Wirtz, 2017; Gilchrist, 2016; Gubbi et al., 2013; Kang et al., 2016; Zhou et al., 2015)
		Cloud computing (and Fog) and cloud manufacturing	(Gilchrist, 2016; Kagermann, 2015; Kang et al., 2016; Xu et al., 2014; Zhou et al., 2015)
	Others	Storage and database technologies	

The basic Industrial Internet related technologies are WSN, actuators, RFID, middleware, big data and advanced analytics and cloud computing. They will be explained below:

Wireless Sensor Networks (WSN)

Sensors are devices that monitor characteristics of the environment or/and a product such as temperature, vibration, humidity, quantity among many others. Sensors create data about the status of manufacturing equipment and its context, and work as an information interface between physical devices (Geisberger and Broy, 2015).

Recent technological advances in low power integrated circuits and wireless communications have made available efficient, low cost, low power miniature devices for use in remote sensing applications (Gubbi et al., 2013).

When multiple sensors (sensor nodes) are used together and interact communicating wirelessly between them, they are called wireless sensor network (WSN) (Atzori et al., 2010; Whitmore et al., 2015). One related term is the Ubiquitous Sensor Networks (USN) the slight difference with WSN is that USN assumes that at some point, everything will be connected and will contain sensors. Sensor networks play a crucial role for Industrial Internet applications, they can be combined with RFID to better track the status of things (e.g. temperature, location, etc.) (Atzori et al., 2010) and deploying more powerful IoT applications that are suitable for the industrial environments (e.g. decision-making of complex systems, industrial plants monitoring, etc.) (Li et al., 2015; Xu et al., 2014). The latest advances in sensor technologies, for example, produce not just more data generated by a component but a different type of data, instead of just being precise (accurate measurement of parameters). Sensors can have self-aware-ness and can even predict their remaining useful life. Therefore, the sensor can produce data that is not just precise, but predictive (Gilchrist, 2016).

WSN contain the sensors themselves and also gateways to transfer the collected data from the sensors on to a server (Whitmore et al., 2015) and thus, act as a further bridge between physical and digital world (Atzori et al., 2010).

The main challenges related to WSN are energy efficiency (scarcest resource in most of the scenarios involving sensor networks), scalability (the number of nodes can be very high), reliability (reporting sensitive data such as urgent alarm events), and robustness (sensor nodes are likely to suffer failures) (Atzori et al., 2010).

Actuators

While sensors monitor characteristics of the environment or the products, actuators can perform actions to affect the environment by for e.g. emitting sounds, lights, etc. (Whitmore et al., 2015). Actuators are frequently combined with sensors creating sensor-actuator networks (Whitmore et al., 2015) where objects not only can be aware of their environment but also interact with people, which is one of the principle of IoT and in consequence applied to industry, Industrial Internet.

Actuators can transform signals into physical actions; examples in manufacturing systems could be robots, heating systems, or laser-cutting objects. This allow operators to remote control some manufacturing processes and carry on remotely repair and maintenance activities.

Radio-Frequency Identification (RFID)

RFID technology is composed of one or more reader(s) and several RFID tags (Atzori et al., 2010). Tags are attached to objects and they have a unique identifier allowing products identify themselves automatically, which is a basic capability for smart products (McFarlane et al., 2003; Meyer et al., 2009). Atzori (2010) defines in a simply manner RFID tag as a small microchip attached to an antenna (for receiving the reader signal and transmitting the tag) in a package similar to an adhesive sticker. RFID contains electronic information that can be communicated wirelessly via electromagnetic fields(Gilchrist, 2016)

There are three types of RFID tag: passive, semi-passive and active RFID tags, determining the range from which the tag and the reader can operate (Atzori et al., 2010; Gilchrist, 2016; Gubbi et al., 2013). The most common used type is the passive RFID tag that are not battery powered and to transmit their ID, they use the power of the query signal transmitted from the RFID reader. Semi-pasive and active tags, are powered by batteries but the difference between them is that in semi-passive RFID tags, batteries powers the microchip while receiving the signal from the reader (radio is powered with energy harvested from the reader signal) and in active tags, the battery powers the signal as well. Obviously the cost of active RFID tags is higher and this reduce their applicability to high-value items such as port containers for monitoring cargo (Gubbi et al., 2013).

RFID tags have multiple advantages when comparing them with for e.g. barcodes. They do not require a direct contact with the reader (from 1m to up to 7,5m) or a line of sight between the reader and tag. Multiple tags (hundreds) can be read simultaneously and they allow identifying unique individuals instead of just the product type level (G. Meyer et al., 2014; Gilchrist, 2016).

Low cost is another important factor of this technology. This fact has allowed a massive deployment of RFID tags, transforming of some production areas such as supply chain management by being capable to identify and track products, inventory, etc.

Some challenges facing RFID technology are the security, because tags can be read by practically anyone in the proximity of the tag (Atzori et al., 2010). Another challenge is the small storage capacity, but companies such as Siemens (2009) are already experimenting with new passive ultra-high frequencies (UHF) RFID transponders that have more than 60 time storage capacity. Also, the addressing scheme IPv4 does not really support the unique identification so the latest IPv6 may alleviate some of the device identification problems (Gubbi et al., 2013) having 128 bits of address space instead of the 64 bits of IPv4 (Atzori et al., 2010; Gilchrist, 2016). With 128 bits, it is possible to define 10^{38} addresses, which should be enough to identify any object which is worth to be addressed (Atzori et al., 2010).

Middleware

Industrial Internet englobe multiple heterogeneous devices such as sensors, actuators and tags generating enormous quantities of variable data (Whitmore et al., 2015). Thus it is needed a middleware to connect the Industrial Internet hardware with the applications that make use of this data for further analysis and exploitation.

Middleware facilitate the communication between different objects and applications that frequently use different communication protocols. Without a middleware, it would be very hard for the applications to aggregate and make use out of the data generated for the devices in different “formats”.

(Bandyopadhyay et al., 2011) defined five required functional blocks for IoT middleware, being these: (i) interoperability; (ii) context detection; (iii) device discovery and management; (iv) security and privacy and (v) managing data volume. (Bandyopadhyay et al., 2011) also presented the four layers of middleware architechture as: (i) interface protocols responsible to provide interoperation and resolve the (ii) syntax and semantics of the devices; (iii) central and management module which is the core element and (iv) application abstraction that provides the interface with local and remote application. Same as in other context, Service Oriented Architecture (SOA) approach is often proposed as an architecture for IoT middleware (Atzori et al., 2010) because of its lower level of complexity for the Application Programming Interface (API).

Big Data and Advanced Analytics

Big Data is just a term to refer to large, complex structured (e.g. variety of sources such as text, forms, web blogs, video and so on) amounts of data that can’t be managed by traditional databases and processing tools (Gilchrist, 2016; Kang et al., 2016). Conventional database technology has difficulties in completing the capture, storage, management and analysis of this massive data collection (Zhou et al., 2015). Due to the advances in sensor technology (miniaturization, low cost, etc.) and wireless radio technology, a huge amount of devices are generating data in Industrial Internet application, the size of the datasets is beyond traditional scales and thus Industrial Internet is seen as a major contributor of Big Data (Gilchrist, 2016). (Laney, 2001) defined the Big Data characteristics through the “Three Vs”: Volume, Variety and Velocity. Basically the increasing of these parameters is what differentiate Big Data from traditional analytics (McAfee et al., 2012). More recent literature has added two more: Veracity and Value (Gilchrist, 2016) and then the characteristics of Big Data are defined by the “Five Vs”.

The concern in Industrial Internet is how to handle these vast unstructured amounts of data generated by the machines, products and environment in order to benefit of the potential information and knowledge out of it. Therefore, technical and special systems, and methodologies such as analysis, capture, data curation, search, sharing, storage, transfer, visualization and information privacy are required to perform predictive analytics and extract value out of the data among others (Kang et al., 2016). In manufacturing industry it is needed an effective analysis, visualization and sharing of all the data generated by the products that are being performed and from the manufacturing processes to be used for predictions and modelling (Kang et al., 2016). Industry already counts on cloud services to manage Big Data, offering unlimited storage on-demand and open sources technologies (e.g. Hadoop) which are cloud-based optimized systems to handle unstructured and structured data. For the analytics there are also tools for industry such as MapReduce, developed by Google for its web search index (Gilchrist, 2016).

In industries, the potential of these vast amounts of collected data is evident (e.g. predictive maintenance) and business efforts are shifting from descriptive analytics that just describes what happened using historical data to predictive analytics to anticipate to what will happen. Next step is prescriptive analytics, which also proposes a solution to an identified problem. In order to achieve these levels, it is required advanced data analytics (advanced algorithms). Some business sectors such as finance, marketing and insurance, have been using advanced algorithms for years but it has been the introduction of Big Data and IoT that have attracted the interest on advanced analytics to many sectors in industry(Gilchrist, 2016).

Cloud Computing

Cloud computing as many other enabling technologies for Industrial Internet has been around for decades. In the mid-2000s it was launched Amazon Web Services and afterwards RackSpace, Google's CE and Microsoft Azure among others hit the market following Amazon's lead (Gilchrist, 2016). (Mell et al., 2011) defines cloud computing as:

> "A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

There exist four types of deployment models (Mell et al., 2011):

(i) private cloud where a single company exclusively uses the infrastructure but it can be owned, managed and operated by this company, a third party or a combination of them;
(ii) public cloud where the infrastructure is provided for the general public;
(iii) community cloud where the infrastructure is shared between specific consumers that share concerns and the ownership can be for one or more companies of the community, a third party or a combination of them;
(iv) hybrid cloud which is a combination between two or more of the already mentioned models that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

For manufacturing industry for example, where real time is required and in general, sensible data is processed, private cloud would be the best alternative. The term for cloud computing in manufacturing industry is often referred as cloud manufacturing

(Kang et al., 2016; Xu, 2012). From the service point of view, there are three different categories (Gilchrist, 2016; Mell et al., 2011):

(i) IaaS (Infrastructure as a Service) which a really interesting model for SME because it allows to pay for only what you use (pay-per-use model), companies can rent compute, storage and network with no necessity for an investment for the infrastructure;

(ii) PaaS (Platform as a Service) was created to not only provide infrastructure but also access to software development languages, libraries, APIs, etc.;

(iii) SaaS (Software as a Service) where instead of accessing a local private server hosting a copy of the application, users use a web browser to access a web-server shared application.

To sum up, the cloud is a key enabling technology for Industrial Internet because it offers solution to Industry requisites concerning to the need for vast resources in compute, storage and networks for processing the big amounts of data (Big Data) generated by the machines captured by the sensors, etc.

2.3.3 Basic functionalities, capabilities and optimization levels related to the implementation of II based technologies

After explaining and categorizing the main enabling technologies for Industrial Internet, it is necessary to understand which basic functionalities, capabilities and optimization levels can be achieved depending on the level of implementation and technology deployment. Acknowledging these will be essential to realize about the potential of Industrial Internet.

The basic functionalities related to Industrial Internet can be divided into four blocks: data collection, transferring the data, data storage and analytics. The smartness, intelligence or maturity level of a system increases as adding blocks starting from data collection which is the basis of any intelligent system. Consequently, analytics is the one that can bring the maximum smartness level to an Industrial Internet related solution (Figure 10). Implementing sensor technology and in some cases using external data sources, enables the first functionality, data collection, and depending on the type of the sensor, it is possible to collect different kinds of data: status, location, operational data (e.g. temperature, pressure, vibration, humidity, etc.). Data collection is the basis for developing further functionalities. Next step is transferring the data to one or various destinations depending on the interest of each case. This can be done wired or wireless by using communication technologies and protocols. After transferring the data, it is necessary to store it for a further use and to convert it into information and knowledge. Data can be stored locally or for example, using Cloud computing technologies that, as mentioned before, can provide unlimited space for storing big data and present interesting service models for the companies (e.g. pay-per-use). Finally, implementing advanced algorithms or the so-called big data analytics, it is achieved the highest functionality and the one that really can transform the collected and stored data into value. Depending on the smartness of the analytics, it can be classified into for levels:

(i) descriptive level, which is the most basic one just showing what has happened in a process or give information related to it;
(ii) diagnostic level, which is able to explain why a failure or event happened and in consequence where should the operator look;
(iii) predictive level, which can be considered real intelligence due to the ability of anticipating failures and events and for instance with direct applications in predictive maintenance;
(iv) prescriptive level, which is the most futuristic approach and the maximum expected intelligence for a system which not only can anticipate future events but also proposes proactively the best solution to solve the problem.

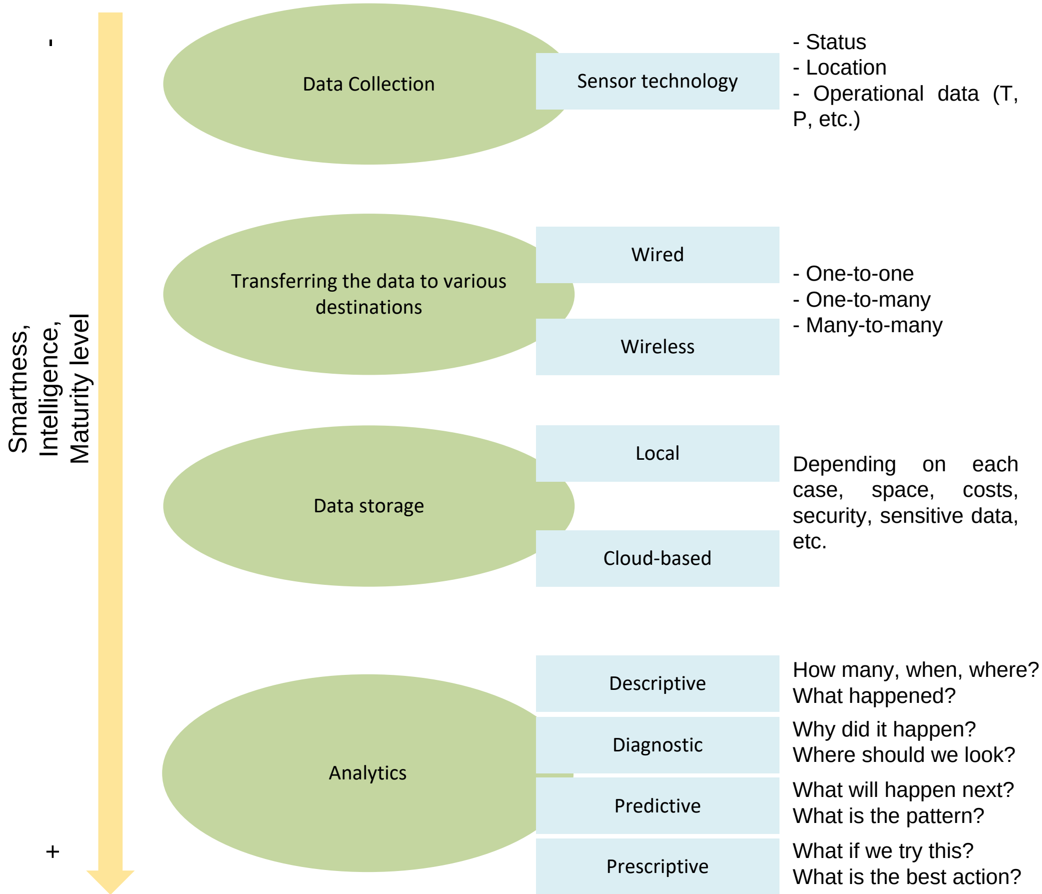

Figure 10. *Basic functionalities related to Industrial Internet*

Intelligence and connectivity enable an entirely new set of product functions and capabilities which can be grouped into four areas: monitoring, control, optimization and autonomy (Porter and Heppelmann, 2014). Each capability is valuable in its own right and also sets the stage for the next level. To have control capability, for example, a product must have monitoring capability. (Porter and Heppelmann, 2014) define the different capabilities as follows:

Monitoring allows knowing the product’s condition, operation and external environment through sensors and external data sources. Using data, a product can alert users or others to changes in circumstances or performance; it also allows to track a product’s operating characteristics and history and to better understand how the product is actually used. In some cases, monitoring is the core element of value creation (e.g. medical devices). To achieve the monitoring capability, it is required at least two basic functionalities: data collection and transferring the data (Figure 10). Making a difference between local and remote monitoring, these data transfer can be done wired for the first case or wireless for the second case.

In the next layer there is control capability through which remote commands or algorithms can be built into the device or reside in the product cloud. It can be for example “if pressure gets too high, shut off the value”. Its capability allows the customization of the product performance to a degree that previously was not viable and also enables users to control and personalize their interaction with the product (e.g. adjust Philips Lighting hue lightbulbs via smartphone). This capability requires to add two more basic functionalities: data storage (local or cloud) and analytics at least in its simplest level, descriptive analytics (Figure 910.

Monitoring and control capabilities enable algorithms that optimize product operation and use in order to enhance product performance and allow predictive diagnostics, service and repair. Optimization capability allows companies to optimize product performance in numerous ways, many of which have not been previously possible. Thus it is required at least diagnostic analytics level as one more basic functionality (Figure 10).

The maximum and more complex stage related to capabilities is the autonomy. Combining monitoring, control and optimization allows autonomous product operation, self-coordination of operation with other products or systems, autonomous product enhancement and personalization and self-diagnosis and service. To achieve this maximum level of capabilities it is also required to count with the most advanced level of analytics: prescriptive analytics as basic functionality (Figure 10).

Once it has been described and explained the first two dimensions (basic functionalities and capabilities), it is time to add the third dimension: optimization levels (Figure 11). Sorting out the optimization levels from the simplest to the most complex one: machine, machine fleet or factory, suppliers or consumers, network or supply chain and finally, ecosystem. It is possible to bring one basic functionality (e.g. data collection) to the most complex level optimization. Note but that the maximum level of intelligence is achieved when having an autonomous ecosystem.

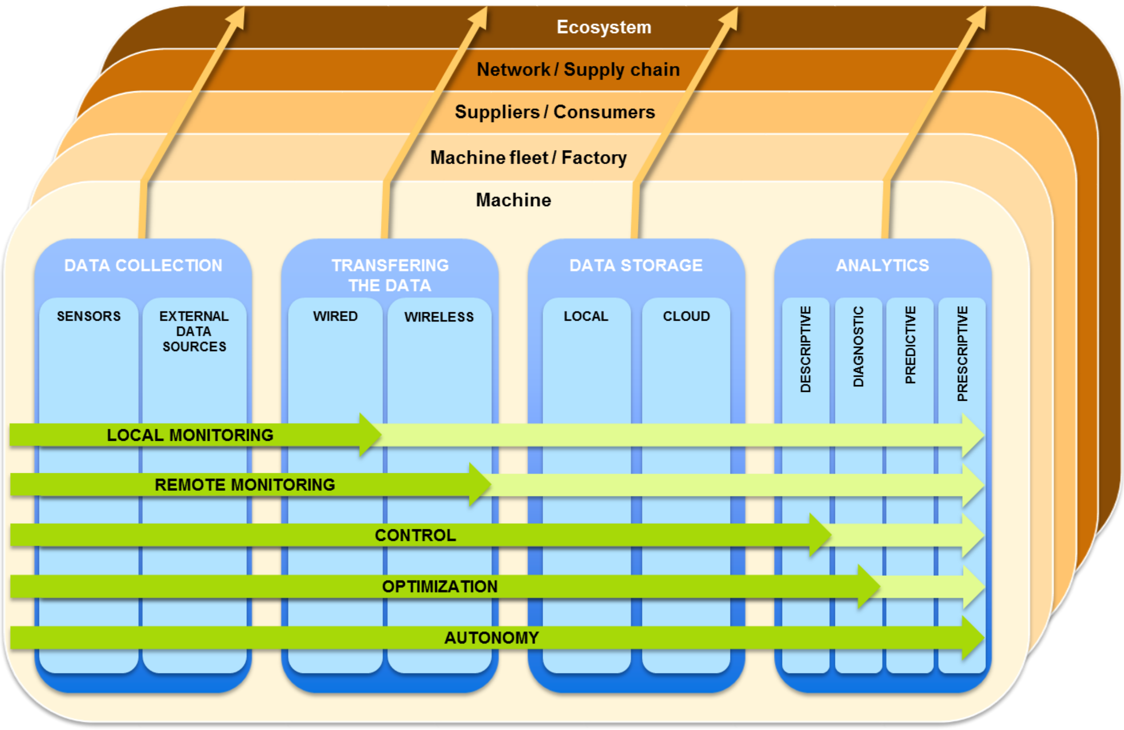

Figure 11. *Three dimensions relation: capabilities, basic functionalities and optimization levels related to II*

2.3.4 Trends related to the basic technologies

The advances and development of already existing and new technologies have made technically and economically possible the emerging of IoT and consequently of Industrial Internet. Some drivers have been for example: breakthroughs in the performance and in energy efficiency of the sensors and batteries, highly compact low-cost computer processing power and data storage (which has made possible to have embedded systems in the products), cheap wireless connectivity and connectivity ports, tools for rapid software development and big data analytics (Porter and Heppelmann, 2014). The new IPv6 internet registration system has been also an important event since it has opened 340 sextillion new internet addresses for individual devices, enabling better security protocols and making possible for devices to request addresses autonomously.

The advance in sensor technologies for example, have been driven by the advent of high-speed and low-cost electronics circuits. The latest trends in sensor technology are miniaturization of the hardware, the widespread of multi-sensor systems and the increasing availability of radio wireless and autonomous sensors (Gilchrist, 2016). These trends play a crucial role in the Industrial internet application. Initially, sensors were embedded into devices but the communication had to be hard-wired or rely on a host system. By the emerging of lightweight communication technologies such as Bluetooth and ZigBee there have been a transformation in sensor technology because now they are able to have an embedded miniature radio for short distance communications (Gilchrist, 2016).

The transition from traditional automation (or mechatronics) to Industrial Internet have occurred because of the convergence between Operational Technologies (OT) and Information Technologies (IT) creating the new paradigm for the Industry 4.0 (Figure 12). This convergence between OT and IT has also been possible due the already mentioned advances and development of certain technologies and the declining price of them. In the actual industry, the trend is no more about just automating and implementing technologies to the existing processes, it is about having networked systems and gather huge amounts of data for a further analysis in order to deliver new value to customers. Moreover, traditional automation is always stick to the factory level meanwhile Industrial Internet breaks through this barrier and allows to bring it to the maximum level, creating an ecosystem where it is included from machines and factory level to supply chain side, customers and suppliers (Figure 12).

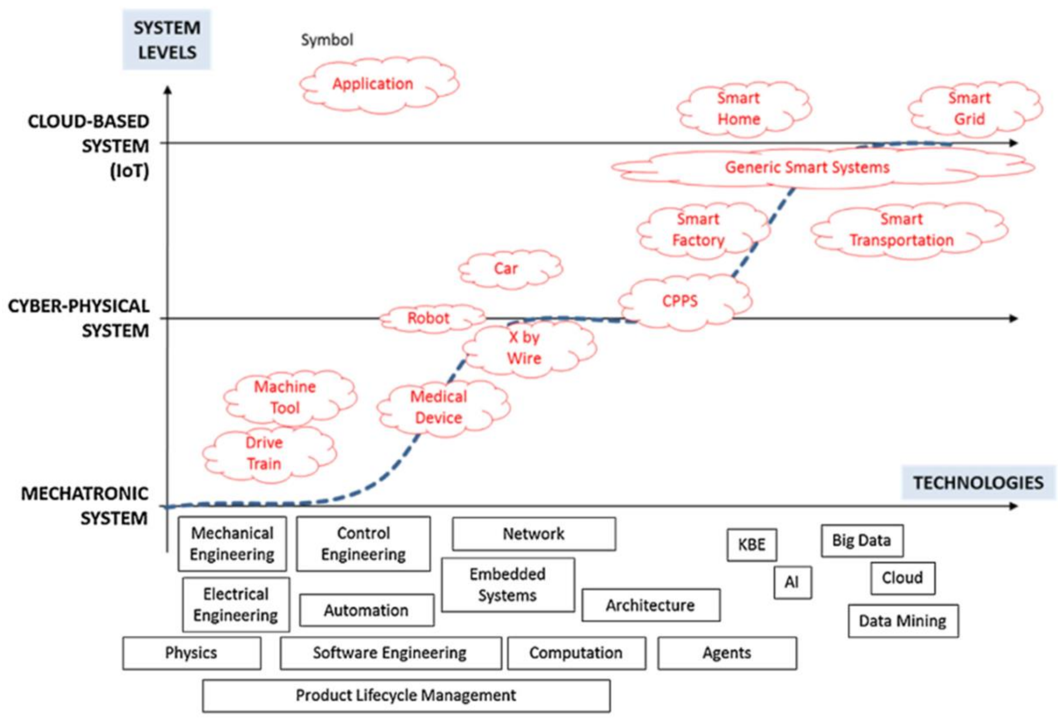

Figure 12. *Transition process from traditional automation to CPS to IoT (Hehenberger et al., 2016)*

2.4 Impact of Industrial Internet in manufacturing companies

Manufacturing companies are an industry sector that can clearly benefit from Industrial Internet on the assumption that information adds value to the manufacturing process (Ehret and Wirtz, 2017). New business opportunities such as predictive maintenance services and new business models such as pay-per-use or rent instead of buy models are emerging for manufacturing industry due to the Industrial Internet implementation.

Academic research has focused in some industrial areas such as health care, transportation and logistics and manufacturing. However, Industrial internet constitutes a relatively young research area and it has been studied mainly from a technological perspective (Arnold et al., 2016) rather than business impacts. Another point is that the case studies presented in the literature are mainly from large companies such as GE, Rolls Royce, Tesla, etc. (Agarwal and Brem, 2015; Porter and Heppelmann, 2015). This fact brings a gap for manufacturing SMEs that have not been paid that much attention from research point of view even though it has been said that Industrial Internet has promising benefits particularly for them (Gilchrist, 2016; Kagermann et al., 2013) and that they constitute a very big percentage of the manufacturing industry. SMEs differ in many characteristics from large companies, on the one hand, SMEs are can move faster since the organization structure is lighter and they also use to be more flexible. However, on the other hand they have limited resources (e.g. human, financial, etc.) and frequently have a lower level of expertise.

Some of the factors that make Industrial Internet interesting and feasible for SMEs are the increasingly low cost of the sensor technologies as well as the cloud storage that were previously expensive and not affordable for small companies. The increasing level of performance of such key technologies and the ease of implementation (e.g. plug and play devices such as sensors, RFID, etc.) have been also a key driver for SMEs interest in Industrial Internet (Figure 13).

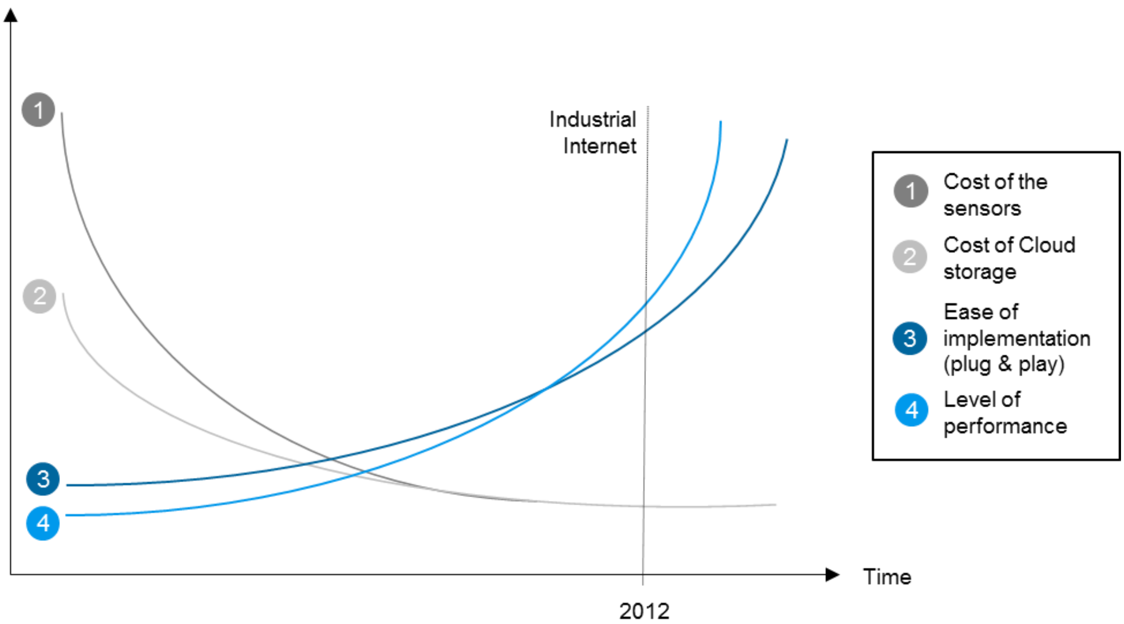

Figure 13. *Factors that make II interesting for SME*

The promises from Industrial Internet to SMES are for example: an increased competitiveness of business enabling them to work together and challenge large companies, increasing productivity and revenue, optimization of manufacturing processes because of the integration and collaboration of all the value chain agents (producers, suppliers and other stakeholders) that allows to reduce the usual time to produce one unit and real-time decision making which is crucial in most industrial scenarios (Gilchrist, 2016).

3. BUSINESS MODELS

The Industrial Internet of Things (IIoT) poses large impacts on business models (BM) of established manufacturing companies within several industries (Arnold et al., 2016). IIoT offers new opportunities and harbours threats that companies are not able to address with the existing business models (Ehret and Wirtz, 2017). In this section, the concept of Business Model and its relation with II in manufacturing SME will be presented as well as the different existing business model frameworks in the business literature in order to introduce the selected one for the empirical part of the thesis.

3.1 Defining Business Model

Business Model (BM) has been a widely discussed topic within the business literature since the 1990s and many different approaches, perspectives and definitions have been made and it does not exist one established BM concept (Arnold et al., 2016; Zott et al., 2011). However, academic literature has begun to agree on some common central characteristics of a BM (Zott and Amit, 2013). Zott and Amit (2013) explain that the convergence turns around the value creation logic for all the stakeholders, the activities preformed not only by the firm but also by partners, suppliers and customers, and the fact that BM is emerging as a new level and unit of analysis.

Due to the lack of convergence and the requirement to agree on one definition for the further understanding of the present document, based on the most relevant and cited business model literature, in this thesis it will be used the (Osterwalder et al., 2005) BM definition:

> “A business model is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm. Therefore we must consider which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences.”

In a simplest definition, (Osterwalder and Pigneur, 2010) stated that “A business model describes the rationale of how an organization creates, delivers, and captures value”. Nine BM building blocks were identified by Osterwalder et al., (2005) after comparing the models mentioned most often in the literature and studied their components. These nine BM building blocks are known as the BM Canvas (Osterwalder and Pigneur, 2010), which serves as the theoretical framework for the empirical part of this thesis and will be explained in detail later on this section.

3.2 Manufacturing SME's Business Models because of the II

(Fischer et al., 2014) stated the fact that there is a transition in business models going on and manufacturing firms are moving towards a service-dominant logic. According to (Fischer et al., 2014) manufacturing companies are nowadays selling their products with low margins or profitability and are focusing on reaching an "installed base" of customers where to provide services in a further stage. In the industry sector, IIoT shapes a novel paradigm ensuring flexibility and adaptability of production systems and value chains in order to maintain the global competitiveness of manufacturing enterprises (Kiel et al., 2016). Moreover, IIoT involves technological changes and it will also result in extensive organizational consequences; existing value chains will change resulting in opportunities for new business models. In the context of technology, the concern among the researchers turns around on how technological potential can be translated into economic value (Ehret and Wirtz, 2017).

The new paradigm brought by Industrial Internet, manufacturing industry among many others, will be able to take profit from it through new BMs such as rent instead of buy, pay per use (e.g. Rolls-Royce), sensor as a service or performance-based contracting (Fleisch et al., 2014; Weinberger et al., 2016). (Fleisch et al., 2014) selected 20 business model patterns that could profit significantly from the IoT and six key components inherent to those patterns where identified (Table 5). These key components and novel business model implementation depend on the maturity level of each company. For example, offering sensor as a service would require less maturity level than a pay per use model or digital add-on components.

Table 5. *Business model components for manufacturing industry that profit from IoT*

Key Component	Definition	Company example
Digital Add-On	Various digital services are offered in the after-sales phase of a physical good	Tesla (Offered an autopilot software update for $ 2,500)
Digital Lock-in	"Razor and Blade" business model pattern. Only Original parts are compatible with the system. IoT enables entirely new means to limit compatibility of system-parts through sensors and actuator technologies	Gillete (its razors have its related blades)
Product as Point of Sales	Physical products can become platforms for digital sales and marketing services which the customer consumes directly at the object or indirectly via smartphone and identification technology	Amazon App
Object Self Service	Not humans but machines reorder spare parts or required ingredients	Amazon dash replenishment service (it offers an option that selected household appliances (e.g. washing machines, printers) automatically reorder

		the required ingredients when necessary)
Remote Usage and Condition Monitoring	Products capability of reporting real-time data about their own condition or the environment surrounding them. This allows companies to detect errors and potential problems in advance, control for the correct usage of the equipment and offer affordable and efficient maintenance	Konecranes
Physical Freemium	Physical good is sold, along with a free digital service (e.g. free digital maintenance or remote control services). Such services enhance the value proposition of the product and might allow companies to sell the physical product at a premium. However it is free for customers to use the basic service itself. In a next step some customers might decide to buy some extended, but charged services	Dropcam

When it comes to Business Model changes, academic literature often refers to BM innovation (Arnold et al., 2016). In spite of increasing interest in open innovation, discussion about the concept and its potential application to the SME sector has been excluded from mainstream literature (Lee et al., 2010; van de Vrande et al., 2009) and large companies have absorbed all the attention. This fact and the importance of SMEs in the manufacturing industry it is worth addressing the issue from an SME perspective in this thesis. SMEs are more flexible and can move faster than large companies due to their lighter organizations which are clearly a strength when it comes to innovation. However, there is a lack of resources and capabilities which act as a barrier when innovating. Collaboration with other organizations (i.e. partnerships) or using their most trusted clients to try and experiment new things can be a solution to overcome their weaknesses.

3.3 Basic building blocks to Business Models

As mentioned previously in this section, for the further development of the thesis in order to analyze what is the impact of II related technologies to the business models, it has been selected the BM Canvas (BMC) framework developed by (Osterwalder and Pigneur, 2010). The BM Canvas is a useful tool to describe and think through the business model of an organization, its competitors, or any other enterprises (Osterwalder and Pigneur, 2010).

In its wider classification, BMC involves four strategy areas of any business: Value Proposition, Infrastructure Management, Customer interface and Financial Aspect (Figure 14). In order to better understand and go through the business model, (Osterwalder and Pigneur, 2010) divided it into nine building blocks (Figure 14):

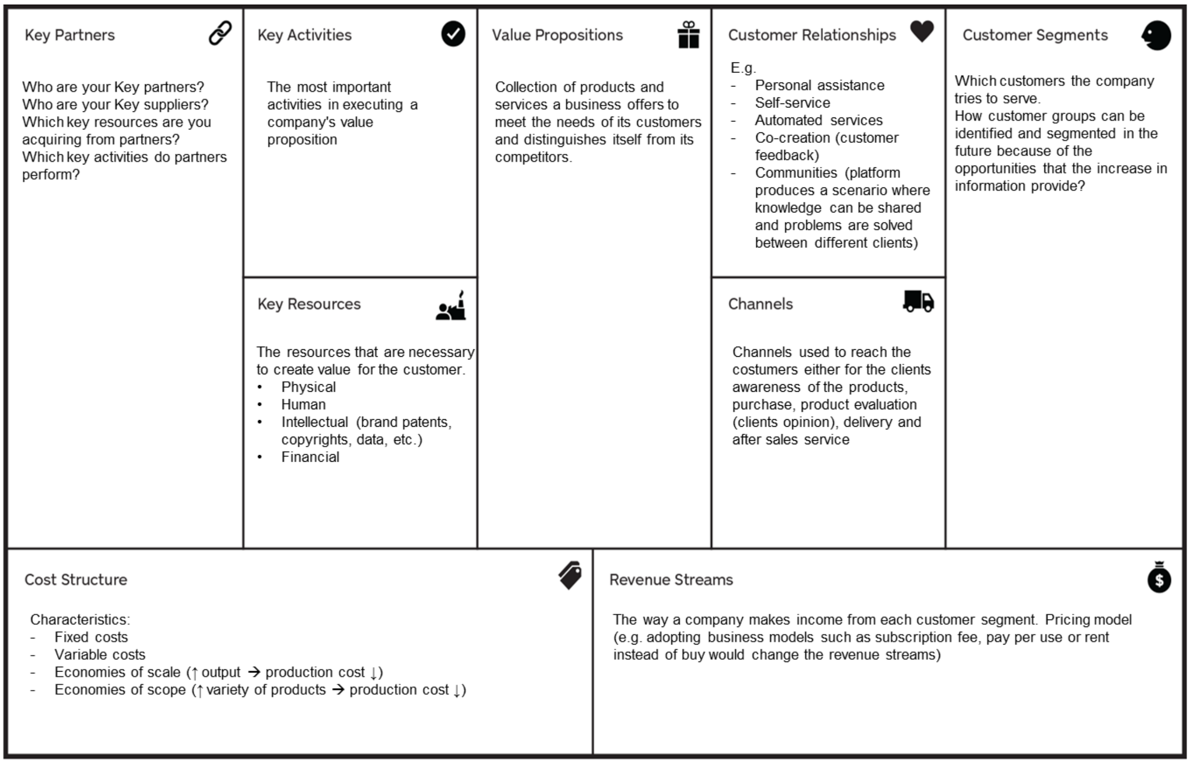

Figure 14. *The Business Model Canvas. Adapted from (Osterwalder and Pigneur, 2010).*

Customer Segments: This block aims to answer the questions “For whom are we creating value?” and “Who are our most important customers?”. Customers are the basis of any successful business model and it is very important for a company to decide to whom they are creating value. In order to do that, the market can be divided into segments (e.g. common needs, behaviors, etc.) and then target the segment/s that fit to their value proposition. After making this decision, a business model can be built around the customers’ needs.

Value Proposition: it includes the products and services that the company offers that create value for a specific customer segment. It should answer to the following questions: “What value do we deliver to the customer?; Which one of our customer’s problems are we helping to solve?; Which customer needs are we satisfying?; What bundles of products and services are we offering to each Customer Segment?”. It is the value proposition which mainly differentiate a company from its competitors. Values may be quantitative (e.g. price, speed of service) or qualitative (e.g. design, customer experience).

Channels: this building block describes how a company is communicating within its customers segment in order to deliver their value proposition. It is composed by communication, distribution and sales channels which can be direct or indirect. There are five phases regarding to the channels that a company should accomplish: (i) awareness (make the company value proposition visible to the potential customers); (ii) evaluation (delivery of the necessary information so that customers can review the value proposition and compare it within the competition); (iii) purchase; (iv) deliver; and (v) after sales (providing post-purchase customer support).

Customer Relationships: it aims to answer to “What type of relationship does each of our Customer Segments expect us to establish and maintain with them?; Which ones have we established?; How costly are they?; How are they integrated with the rest of our business model?”. It is very important for an organization its relationship among the customers and how do they perceive the company. There are many different categories which can actually co-exist of customer relationship such as personal assistance, self-service, automated services, co-creation, etc.

Revenue Streams: this building block seeks the answer to “For what value are our customers really willing to pay?; For what do they currently pay?; How are they currently paying? How would they prefer to pay?; How much does each Revenue Stream contribute to overall revenues?”. It is the way that a company makes incomes from each customer segment.

Key Resources: it refers to the most important resources that are necessary to create value, reach, and maintain relationships with the customer segments. It includes physical (e.g. machines), human (e.g. employees), intellectual (e.g. patents) and financial (e.g. credit lines) aspects. Key resources can be either owned or leased by the company or acquired from key partners.

Key Activities: describes the most important actions a company must do to make its business model work successfully. Like key resources, they are necessary to create value, reach markets and maintain customer relationships and earn revenues. A proposed categorization for key activities is production (for companies offering tangble products), problem solving (e.g. hospitals and consultancy) and platform/network (e.g. Microsoft continuously needs to maintain and develop Microsoft Windows to ensure its BM).

Key Partnerships: it is often required to establish specific partnerships in order to make a business model work. There are different types of partnerships: (i) strategic alliances between non-competitors; (ii) strategic alliances between competitors (Coopetition); (iii) joint ventures to develop new businesses; and (iv) buyer-supplier relationships. The most common motivations to start a partnership are the optimization and economy of scale, the reduction of risk and uncertainty and the acquisition of particular resources and activities.

Cost Structure: refers to all costs effectuated to carry out a business model. From creating and delivering value to customer relationships, it all include costs associated. Some business models are more cost-driven than others.

All the nine building blocks are somehow interconnected to each other as it is shown in Figure 15.

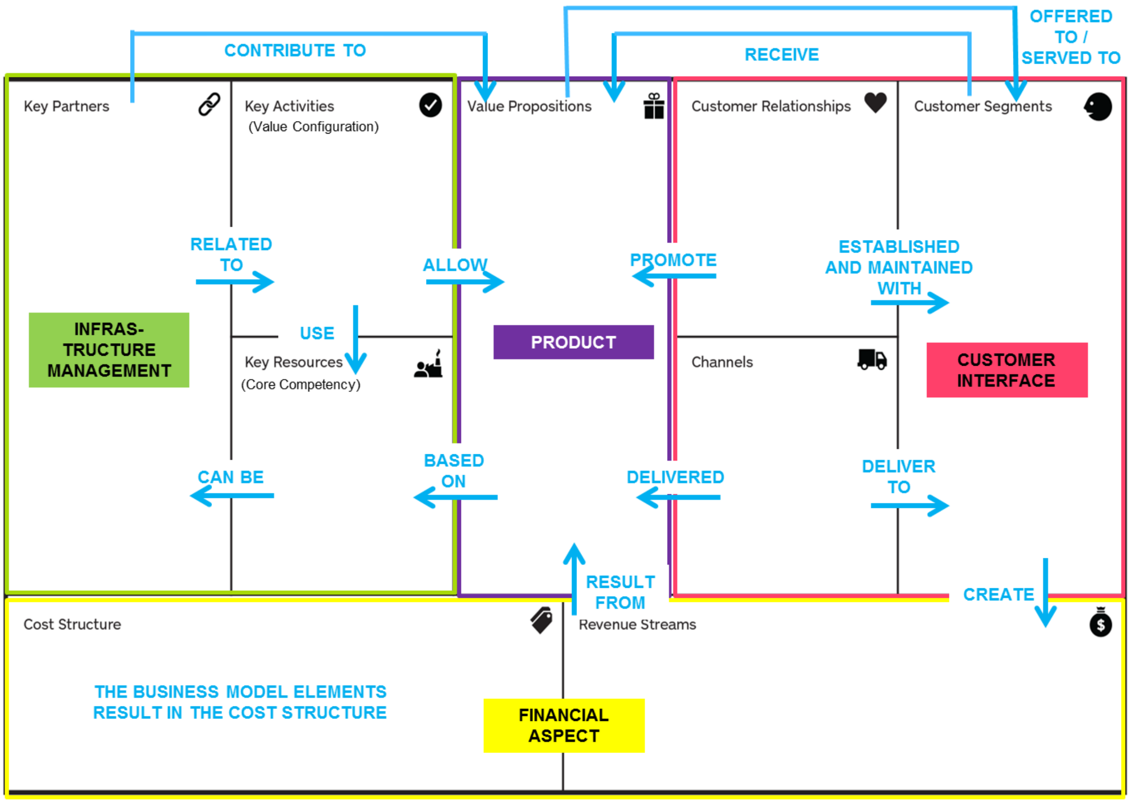

Figure 15. *Business Model Canvas building blocks interconnection. Adapted from Osterwalder and Pigneur (2010)*

3.4 Business Model frameworks

Business model theory has been deep and widely studied by many authors and researchers and also there has been proposed different tools and frameworks based on different perspectives or approaches. Some of them are proposed as design tools whereas others are more about conceptualization or building tools.

These frameworks are useful when the purpose is to analyze a specific or various business models which is one of the goals of this thesis. In order to analyze the impact of Industrial Internet to the production line manufacturers' business models, it has been chosen the BMC approach after observing the most relevant business model existing tools in the literature as it has been explained in the prior section. BMC is a static approach, it allows to build typologies and study the relationship between a given BM and performance, giving an overall picture of the different BM components and how they are arranged (Demil and Lecocq, 2010). Static approaches weakness is their inability to describe the BM evolution because they do not aim to. Transformational approaches are useful to reflect how to change a BM but it tends to mobilize the BM concept rather than looking at how business models change themselves (Demil and Lecocq, 2010; Teece, 2007; Yip, 2004).

In the following section, due to the relevance impact on this thesis, it will be briefly presented some of these other business modeling tools.

Gary Hamel's model bridge model

(Hamel, 2000) presented the first holistic approach for explaining the business model concept which differs in some aspects when compared to the current vision of it. His approach was based mainly on putting the theory concepts into practice thus and it is more about a conceptualization business model tool but his work was an important advancement at that time.

(Hamel, 2000) introduced four major components of a business model: (i) core strategy; (ii) strategic resources; (iii) customer interface; and (iv) value network. These major components are composed by multiple sub-components and Hamel argued that they cannot be considered as isolated blocks but there have to be interconnections between them in order to have the complete picture of a business model (bridges).

Hamel stated that in order to analyze if rather a business model will succeed or not, it is necessary to take into account the efficiency, fit, uniqueness and profit boosting ability of each component of this BM.

Business Model Wheel

Business model wheel was presented by (Ahokangas et al., 2014) and it argues that business opportunity should be the central block in any business model instead of the value proposition. Its approach relies on the assumption that the way of doing business depends on the opportunities that there are in that specific market. Since normally opportunities do not last long periods of time, companies have to find new ones and readapt their business models periodically and thus, this is a transformational and action oriented business modeling tool conversely to the BMC that is a static tool and does not take into account the market transformations. Ahokangas et al. (2014) argue that value proposition is often an internal decision and vague articulation of entrepreneurial bias about their own product and thus, value proposition should rely on the market conditions and business opportunity.

The Business Model Wheel launches four questions to be answered by a company, *what* (value proposition, differentiation, customer segments and offering), *how* (key activities, operations, partnerships, channel and marketing), *why* (cost drivers and elements, base of pricing, etc.) and *where* (internal or external actions).

This tool is helpful for considering the main changes that a market might suffer and its implication to the business opportunities that can be different over time. This vision focuses on the importance of being aware of the market variations to redefine the business core and opportunities when needed in order to stay profitable and successful.

RCOV (Resource and Competences, Organization and Value propositions)

Demil and Lecocq (2010) presented the RCOV framework aiming to reconcile the static and the transformational approaches in order to sum its strengths and mitigate their weaknesses. The authors state that a BM can be described with three core components (RCOV):

(i) Resources and Competences – It is necessary to be defined even for startups, resources can be achieved rather internally or from external markets while competences reflect the knowledge and abilities to improve, recombine or change the services that their resources can offer;
(ii) Organizational structure – This components encompasses the organization's activities and the relations it establishes with other parties to combine and exploit its resources. Thus, it includes its value chain of activities and its value network.
(iii) propositions for Value delivery – This is the common block in almost all BM frameworks which contains the value proposition that a company delivers to customers, in the form of product or services.

These three core components (RCOV) will each encompass several different elements and the structure and volume of the organization's costs and revenues follow from them (Demil and Lecocq, 2010).

Lean Canvas

This framework is based on the BMC, created and licensed by Ash (Maurya, 2012). Its main differentiation is its application, through some modifications; it aims to target startups, entrepreneurs and similar business:

> "My main objective with Lean Canvas was making it as **actionable** as possible while staying **entrepreneur-focused**. The metaphor I had in mind was that of a grounds-up tactical plan or blueprint that guided the entrepreneur as they navigated their way from ideation to building a successful startup." (Ash Maurya, 2012)

The author liked the idea of having a one-page tool like BMC and designed the Lean Canvas sample which should be possible to fill in around twenty minutes. The sample is composed by nine building blocks as it happens in the traditional canvas but four of them are different. Thus, five components remain the same and these are: value proposition, channels, customer segments, cost structure and revenue structure.

Mayura stresses on the importance of having a unique more than a generic value proposition but a company should not build its business model just focusing on it. The author brings up the importance of identifying the problem (problem is one of the novel blocks) that is to be solved and targeting the right customers in order to determine this unique value proposition. The novelty of this tool resides in these new four components: problem, solution, unfair advantage and key metrics. Unfair advantage is just another way to refer to competitive advantage or barriers to entry.

Lean Canvas is a business modelling tool for the new business model generation and it will have an important role in the nowadays startup revolution. It offers to entrepreneurs a less static and a leaner framework compared to the traditional BMC. However, for the purpose of this thesis, it is better to use the BMC because of the traditional studied industry of production line manufacturers.

4. EMPIRICAL PART

4.1 Case study approach

The term ‘case study’ is a multifaceted concept that it covers both a process of inquiry about the case and the product of that inquiry (Stake, 2000, p. 144). Robert Yin, one of the most relevant researchers in the case study field, defines it “as an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2013). Case study enables a research in a context-sensitive way to learn deep phenomena, which can be exclusive and advantageous when the researchers have very little or no control over the context of the study (Yin, 2013).

Single-case design is relevant when the case represents a critical, extreme or unique case worth documenting; a typical or a revelatory case with unique opportunity to observe previously inaccessible or common situation; or a longitudinal case, where the same case is studied at various points in time. Multiple-case study design is generally considered more applicable when researcher seeks exemplary outcomes (i.e. literal reproduction or generalization) or contrasting results for predictive reasons (i.e. theoretical reproduction) in relation to a specific theory (Saunders and Lewis, 2009; Yin, 2013). The preferable number of case studies has been widely discussed; some authors prefer multiple cases in order to obtain generalizations and some others are more likely to use single case studies when it is needed to have a deep understanding of the phenomena.

In this thesis it has been selected a multiple-case approach in order to contrast and to have a general view of how the Industrial Internet is impacting the business and the business models of mid-sized production line manufacturers. The novelty of the topic which implies that it is not a mature field for the targeted companies, suggests that a multiple-case is the best approach in order to have a general perception and point out similarities and differences between those companies rather than a single case which aims to have a deeply understanding of a critical case. The number of case replications depends upon the certainty wanted to achieve and richness of the underlying theoretical propositions (Yin, 2013). In this study, due to limitation of time and access’ barriers to the companies, there have been studied three cases. This fact will be taken into account and no strong generalizations will be stated due to the size of the sample.

Flyvbjerg (2006) presents the strategies for the selection of samples and cases being those: (A) Random selection; and (B) Information-oriented selection. In this thesis, it has been followed and information-oriented selection taking into account different factors: the access to the interesting companies, the use of an automation expert for the companies' selection and the targeting of mid-sized production line manufacturers that have different ways to use Industrial Internet.

The purpose a study can be explorative, descriptive and explanatory (Saunders and Lewis, 2009). This study has an overall aim to understand "*How major Industrial Internet technologies are affecting the business and business models of production line manufacturers"* and it is clearly an exploratory purpose. Explorative research is preferable when the problem is not clear and it is sought a better understanding of it (Saunders and Lewis, 2009). However, in this thesis, there is also present a descriptive purpose as an extension of the explorative purpose as it often happens according to Saunders and Lewis (2009).

Finally, the research strategy can be divided into two different categories: qualitative or quantitative (Bryman and Bell, 2011). Explorative researches are associated with qualitative strategies and thus, this thesis will have a qualitative approach. The definition of qualitative research strategies depends highly on the aim of the study and can therefore vary by every person asked (Bryman and Bell, 2011; Saunders and Lewis, 2009; Yin, 2015). A qualitative research is carried out under real-life conditions so that the topic is studied in its natural environment; the objective of a qualitative research is to understand the phenomenon from the participants' perspective and the purpose is to develop new concepts to explain social behaviors. In this thesis, the impact of the Industrial Internet related technologies to business and business models will be studied under a real condition (mid-sized production line manufacturers) in order to understand their perception about the opportunities and risks brought by it as well as the impact in their actual business models which favors a qualitative strategy approach.

4.2 Conducting the research

4.2.1 Companies' selection strategy

The companies' selection strategy has been mainly based on the understanding of the research questions of this thesis. The sought companies were mid-sized production line manufacturers. The selection criteria were designed in order to add novelty to the topic and contribute to fill the gap with this study. Industrial Internet can be considered as a relatively new topic. A few large companies have been studied and analyzed throughout the literature (i.e. GE, Rolls-Royce, etc.) and they are often presented as pioneers and referents in the Industrial Internet or the Industry 4.0 implementation. Therefore, having the perspective of mid-sized companies of a traditional industry such as production line manufacturers is considered an interesting contribution to the topic since the vast companies of this kind of industrial sectors are mid-sized and haven't been studied in depth among the literature. Companies' choice was also affected by the access barriers to some industries and the fact of having an automation expert available for the selection of the companies who was able to introduce interesting companies that were somehow already familiarized or even starting with Industrial Internet applications. Another aspect sought during the companies' selection was that these companies should preferably be in different end-users industries and have differences in their experiences or understanding of Industrial Internet but with a certain level of implementation. The fact of having such differences adds interesting findings to the empirical part and allows having different perspectives of the perception of the Industrial Internet in this sector. In order to be able to compare the cases, it was created a scenario for all the companies as it is explained in the section below.

4.2.2 Proposed scenario for the companies

Before every interview it was given the same scenario to all the companies as a basis for answering the questions. It was presumed that Industrial Internet of Things would be something in line with predictive maintenance, meaning that:

- There would not be interruptions in production lines because of failures
- It would be possible to predict three or four weeks prior to the actual failure
    - When the failure happens (time)
    - Where it happens (exact location of the failure in the production line)
    - Which spare parts and tools are needed to fix the failure
    - Who might fix it (Which skilled maintenance personnel is needed)
- Because of the above implementation, some changes might occur in the Business, Processes, etc.
    - Change in inventory Management
    - Maintenance Personnel Management
    - Customer Value – Reduction of Downtime

Predictive maintenance was the scenario proposed because it is far enough but also tangible and it explains the change of Business models. A scenario illustration was also given to the companies (Figure 16) in order to have a visual case of what predictive maintenance would mean.

The reasons for providing a scenario to the companies were the following ones:

(i) To make sure that the starting point is the same for all the companies
(ii) To be able to compare the cases. Industrial Internet of Things is a wide concept and could mean very different things or perspectives for each company
(iii) To provide a universal and understandable concept to all the companies where they feel comfortable answering the questions

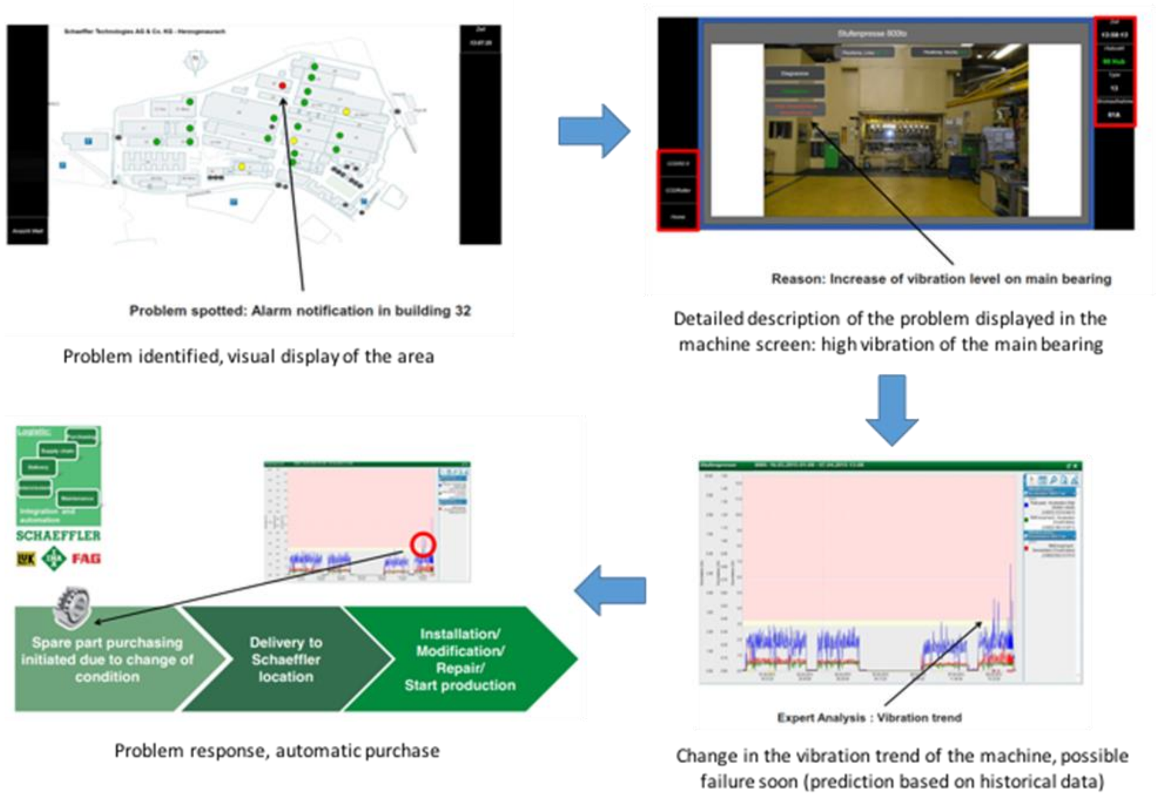

Figure 16. *Scenario illustration given to the companies*

4.2.3 Data collection

The data collection was done through three interviews to three production lines manufacturers as interviews is a common method for data collection when doing an explorative study (Saunders and Lewis, 2009) which requires data rich in information. This thesis seeks to explore in depth the impact of Industrial Internet related technologies into the business and the business models of medium-sized production line manufacturers and thus, qualitative interviews will provide the necessary information including the perspective of each respondent which is highly interesting for this purpose.

There exist different types of interviews; the two most common types are unstructured and semi-structured interviews (Bryman and Bell, 2011). In this case, a semi-structured type of interview was chosen and therefore, an interview guide was designed in order to cover the specific topics which needed to be discussed but the interviewees where encouraged to add any contribution or discuss any related topic that they perceived as related and important as well as depending on the answers some follow-up questions were formulated in order to clarify or to extract more information.

The three interviews were carried out face-to-face which is a better method than telephone interviews as stated Bryman and Bell (2011). If the telephone interview takes long time, it is easier for the respondents to finish it and also (Bryman and Bell, 2011) stated that while doing face-to-face interviews it is possible to study the body language.

(Yin, 2015) stated that when doing qualitative interviews, it is more like a conversation and therefore the respondents may be more direct in the answers. It is not always easy to understand what is exactly being said since it has to be taken into account the direct and indirect inputs (Yin, 2015) and the researchers have to make an effort to not bias the answers or interpret as is their "mind-structure" what they think that has been said. There are six factors that should be taken into account when doing qualitative research according to Yin (2015):

- Speak in modest amounts: The idea is to let the respondent speak and elaborate further every answer. *Open* questions are a good way to do it as they cannot be answered by a yes or no. During the interviews, after formulating every question, the strategy was to stay quiet and give them enough time to develop and elaborate the answer.
- Being nondirective: It is important to ask nondirective questions in order to let the interviewees express their own perspective and priorities. This factor becomes hard to apply after doing some interviews because indirectly some conclusions or findings have started to appear and an effort has to be made in order to not direct the respondent to the expected or wished direction to strength those findings.
- Staying neutral: This factor is close related to being nondirective. Expressions or body language can transmit to the respondent your approval or disapproval to what they are saying and this can push them to remake the point or simply not elaborate further and therefore result in bias. During the interviews, the respondents were encouraged to answer as they pleased while ensuring that all the topics of the interview guide were covered collecting the necessary data.
- Maintaining rapport: In this thesis, the research questions itself did it in a natural way.
- Use an interview guide: Despite using an interview guide is not compulsory when doing an interview, in this thesis it has helped in order to ensure that the research questions were covered.
- Analyzing when interviewing: As mentioned before, in order to ask follow-up questions, it is necessary to analyze while the respondent keeps answering to get more details or to make them clarify the point.

The interview design was structured into three blocks t to be answered in around twenty minutes. After presenting and explaining the scenario (seen in the previous section), the flow of the interview starts with the strategic questions, followed by opportunities and risks perception and ending with BM Canvas related questions.

Strategic Questions:

Strategic questions were designed in order to introduce the respondents to the topic and the interview's dynamics (general benefits of Industrial Internet and the growth of Industrial Internet in their industry) and also to collect information about the role of data and information in their business because of Industrial Internet related technologies. The questions formulated were the following ones:

- *Which particular product or production line would be the first to adopt IIoT fully and take its capabilities towards predictive maintenance for example so that your customer sees the value already with that particular product?*
    - *Are the benefits from this clear for the customers?*
- *What do you think is the growth of IIoT in your own business or in the industry you are in?*
    - *How significant is this change in business? Why?*
- *How do you think has the role of data and information as a resource changed your business because of IIoT based technologies today?*
- *Do you think that the role of information has increased in comparison with the traditional resources such as machinery, people, etc.?*

Opportunities and Risks perception Questions:

This block dynamics was different. In this case, a general question was formulated as a heading for the whole section and it consisted in rating from 1 to 5 (being 1 very low risk/opportunity perception and 5 very high) each already identified risks and opportunities (literature framework) and leaving an *other risks or opportunities* in order to allow the interviewees to add their inputs in case they felt that something was missing. Some risks can be also seen as opportunities or reversely (i.e. product differentiation or customer switching cost) and therefore, they figure in both categories. In addition, a *why* question was formulated for every answer which was the most important to collect qualitative data. The fact of having a scale is just guidance in order to identify the most or low perceived risks in the three cases but in any case, the scale has been analyzed independently to the *why* question. *Why* question is very important since the fact of rating with a 5 (or any number) a risk or opportunity might mean very different things depending on the perspective of the respondent. The format of this block is shown below:

- *How important are the following risks and opportunities due to increase in data and information because of IIoT technologies (Scale 1-5)? Why?*

    Overall risks/threats for your business

    - *Product Differentiation*

1	2	3	4	5

    - *Customer Switching Cost*

1	2	3	4	5

- *Because of the availability of information from IIoT, will you have new competitors for example, analytics companies, service companies, etc.?*

1	2	3	4	5

- *New capabilities (e.g. in-depth data analytics), will be required to acquire or develop within the company.*

1	2	3	4	5

- *Security and privacy of the data (What if the machine is hacked, can someone stop the production process, can someone introduce defects on the products, etc.?, What if the data is stolen?) From your perspective? And from your customer's experience?*

1	2	3	4	5

- *Difficult to demonstrate Benefits of IIoT investments to Customer*

1	2	3	4	5

- *New unexplored Business models*

1	2	3	4	5

- *Other Risks –*

1	2	3	4	5

Overall opportunities and benefits for your business

- *Product Differentiation*

1	2	3	4	5

- *Customer Switching Cost*

1	2	3	4	5

- *Effective and efficient production planning and maintenance scheduling*

1	2	3	4	5

- *Reduce breakdowns (improve global production efficiency) improvement of the product*

1	2	3	4	5

- *Start selling product + service (selling uptime) Product-Service System*

1	2	3	4	5

- *Cost savings because of the acquired data (Raw Material Costs, Personnel Costs etc)*

1	2	3	4	5

- *New options for a business model (e.g. selling some data to data aggregators companies or offer new models such as rent instead of buy or pay per use)*

1	2	3	4	5

- *Improvement in customer relationship*

1	2	3	4	5

- *Other Opportunities/Benefits –*

1	2	3	4	5

Business Model Canvas Related Questions:

The third and last block dynamics is very similar to the previous one. It begins with a generic question about the information intensity (referred to the increase of the valuable information) impact to the business in their industry or products, followed by a heading question as in the previous part of the interview where it is asked to scale from 1 to 5 the impact to each business model component because of the increase in information intensity and *why*. In order to rate the business model Canvas components, it was given to the respondents the BMC framework tool (Figure 17) to have the global picture and they were free to start with the component the felt more comfortable with and go through the others in the order that they preferred. The last part of the interview is shown below:

- *How does the increase in information intensity* impact to the business in your industry/your products?*
- *Taking as a reference the Canvas Business Model (see template attached below): How business model components are impacted because of the increase in information intensity* because of IIoT technologies (Scale 1-5)? Why?*

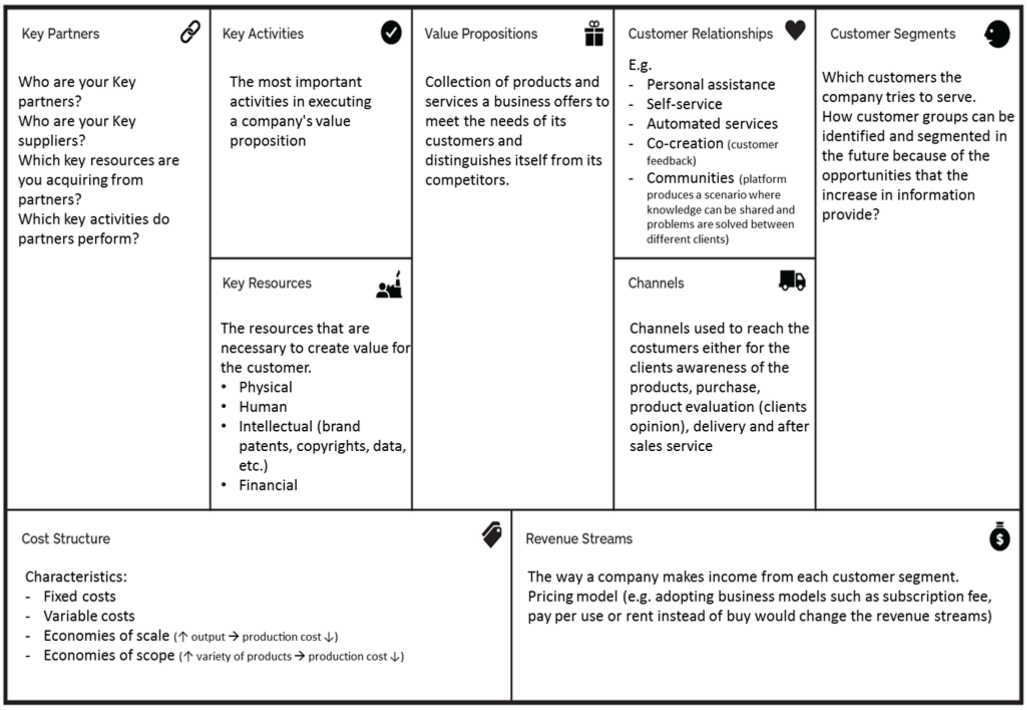

Figure 17. *BMC tool given to the respondents*

4.2.4 Analysis method

The establishment of the relationship between data and theory can be done either in a deductive or inductive manner (Bryman and Bell, 2011). Inductive approach (bottom-up logic) is indicated for where data are to be used to establish new concepts (Yin, 2013) while deductive reasoning (top-down logic) uses statements or known concepts to reach a logically certain conclusion. However, for qualitative studies, a common logic is the abductive approach which consists in a mix of the two previous ones. In this thesis, established concepts have been used in order to define the empirical part (i.e. theoretical framework to establish the most interesting approach, the research gap to cover, the needed data and thus the interview design, etc.) which is a deductive logic. Nevertheless, this thesis also has an inductive approach where the collected data is to be used to establish new findings and concepts. Therefore, in this thesis it has been used the abductive approach. In Figure 18 it is shown the deductive and inductive reasoning of this study.

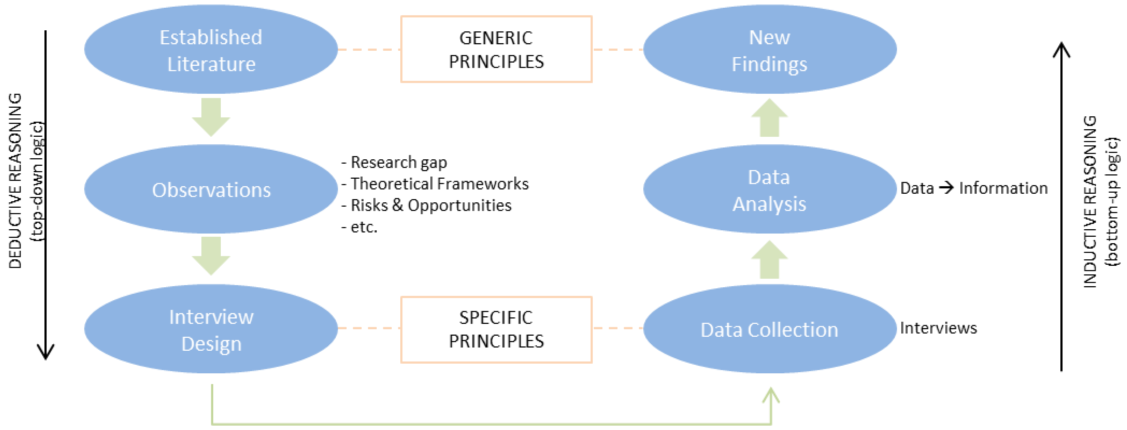

Figure 18. *Deductive and Inductive reasoning of the thesis*

Relevant qualitative data analysis literature (Bryman and Bell, 2011; Saunders and Lewis, 2009; Yin, 2015) present similar methods to analyze qualitative data. The process structure is to categorize or disassembly the data, to compare and interpret the data and to conclude or finalize the data. In this thesis, it has been used a similar process in order to analyze the collected data of the interviews.

The fact of having a structured and divided interview guide (three interview parts), has allowed categorizing the data already before collecting it. It means that there are three categories for the data: strategic data about the role of the valuable information in the business or industry, the perception of risks and opportunities because of Industrial Internet related technologies and the impact of the increase of information because of Industrial Internet related technologies to the business model Canvas' blocks. As mentioned in the previous section, all the questions stuck to the scenario and thus were answered from the predictive maintenance application perspective.

The collected data of the last two parts has been organized in tables, first in individual-case tables and afterwards in a summary table of the three case studies in order to have an overall view of the perceptions and analyze the commonalities and differences.

5. RESULTS AND FINDINGS

This chapter focuses on the results and findings of the three case interviews to medium-sized production line manufacturers. From now on, these three companies will be referred as COMPANY A, COMPANY B and COMPANY C.

The structure of the chapter follows the interview structure explained in the previous section. Therefore, the results and findings have been divided in three sections: 5.1 Perceived risks and opportunities, 5.2 Impact of the Industrial Internet related technologies to the business model's blocks (Canvas framework) and 5.3 Role of data and information in the companies (strategic questions).

5.1 Perceived risks and opportunities

This section presents the results and findings related to risks and opportunities perception due to the increase in data and information because of IIoT technologies. First, each company will be presented separately making use of tables (see Tables 6 to 11) in order to have the details of every company's interview. In this tables it can be found every risk or opportunity, the rate that was given using the scale 1-5 (meaning 1 a very low risk/opportunity and 5 very high), the summary of the answer of the interviewee and a quotation when there is risk of misinterpretation from the answer of the respondent.

After presenting each case individually, two summary tables (Table 12 and 13) are shown putting the three cases together in order to have an overall view of the risks and opportunities and being able to find similarities and differences between the companies. In these summary tables, the quotations haven't been included with the purpose of making the content lighter and easier to read and the answers have been summarized in short points. The main purpose for elaborating the final tables is to pinpoint the differences and similarities between the companies but since this thesis is a qualitative study, the reasoning given by the companies through the *why* and *how* questions will be highly important when elaborating findings and conclusions. Therefore, the score usefulness is just as a matter of guidance but in any case it can be separated of the reasoning.

Finally, the findings related to risks and opportunities are presented explaining the commonalities and the differences that have been found and the reasoning given by the companies.

<u>COMPANY A</u>

Table 6. *Company A perceived risks*

Risk	**Score**	**Summary**	**Quotation from interview (if needed)**
Product Differentiation	2	Very similar product as the competitor because of IoT	
Customer Switching Cost	1	Customers like to have only one platform and keep everything there and therefore it is one-time decision purchase	
New competitors (e.g. data analytics, service companies) because of availability of information from IoT	2	The interviewee sees the company's key business in providing good quality data from the machine level and the openness of the system is perceived more as an opportunity so that the client can use for e.g. the competitors analyzing system	"This not our key business, our key business is to provide good quality data from the machine level to the factory so clients can use it how they want, but we can also provide overall system if the customer don't have their own. (…) I think that is our benefit that we are open on that level and then they can use the competitor analyzing system"
New capabilities (e.g. in-depth data analytics), will be required to acquire or develop within the company	1	It is not perceived as a risk, new capabilities will be achieved by hiring some extra workers but the company will remain in a general level (machine level), just providing the raw data so that the customers can use it in their own	"Some specialist to get the data from the machines and then analyzing the end product, it is hard to say but I think it will be quite general because we can provide the raw data and customers can use it as their own (…) we are the machine level specialist anyway"
Security and privacy of the data (What if the machine is hacked, can someone stop the production process, can someone introduce defects on the products, etc.?, What if the data is stolen?)	1(for Company) 4 (for Customer)	It is seen as a risk for the customers which comes back to the company as a risk too. The interviewee feels that there is no expertise related to security field in the company so it would be better to have a standard solution for the data transfer rather than building its own system	"For our customer maybe, it is a risk because they will store the data of their production but we only get the service data to us so for the company it is not a risk. (…) But if it is customer risk, it comes back to us. (…)it would be good to have some standard platform because we are not experts on that level

			to rely on”
Difficult to demonstrate Benefits of IIoT investments to Customer	1	The interviewee sees this aspect clearly as an opportunity and not a risk because it is very easy at this point to demonstrate the value and everyone is interested in this kind of solutions now	
New unexplored Business models	3	At this level, there might be some risks in how it will work out	
Other Risks – Provide a good and better system than competitors	3	The main risk for the company is to be able to get the maximum and not just basic information out of the data from the machine level and have a higher level system than the competitors	

Table 7. *Company A perceived opportunities*

Opportunity	**Score**	**Summary**	**Quotation from interview (if needed)**
Product Differentiation	5	It is perceived as a big opportunity because the company can understand better than their competitors the software side because competitors are mainly from the metal industry	
Customer Switching Cost	3	The customer switching cost is perceived as a moderate opportunity if their system is clearly better than the competitor’s	“Our system must be clearly better so that the customer might change it to us. So the switching cost is low.”
Effective and efficient production planning and maintenance scheduling	4	This is clearly seen as an opportunity because the company will be able to point out the real things that need maintenance but the importance relies on how to analyze the data	
Reduce breakdowns (improve global production efficiency) improvement of the product	5	Clearly seen as a big opportunity. No comments or clarifications were made	
Start selling product + service (selling up-	1	Selling uptime is not perceived as an opportunity at	

time) Product-Service System		this moment because in this industry there is still a lot of manual work and many things that would affect it making difficult to sell uptime	
Cost savings because of the acquired data (Raw Material Costs, Personnel Costs etc)	3	It is seen as a moderate opportunity. No extra comments or clarifications were made	
New options for a business model (e.g. selling some data to data aggregators companies or offer new models such as rent instead of buy or pay per use)	3	It is seen as a moderate opportunity. No extra comments or clarifications were made	
Improvement in customer relationship	5	Very important perceived opportunity because of the improvement of the production up time, which could be clearly seen by the customer	"That is very important because improves the production up time and that is the clearest thing."
Other: Knowledge of the low-level systems	5	The interviewee sees an opportunity in the knowledge that the company have of the low-level system that will make possible to take out the important data and create useful reports better than the companies that are just making the higher-level system	"The opportunity is that we know our low-level system very well so that we can really take the important data out and it is easier for us to create the really useful reports out of it than the companies that are just making the higher-level system, they connect just a couple of variables and try to create a system but we really have all the low-level data"

COMPANY B

Table 8. *Company B perceived risks*

Risk	**Score**	**Summary**	**Quotation from interview (if needed)**
Product Differentiation	2	It can be risk but also an opportunity and the interviewee sees it more as an opportunity than a risk even though is difficult to rate	

Customer Switching Cost	2	Not a big risk because in there are still some elements where the company will be the only option	
New competitors (e.g. data analytics, service companies) because of availability of information from IoT	2	These companies are needed and the respondent sees it more beneficial for partnerships than a threat. The company needs them because there are many things to do and all of them cannot be done "in house"	
New capabilities (e.g. in-depth data analytics), will be required to acquire or develop within the company	3	The perception is that it can be a little bit of risk because as the interviewee is aware of the difficulties there might be in finding the right kind of capabilities because if they are in the core in the business it would be better not to outsource them	
Security and privacy of the data (What if the machine is hacked, can someone stop the production process, can someone introduce defects on the products, etc.?, What if the data is stolen?)	5	The interviewee states that when it comes to the fourth industrial revolution which is based mostly in digitalization, security is still one of the most important questions. It is perceived as a high risk because of some sensitive information of the customers that could be stolen. The ownership of the data is seen as a critical thing and despite some models related to the ownership are developing there will be still difficulties because there will always be negotiations between two human beings so the trustiness and transparency become a critical factor	"This is a very high level risk because hacking nowadays is not anymore a hobby (…) from our customers' point of view there is some critical data for example NC programs and if you have access you can manipulate or steal the programs (...) of course there are some solutions but it is a twofold question, first is the security that no one don't have access to data and second is the trust between our company and our customer and typically this is related to the ownership of the data, how we can use the data and transparency is really critical thing"
Difficult to demonstrate Benefits of IIoT investments to Customer	4	There is a risk perception, for example proactive maintenance could be difficult to be appreciated by customers because they won't see the company in the factory that often and thus it could be	"(…) when we can keep the system running all the time, customers don't actually value if it's no so transparent, if we are doing things proactively, they will be asking: why

		perceived as not transparent	are we paying? because we haven't seen you in the factory"
New unexplored Business models	2	It is seen more as an opportunity than a risk or a threat	
Other Risks – Legacy device connectivity	3	Legacy device connectivity could be a risk but there are options too to create solutions for that which can be shifted as an opportunity for the company	

Table 9. *Company B perceived opportunities*

Opportunity	**Score**	**Summary**	**Quotation from interview (if needed)**
Product Differentiation	4	It is seen as an opportunity for the company to differentiate their products from competitors	
Customer Switching Cost	3	The respondent sees it as an opportunity for the company but despite being possible to increase the switching cost, it can be turned into a risk because if customers know it, they will not buy it. In many cases, customers want freedom to select and that is the reason why they are investing in those novel technologies	
Effective and efficient production planning and maintenance scheduling	5	It is clearly perceived as a big opportunity because it is core business for the company	
Reduce breakdowns (improve global production efficiency) improvement of the product	4	It is seen as a big opportunity for the company but compared to the previous point where the company can help customer to earn more money, in this case it is about helping the customer to save money so it is a little bit less opportunity	
Start selling product + service (selling uptime) Product-Service System	4	It is seen as an opportunity. Although this sector is in general terms very traditional and old-fashion thinking at the moment the respondent expects that in future, customers will be	"I strongly believe that in future they are paying for outcome, so they are not necessarily owning the equipment neither operating

		happy to pay for the outcome (pay-for-use) and not for the ownership of the equipment. Nowadays there are some customers that do not own the equipment but they do still operate and do some maintenance	or doing those services by themselves. At the moment what is happening is that they are not necessarily owning, but they are still operating and sometimes doing some parts of maintenance by themselves”
Cost savings because of the acquired data (Raw Material Costs, Personnel Costs etc)	3	It is perceived as an opportunity but not that big compared to the others	
New options for a business model (e.g. selling some data to data aggregators companies or offer new models such as rent instead of buy or pay per use)	5	It is seen as a clearly a big opportunity to have new options for a business model	
Improvement in customer relationship	4	It is seen as an opportunity, no extra comments were made	
Other: Legacy device connectivity	3	Legacy device connectivity can be a risk but the company can create solutions in this specific area (but maybe it is not the company's core business)	

<u>COMPANY C</u>

Table 10. *Company C perceived risks*

Risk	**Score**	**Summary**	**Quotation from interview (if needed)**
Product Differentiation	4	It is difficult for the respondent to imagine at this stage how to make really different products than competitors because everybody wants to go to the same direction. It is perceived as a risk but the interviewee thinks that it will not be easy for competitors to follow the company developing this kind of new services. Other countries like China are growing really fast and improving their machines but it could	“Imagine if everybody goes to the same direction and gets to the same level, kind of what has happened with machine hardware, then I would say at least 4 (…) at the moment I cannot really imagine how to make it so different that the other people (…) I think it can be a risk

		be difficult for them to sell in western countries services related with data gathering because the customers won't feel safe sending their data to China for example so it could become a barrier for these emerging and fast-growing markets. However, it is perceived as a risk because the mindset could change a lot in the future	but also but I think that in our industry if we start developing this kind of a thing, I think it will be difficult for our competitors to follow (…)"
Customer Switching Cost	1	It is perceived as a low risk because the respondent states that the industry is not going to develop an standardized model for data gathering and transfer so in some way, customers are locked because the systems are built around the machines which are different so it will be difficult for the customer to switch to competitors	(…) "I don't think that industry is going to make this really huge open data set or standardized model so they will be always locked, once you make the deal then you are locked with that system (…)"
New competitors (e.g. data analytics, service companies) because of availability of information from IIoT	4	It is very difficult to predict for the interviewee but it is perceived as a risk because new competitors could just plug in sensors to the machines without needing to access to the control systems to gather the needed information. These competitors will be able to offer lower prices and be more efficient than the company because they will be lighter organizations and can make simplest solutions just focusing on one area like analytics. With II related technologies, the know-how of the company about this traditional industry is not valuable anymore because everyone can plug-in sensors, analyse the gathered data and offer services like predictive maintenance relying in numbers	
New capabilities (e.g. in-depth data analytics), will be required to acquire or develop within the company	2	It is not perceived as an important risk because the new talent acquired in understanding the information could be relocated somewhere else. If the company got a lot of resources for II purpose and it pass away, then	

		there could be a small risk	
Security and privacy of the data (What if the machine is hacked, can someone stop the production process, can someone introduce defects on the products, etc.?, What if the data is stolen?)	5	It is seen as a big risk, in the future, much of the business of the company would be about data and if someone could hack in the system it would be a big problem because the business would be mainly about trustiness with the customers and it would be very difficult to get I back. Security is considered one of the biggest concerns by the respondent	
Difficult to demonstrate Benefits of IIoT investments to Customer	3	The perception is that it could be quite difficult to demonstrate the benefit of predictive maintenance to the customers so that they would be happy to pay for it. The machines that the company is selling don't have that many "moving parts" that can break and are not critical for the process. The company is already working in the arguments to demonstrate the benefits to most of the customers	
New unexplored Business models	3	The company counts with some experienced workers that have a lot of information and knowledge about the machines and in case that no historical or huge amount of data weren't available yet, this expertise could be a mitigation for risks when exploring new business models	
Other Risks – ownership of the data	Not rated	Ownership of the data could be a risk, probably in some other industries a big risk. At this moment the company is just storing data but it could get interesting if they develop a model based on that data, negotiations with the customers would be necessary	

Table 11. *Company C perceived opportunities*

Opportunity	**Score**	**Summary**
Product Differentiation	3	Even if everybody is doing it, data gives the opportunity to think about new things to make the product different from competitors. Nevertheless, the interviewee thinks that

		product would be still the center and everybody will be using data so doing it will become a must but no big product differentiation will be achieved by using the data
Customer Switching Cost	3	It is perceived as a medium opportunity because the life of the machines is around 20 years and if the customer wanted to change, they would lose a lot of data and even if they could have the data, the interviewee don't think that there will be standardized models for data gathering and transfer so it could become difficult to integrate it into the new system
Effective and efficient production planning and maintenance scheduling	5	It is perceived as a big opportunity because if the machine broke in the wrong time, it could suppose a lot of money
Reduce breakdowns (improve global production efficiency) improvement of the product	4	Reducing breakdowns globally can be a good opportunity mostly for the bigger customers which have tens of tens of machines globally. For those companies, knowing in advance that some machine is going to break can transfer the production to another line before there is a breakdown in the actual line
Start selling product + service (selling uptime) Product-Service System	4	The interviewee believes that just selling predictive maintenance is not enough, it is necessary to know the process itself in order to be efficient and not just keeping the machines running in good condition. Selling uptime with predictive maintenance is not enough but when combining it with the process, it can be something big. The company has already though about the possibility of selling production (guarantee an amount of production with good quality and maximum yields). Despite perceiving a big opportunity, the interviewee points out that in this traditional industry there will also be reluctant opinions in the beginning with this kind of new models
Cost savings because of the acquired data (Raw Material Costs, Personnel Costs, etc.)	3	The interviewee does not perceive big savings in personnel or raw materials because of IIoT application for the company. However, there would be some benefits such as time saving at customer's sites for the maintenance staff because they will know in advance what is the exact problem and what is necessary to bring there to repair it
New options for a business model (e.g. selling some data to data aggregators companies or offer new models such as rent instead of buy or pay per use)	4	The interviewee sees a big opportunity in new options for business models because the company has a wide variety of end users and if they had the right information; it would be possible to sell different things such as pay-per-use or production time depending on the segment. The interviewee clarifies that just having predictive maintenance could not be enough and it has to be combined with production to have the whole picture
Improvement in customer relationship	4	It is seen as a good opportunity because with the new information it will be possible to offer better services to each customer. However, the interviewee marks that the right use of this information is important in order to not

		create strange situations with customers (e.g. having too much information) and that it is also important to keep doing visits to them in order to strengthen the relationships. The overall view is that using the information in an appropriate way, it can become a good opportunity for improving customers' relationships
Other:	4	Selling production time to the customers' customers through a platform

After presenting the three companies' perception about risks and opportunities separately, two summary tables (see Table 12 and 13) have been elaborated in order to make easier the analysis and to have an overall picture. The findings related to risks and opportunities perception are presented below:

From the risks side, *security and privacy of the data* is the major concern within the three companies. It is perceived as a huge risk and COMPANY A is not willing to develop an internal security system but outsource it to an experienced and specialized security provider since they feel that they do not have enough expertise in this area. The ownership of the data is the major concern for COMPANY B which is related to the necessity of trustiness between the company and the customers that pinpointed COMPANY C. *Customer switching costs* is the lowest perceived risk for all the three respondents. However, it has to be noticed that their reasoning to rate it as a low risk is different in all the three cases. COMPANY A relies on the customer preference for having just one system which means that it would be a one-time decision while COMPANY B believes in their uniqueness which will make them the only option and COMPANY C points out the lack of standardized solutions for data transfer and gathering in the industry which creates lock-in and thus high customer switching costs. COMPANY B and C agree on the *difficulty to demonstrate benefits of IIoT investments to customers* if it is only about predictive maintenance and COMPANY A just expressed that in general terms IIoT benefits are clear for the customers which is aligned with the other two companies' perception talking in general terms and not only from the predictive maintenance side. The risk associated with *new capabilities required to acquire or develop within the company* is not perceived as a high risk in any case because of the possibility of outsource those capabilities that are not in the core business and the fact that this kind of capabilities related to the information understanding can be relocated within the company if needed. COMPANY A and B agree on the low risk of *new competitors because of availability of information from IIoT*, but in the first case it is because it will not be their key business and in the second case a strategic move through the new possibilities of partnerships is appreciated. Nevertheless, COMPANY C sees it as a big threat since new smaller and lighter organizations will be able to offer some services at a lower price and points out that IIoT devalues the *know-how* of the company because allow new industries and companies to enter to their industry relying in the "numbers" and algorithms without the need of expertise in the sector. *New unexplored business* *models* are perceived as a moderate risk and COMPANY A express its feeling of uncertainty when it comes to materialize this idea and not only talk in general terms. Some other interesting risks were pointed out by the companies such as the *legacy device connectivity* which is a twofold issue since it can become also an opportunity if the company starts to offers solutions to it and the *ownership of the data*.

From the opportunities side, *effective and efficient production planning and maintenance scheduling, reduce the breakdowns* and *improvement in customer relationship* are the three highest perceived opportunities in all the three cases. The first one affects to the core business of the companies and it would mean to increase the earning of the customers so the opportunity seems to be clear for all of them. The second one, is also clearly seen as an opportunity since but a little bit lower than the previous one since it concerns to the saving money side of the customer more than increasing revenues. Finally, the last one is perceived as a good opportunity because IIoT related technologies allow the possibility of offering new and better services to the customers because of the new available information and the fact that benefits of IIoT such as improvement of the production are clearly seen by the customers. However, COMPANY C points out the importance of making the right use of that information in order to not create mistrust with the customers. *Product differentiation* is seen as an opportunity more than a risk in all the three cases. COMPANY B and C agree on the good opportunity of *start selling product + service (selling uptime)* and both have the feeling that despite being in a traditional industry, and there will be some reluctant opinions to this kind of models, it will shift in the future and customers will be willing to pay for outcome instead of equipment. COMPANY A differs in this point because in its industry there is still a lot of manual work so it is difficult to sell and prove the uptime because of IIoT related technologies. The *costs savings because of the acquired data* are not perceived as a high opportunity but as a low-moderate one in what concerns to the time saving of the maintenance works. *New options for business models* represent a clear opportunity for COMPANY B and C but the lasts one states that predictive maintenance is not enough and it has to be combined with production improvement.

It can be said that there are some commonalities within the three cases' perception of the risks and opportunities but also some differences attributed to different facts. They are all in different end industries with different needs and realities. Another fact is that they are not in the same Industrial Internet maturity level which affect to the answers in a way that for example, the ones that are less advanced are not as aware of the risks as the others.

Table 12. *Perceived risks summary table*

Risk	Company A		Company B		Company C	
	Score	Reasoning	Score	Reasoning	Score	Reasoning
Product Differentiation	2	• Very similar products as the competitors because of IIoT	2	• More perceived as an opportunity despite being difficult to predict	4	• Difficult to imagine how to create different products. Everybody is heading the same direction • However, perception that it will not be easy for competitors to follow the company developing new services
Customer Switching Cost	1	• One-time decision purchase for customers • Customers preference to have only one platform	2	• There will be still some elements where the company will be the only option for the customers	1	• Lack of standardized models for data gathering and transfer which creates lock-in for the customers
New competitors because of availability of information from IoT	2	• Key business is to provide good quality data • Openness of the system is perceived as an opportunity	2	• Beneficial perception due to possible partnerships • Neediness of new companies in order to provide solutions that the company cannot do in-house	4	• New small companies could offer specific services at lower prices and maybe be more efficient because of their lighter structure and “single focus area” of expertise. They could plug sensors to the machines without accessing to the control system to gather the needed information • IIoT technologies devalue the know-how of the company allowing to offer services relying “in numbers” and algorithms
New capabilities required to acquire or develop within the company	1	• It can be achieved by hiring new employees • It will remain in a general level, just to provide the raw data for customer’s use so no deep capabilities in data analytics will be needed	3	• Some new capabilities will be difficult to reach and mainly if those are in the core business because the outsourcing is not an option	2	• Not a big risk perception due to the possibility to relocate the new talent acquired in understanding information somewhere else in the company • Small risk if the company invest in a lot of resources for IIoT purposes and it pass away

Security and privacy of the data	1-4	• Low risk for the company (1) but high for the customer (4) • Not willing to develop internal security system because of lack of expertise • Standard solution will be required for data transfer	5	• Security is still an important question in this digitalization era • Some customers' sensitive information could be stolen creating potential damage • The ownership of the data is critical and pending of negotiations	5	• Future business would be about data and customers' trust. If the system is hacked the damages would be severe • Very difficult to get a customer back after having security problems
Difficulty to demonstrate benefits of IIoT investments to customers	1	• Benefits are clear for the customers • Everyone is interested in IIoT solutions at this point	4	• Proactive maintenance can be difficult to be appreciated by the customers • The fact the company is not going to visit the customer's factory so often and is doing proactive things could be perceived as not transparent	3	• Benefits of predictive maintenance could be difficult to demonstrate. The machines don't have that many critical and spare parts that could suddenly break and stop the process
New unexplored business models	3	• Risk associated to the uncertainty of how it will work out	2	• It is perceived more as an opportunity than a threat or risk	3	• Experience and knowledge of the company could be used to as a mitigation when exploring new business models without having huge amounts of data yet
Other Risks	3	• Provide better solutions than the competition • Risk associated to the company's ability in getting the maximum valuable information out of the data	3	• Risk associated to the legacy device connectivity • It could shift also to an opportunity for the company creating solutions for it •		• Risk associated to the ownership of the data

Table 13. *Perceived opportunities summary table*

Opportunity	Company A		Company B		Company C	
	Score	Reasoning	Score	Reasoning	Score	Reasoning
Product Differentiation	5	• Competitive advantage of the company in better understanding in the software side because of the background of its competitors	4	• Possibility to differentiate the products from the competition	3	• Data gives the opportunity to think about new things to differentiate the product even if the rest is also heading the same direction • Product will remain the center for differentiation and data use will be a must to have
Customer Switching Cost	3	• Could be an opportunity if the company gets to have a much better system than competitors	3	• It will be possible to increase the switching cost • It could become a risk because customers want freedom to select	3	• Lack of standardized models for data gathering and transfer which creates lock in to the customer • Machine life is around 20 years and if switching, customer could lose a lot of data
Effective and efficient production planning and maintenance scheduling	4	• Capability of pointing out the real things that need maintenance • The importance relies on how to analyze the data	5	• It is a big opportunity because it is the core business of the company • Increase the earnings of the costumers	5	• If some specific machine broke at the wrong time, it could suppose a lot of money for the customer
Reduce breakdowns (improve global production efficiency) improvement of the product	5	• Big opportunity, no comments or clarifications were made	4	• Good opportunity but less than the previous one • This can help costumer to reduce costs but not to increase earnings	4	• For bigger customers that have tens of tens of machines globally the awareness of a failure in advance would allow them to transfer the production to another line before it happens which is a good opportunity
Start selling product + service (selling uptime) Product-Service System	1	• There is a lot of manual work in this industry and other facts that would affect to the uptime so it is difficult to sell and prove it	4	• Despite being in a traditional industry, it is expected that in the future customers will be willing to pay for outcome (pay-per-use) instead of equipment	4	• Selling predictive maintenance is not enough but combining it with the improvement of the processes could be big • It is a traditional industry and there would be some reluctant opinions related to selling production models

Cost savings because of the acquired data (Raw Material Costs, Personnel Costs etc)	3	• Moderate opportunity, no comments or clarifications were made	3	• Opportunity but not as big as the rest	3	• Not big savings in personnel or raw materials because of IIoT application • Time saving at customers' site for the maintenance works
New options for a business model (e.g. selling some data to data aggregators companies or offer new models such as rent instead of buy or pay per use)	3	• Moderate opportunity, no comments or clarifications were made	5	• Clearly an opportunity to have new options for business models	4	• The company has a wide variety of end users and with the right information, it will be possible to sell different things such as pay per use, selling production time, etc. depending on the segment • Predictive maintenance is not enough, it has to be combined with production to have the whole picture
Improvement in customer relationship	5	• Improvement of the production up time would be clearly seen by the customers	4	• Good opportunity, no comments or clarifications were made	4	• Possibility to offer better services to each customer due to the new information • Importance of making the right use of the information to not create mistrust with customers • Importance in keep doing visits to the customers
Other:	5	• Opportunity related to the company knowledge of the low-level systems • Better understanding of the important data which will create better reports than companies which are making just higher-level systems	3	• Opportunity related to legacy device connectivity solutions • This specific area is not the company's core business	4	• Opportunity related to selling production time to the customers' customers through a platform

5.2 Impact of the II related technologies to the business model's components

This section presents the results and findings related to the impact of the IIoT related technologies to the business model's blocks using the Business Model Canvas. The flow of the section is the same as the previous one. First, each company will be presented separately making use of tables (see Tables 14 to 16) in order to have the details of every company's interview. In this tables it can be found every BM block, the rate that was given using the scale 1-5 (meaning 1 a very low risk/opportunity and 5 very high), the summary of the answer of the interviewee and a quotation when there is risk of misinterpretation from the answer of the respondent.

After presenting each case individually, a summary table (Table 17) is shown putting the three cases together in order to have an overall view of the BMC components impact and being able to find similarities and differences between the companies. In these summary table, the quotations haven't been included with the purpose of making the content lighter and easier to read and the answers have been summarized in short points. As in the previous section, the main purpose for elaborating the final table is to pinpoint the differences and similarities between the companies but since this thesis is a qualitative study, the reasoning given by the companies through the *why* and *how* questions will be highly important when elaborating findings and conclusions. Therefore, the score usefulness is just as a matter of guidance but in any case it can be separated of the reasoning.

Finally, the findings related to the BMC components impact are presented explaining the commonalities and the differences that have been found and the reasoning given by the companies.

<u>COMPANY A</u>

Table 14. *COMPANY A perceived impact of the II related technologies to the BMC components*

BM block	Score	Summary
Key partners	1	IT companies will be needed as key partner because of lack of IT expertise in the company. The first step would be to build up an IoT platform where all the gathered data can be stored and transformed into valuable information for further analysis and reports for the customer
Key activities	4	New key would be to build up the communication system between machines and cloud storage and the reporting system. At this moment the company has activities related to data collection but only locally

Key resources	2	Not many new key resources would be needed; maybe some employees to build up the system at first and when it would be running some people to make business intelligence in order to have real value out of the reports. Financial resources for example would not get affected so much
Value proposition	4	Because of the real and reliable gathered data, it will be possible to increase the value proposition for the customers. Graphics and data visualization will show the customers what or why should they contract some services from the company. Increasing in the production due to the data and information would be another value proposition
Cost structure	1	There will be some differences, mainly with the variable costs because of the new possibilities to rent the machines for example and other new business models like flexible pricing for up time for instance (for example welded material in kg)
Customer relationships	4	There is a positive aspect, the clients feel that the company is more present even if the physical distance is big if they feel that they have good support
Channels	4	It is not appreciated a big impact on delivery channels. Maybe the after sales channels and spare part delivery (it can be optimized and delivered earlier thanks to the information and data) could get affected somehow
Customer segments	1	The company already have customer segments but with the new services allowed with IIoT technologies, it will appear more segments for those services
Revenue Streams	4	There will be some impact in the revenue streams because the company will be able to make different kind of products on top of the IIoT system to commercialize. For example different level of data tracking (general data and average values, measured data in millisecond level, etc.) or some other new inventions

<u>COMPANY B</u>

Table 15. *COMPANY B perceived impact of the II related technologies to the BMC components*

BM block	**Score**	**Summary**	**Quotation from interview (if needed)**

Value proposition	3	It will be quite impacted, maximizing uptime is saving money side (not increasing revenues) so the customers should be willing to pay for these extra capabilities of the products, that is the reason to rate it in between and not too high	
Revenue Streams	3	It can get impacted, for example it will be possible to have some kind of insurance fee, similar to what we already have in insurance industry business models. Offering insurance services is a really big change in thinking, it would be possible through very good historical data	"Could be some kind of insurance fee based on the system side, access to customer, what has happened in there?, pretty much also same things as we have in insurances. What has happened in history and what is the condition (…), with very good history data (…)"
Customer segments	2	This is definitely a thing that they cannot offer to all to their customers (or they are not buying this kind of models). Because customers have different "drivers" when they are investing such as efficiency of the production (main driver), flexibility (most common need among their customers), traceability and safety. These drivers will affect to if they are buying it or not. Companies that are targeting a very high level of efficiency and usability of the systems, customers using the equipment 24/7 and where their equipment has a very critical role in production would buy this kind of thing. When these novel services will be efficient and in the market, segmentation will change, but probably not so big, because the main criteria for segmentation does	"(…) When we start to use these technologies in more efficient way and we will have novel services based on these technologies, segmentation will change. (…)"

		not change	
Customer relationships	3	The role of remote services could make the customer feels that they are not visiting him so often anymore but anyway, role of remote monitoring and operations will increase the relationships if they are transparent, but the communication value would be a very critical point	"(…) anyway, role of remote monitoring, and remote operations, it will increase, but those operations must be transparent enough, it better to communicate value, communication value is very critical in there (…)"
Key partners	4	Partners helping the company with some key capabilities, for e.g. analytics, platform partners, etc., are really needed so key partners will get very impacted	
Key resources	3	It depends on what kind of parts of the service they will create using own resources for e.g. data analytics. However, when delivering this service, there is not much difference compared to current situation because they already have the teleservice in there. The impact will not be so big, but it would be different if the company had to create this service	
Key activities	2	Some key activities might change but since nowadays they are already capable of solving 83% of fault situation remotely, the change will not be big	
Cost structure	3	Compared to current situation it will not change so much, it still will be like product centric. When it comes to cost scalability of the service, it has to be kept in mind, the cost structure when there is change will be to saving side. This kind of services have to be built to be scalable	

Channels	(no value pro-vided)	The impact would be low because they would use the infrastructure they already have to deliver the product	

COMPANY C

Table 16. *COMPANY C perceived impact of the II related technologies to the BMC components*

BM block	**Score**	**Summary**
Value proposition	4	Value proposition will get pretty impacted because with the gathered data and information it will be possible to offer different and nice things and to offer them to the right customer
Key partners	3	It is possible that the company will not be able do everything and then some collaboration will be needed. In that sense, new players that are not in the business at this moment could become key partners. Suppliers would most likely stay the same. Nevertheless, data storage suppliers will get a major role than the traditional IT suppliers considering the ownership and security of the data. Key partners will get impacted but still not hugely because the current partners and subcontractors will continue being necessary and maybe this new role of data and information can be used with them too (they will also adopt this new technologies and so on)
Key resources	3	The perception of the change in key resources goes through a less dependency on the people because the traditional know-how will be replaced by data and algorithms. The impact is perceived as the human factor will go a bit down but the intellectual properties will go higher, it is perceived as a medium impact
Key activities	2	Key activities' impact is estimated as a low one. The activities that the company is currently doing will be pretty much the same in this scenario, maybe some parts might be different but anyway it will be similar to the current situation
Customer relationships	3	Co-creation is an example of a change in customer relationship. At this moment, in maintenance activities, the company usually competes against the own customer's maintenance department and in this new scenario it could be possible the

		co-creation because of the data that the company would have. A mid-level impact is perceived as there could be some changes in the relationship's dynamics with the customers
Customer segments	2	The company already has a customer segmentation depending on size, end products, kind of business, etc. and the interviewee's perception is that it will not change that much. With new data and information there might be some changes but it would more or less stay the same
Channels	3	Channels are already changing in how to reach the customer such as portals where the customer can log in. In the future, in these portals, the customers would be able to follow how their manufacturing is going on and this is a big change for this traditional industry. The interviewee's perception is that channels on how to reach the customers will change quite much but maybe not only due to the new role of data and information but because of digitalization
Cost structure	2	From the maintenance point of view it is not perceived a big impact in the cost structure. Maybe some stocks could be reduced but the company does not have many stocks so it would not mean a big change. The interviewee rates it as a 2 because of possible things that might change that are difficult to predict now
Revenue Streams	5	Revenue streams impact is perceived as a huge one. It is most likely that new models such as monthly fee (subscription model) for predictive maintenance will come up

In general terms, it can be said that the entire business model components will somehow get affected by the Industrial Internet related technologies. It means that the overall impact of the IIoT application will be huge in the industry's business models. Key partners, Value proposition and revenue streams have been perceived as the most impacted BM blocks. New partnerships (i.e. with new suppliers) are perceived as a necessity in order to achieve some required capabilities such as IT vendors (e.g. cloud, etc.) or security of the data or big data analytics. New services available due to the new reliable gathered data and valuable information will be possible to offer to the customers and not only to the customers in general but to the right customer in every case and also value propositions such as increasing the production time will be possible. COMPANY B points out the threat that despite *value proposition* will get quite impacted, if it is not related to the earning money side for the customer, they should be willing to pay for those extra capabilities of the products such as predictive maintenance. Because of this new value propositions, *revenue streams* will also get very impacted because it will be possible to offer services to the clients such as insurance fees or monthly fees for predictive maintenance. *Customer relationship* has also been identified as an impacted component as a better service will be provided to the customers. However, it is important to have a good communication with the customers in order to overcome the physical distance (created by the remote services) and to adapt to the new relationship dynamics. COMPANY C points out the new possibilities for co-creation that will be possible because of the IIoT related technologies which will soften the current rivalry in some cases (i.e. rivalry between the company maintenance department and customer maintenance department). *Key activities, cost structure* and *customer segments* have been identified as the less impacted components. Current activities of the companies will remain the same so there will be just a small impact in some changes in some parts of the actual activities. Related to the cost structure, COMPANY B states the importance of the scalability cost of the new offered services since they have to be built to be scalable. COMPANY C adds that from the predictive maintenance side, there won't be a big impact into the cost structure but since it is difficult to predict, options should be kept opened. Finally, COMPANY B and C agree on the low impact into the *customer segments* because the view is that the main segmentation criteria will be similar to the current one despite having some changes. *Key resources* impact perception is moderate, being the human resources the most affected one (more personnel needed or personnel replaced by algorithms) while financial resources are perceived as the lowest impacted. Lastly, *channels* will also get somehow impacted, mostly the aftersales channels and the communication channels with the customers. However, delivery channels are perceived to remain the same.

To sum up, business will have a big impact because of the information intensity or valuable information that Industrial Internet related technologies will provide. The fact that it has been appreciated at least a small impact in all the business model components by all the interviewed companies, means that the overall impact to their business is perceived as a big one. New value propositions, new revenue streams, new partnerships and so on will also allow to some traditional industries, as it is the case of this study, to develop new business models or change their actual business model.

Table 17. *Perceived impact of the II related technologies to the BMC components summary table*

BM Component	Company A		Company B		Company C	
	Score	Reasoning	Score	Reasoning	Score	Reasoning
Key partners	1	• IT suppliers needed because of company's lack of expertise	4	• New partners would be needed for some capabilities such as analytics and platforms	3	• Some collaboration might be needed • Players that are not in the business at this moment could become new partners • Suppliers would remain the same but storage suppliers would get a major role than traditional IT vendors because of the security related issues • Current partners would be still needed and the new role of data and information could be used with them too
Key activities	4	• New key activities such as building up the communication system between machines and cloud storage	2	• The company is already solving 83% of fault situations remotely	2	• Current activities would be still carried out. Nevertheless, some parts might change a little bit
Key resources	2	• Not many changes, new employees to build up the system and for business intelligence purpose • Financial resources wouldn't get very impacted	3	• Depends on who is creating the service. If the customer were using its own resources for analytics, the current situation would not change so much. The company already has tele-service. If the company had to use its owns resources, it would get more impacted	3	• Less dependency on the people because traditional expertise would be replaced by data algorithms.
Value proposition	4	• Increase of the value proposition with new services due to the real and reliable gathered data • Increasing in the production of customers would be another value proposition	3	• There would be quite impact but maximizing uptime is in the saving money side and not generating revenues. Customer should be willing to pay for those extra capabilities of the products	4	• New gathered data and information will make possible to offer different things and to offer them to the right customer

Cost structure	1	• Impact mainly in the variable costs due to new possibilities such as renting the machines, flexible pricing, etc.	3	• Cost structure would remain product centric • Cost scalability of the service has to be kept in mind. Services have to build to be scalable	2	• From the maintenance point of view it is not perceived a big impact in the cost structure • Stocks could be reduced but it is not critical in the company • Difficult to predict, keep options open
Customer relationships	4	• Customers would feel that the company is more present even if there is a physical distance	3	• Remote services could create the feeling that the company is not present • If the operations are transparent and there is good communication, it will increase customer relationships	3	• Co-creation would replace the actual rivalry between the company and the customer's maintenance department • Changes in the relationship dynamics with the customers
Channels	4	• Delivery channels wouldn't get very impacted • After sales channels and spare part delivery could be optimized	-	• Delivery channels would remain the same and use the infrastructure that the company already has	3	• It is already changing in the traditional industry, portals where customers can log in and in the future they could follow the production which would be a big change • The channels of how to reach the customers would change but not only because of the data and information but also because of digitalization
Customer segments	1	• IIoT application would create even more segments for the new services	2	• Companies seeking for high levels of efficiency and where equipment is working 24/7 with a critical role in production would be interested, but not all customers • The main criteria for segmentation would remain the same despite some changes	2	• The current segmentation would mainly remain the same
Revenue Streams	4	• New products on top of the IIoT system to commercialize and it will create some impact	3	• Possibility of having some kind of insurance fee or similar • Offering insurance services would mean a big change in thinking but it should be based on very good historical data	5	• New models such as monthly fee for predictive maintenance would be possible

5.3 IIoT growth and role of data and information in the companies

This section contains the findings of the first part of the interviews where some general questions about Industrial internet and the role of data and information and its impact into their business or industry were done. Before starting the interviews the scenario was explained (as mentioned before) and since it is about predictive maintenance, the first question was related to its benefits:

Are the benefits of predictive maintenance clear for the customers?

All the respondents agreed on the fact that customers clearly see the benefits of it. COMPANY A, points out that it is mostly interesting for the bigger players rather than the small sized customers and COMPANY B sees predictive maintenance as an interesting and necessary thing to offer but express that other capabilities that II related technologies can offer such as production optimization services would be even more attractive to the customers since it would affect their earning money side.

Next questions were related to the growth of IIoT in the industry:

What do you think is the growth of IIoT in your own business or in the industry you are in?
How significant is this change in business? Why?

Despite expressing uncertainty due to the traditional nature of the industries of the interviewed companies which means that Industrial Internet is still quite far to be implemented in its highest levels such as predictive maintenance capabilities, there is an agreement on the fact that II will be widely adopted because its benefits seem to be clear. It has also been identified the lack of information that this medium-sized production line manufacturers have about what is doing the competition in this area. The general feeling is that everybody is already starting to implement some IIoT related technologies (i.e. start deploying sensor and gathering some data remotely, etc.). The change in the business is perceived in a form that different business models will come up due to the new amounts of gathered data and information but it is still quite far and it is difficult to be more specific and think about different options than new services at this stage.

After these introductory questions, as the new information available due to the Industrial Internet related technologies was indirectly been introduced, the next two questions that were asked to the respondents were more specific about the role of data and information:

How do you think has the role of data and information as a resource changed your business because of IIoT based technologies today?

At this point, this change of the role of the data and information is still not present in the interviewed companies' industries. They are all traditional industries and the old-stagers are a little bit reluctant to admit that this is going to happen. The change is still not clear, COMPANY A imagines it towards integrating the production into a manufacturing system so that it will be possible to make changes late in the process and in real time. However, the perception of COMPANY C is that data and information will bring huge changes and it will be the future even in its traditional industry.

Finally, before entering into the impact to the BMC components, it was asked for the perspective of the general impact to the industry or business of the increase in information intensity:

> *How does the increase in information intensity impact to the business in your industry/your products?*

There haven't been any changes yet. COMPANY A states that the real changes will happen in a two-years timeline when there will be enough historical data to rely on for decision-making. COMPANY B is already participating in different research activities related to the future business models but at this moment business models are still quite "traditional" and haven't been impacted yet. COMPANY C points out the importance that more and accurate available information will have in the business, mainly for decision-making.

6. DISCUSSION AND CONCLUSIONS

After presenting the cases, the gathered data and the most relevant result in the previous section, now it is time to show the relevance of these results in the context of this thesis. This chapter contains the most relevant findings coming from the literature review and the empirical part of this study as well as the discussion of its meaning related to the research questions already presented in the first chapter of the present document. After that, a global answer to the primary ontological question is presented as a summary of all the content of this study. Concluding the chapter, limitations and future research are briefly discussed.

6.1 Discussion

Moving back to the first chapter of this thesis, the research gap for this study was presented as well as the primary ontological question of the thesis and the research questions. Chapters 2 and 3 provided the literature and the theoretical part of this study and finally, chapters 4 and 5 presented the empirical part. In the following section, the research questions will be answered one by one through a discussion of both theoretical and empirical part.

Q0. What is II and differences between other concepts (II, IoT, Industry 4.0., CPS (CPPS), Smart Factories/Manufacturing, traditional automation?

This question was numbered as the zero research question since it was related to the most basic concepts concerning to the topic. Nevertheless it was of great relevance since it establishes the basis for the further development of the study. The whole thesis is about Industrial Internet and therefore it is of the utmost importance to define this concept and the related ones and in this case since there can be a lot of confusion due to the similarity of some concepts, it has been found necessary to explain the differences between them. Section 2.1 provided the Industrial Internet definition and its background and section 2.2 presented the related concepts and its differences. The term was coined by General Electrics in 2012 and it is synonymous to the Industrial Internet of Things term. IoT is the general concept used to refer to physical objects that are connected to the internet so that they can send and receive data and when it comes to an industrial application, it is called Industrial Internet. Agarwal and Brem, (2015) and Annunziata and Evans (2012) describes it as a phenomenon that involves the merging of the digital world with the world of machines. It is the convergence of the global industrial systems with the power of advanced computing, analytics, low-cost sensing, and new levels of connectivity provided by the internet. II is seen as the next industrial revolution which in Germany was coined with a different name: Industry 4.0. as in the German context it would be the fourth industrial revolution (Kagermann, 2015). Despite the terms Industrial Internet and Industry 4.0 are often used to refer to the same phenomenon, there is a slight difference in the concept and background. From generic IIoT concepts and principles, we can move forward Industry 4.0, which relates to industry in the context of manufacturing (Gilchrist, 2016) whereas II sectoral focus also includes others like energy, transportation, agriculture, etc. In addition, Industrial Internet emphasizes the vision of a future network of interconnected industrial assets and Industry 4.0 is more about the next revolution and state of the manufacturing industry. These two concepts also depend on the classification of the earlier industrial revolutions which in the American context (II) have been three and in the German context (Industry 4.0), four. Cyber-Physical Systems (CPS) are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa (Kagermann et al., 2013). CPS are a key enabling for Industrial Internet application. Smart Factories are the core of the Industry 4.0 and they are the new approach for industry where all its hosted assets will have smart capabilities, from machines to products or even the building (Gilchrist, 2016; Kagermann et al., 2013). Smart manufacturing is a completely new approach to production due to the use of II related technologies such as RFID. In the actual industry, the trend is no more about just automating and implementing technologies to the existing processes, it is about having networked systems and gather huge amounts of data for a further analysis in order to deliver new value to customers. Moreover, traditional automation is always stick to the factory level meanwhile Industrial Internet breaks through this barrier and allows to bring it to the maximum level, creating an ecosystem where it is included from machines and factory level to supply chain side, customers and suppliers.

Q1. Which are the basic technologies that are related with II?

Industrial Internet as per se is only a concept, what is behind it is the related technologies that make possible the resulting phenomena. Therefore, it is highly important to go through Industrial Internet concept and not only point out the most relevant related technologies that make it possible but also to know which functionalities, capabilities and optimization levels are allowed depending on those technologies implementation. This information is presented in section 2.3. The widest classification proposed by the author of this thesis for such technologies is divided into three categories: Physical Product/Asset (divided into Hardware and Software); Connectivity (divided into Middleware Cloud Protocol and Communication); and Product/Asset Cloud. The most relevant technologies related to II are: WSN, Actuators, RFID, Middleware, Big Data and Advanced Analytics and Cloud computing. After going through the literature, it was decided to elaborate a three dimension relation between the identified capabilities, basic functionalities and optimization levels (see Figure 10) since it was not found in the most relevant read papers. The basic functionalities related to Industrial Internet can be divided into four blocks: data collection, transferring the data, data storage and analytics. The smartness, intelligence or maturity level of a system increases as adding blocks starting from data collection which is the basis of any intelligent system. Intelligence and connectivity enable an entirely new set of product functions and capabilities which can be grouped into four areas: monitoring, control, optimization and autonomy (Porter and Heppelmann, 2014). Each capability is valuable in its own right and also sets the stage for the next level. Finally, the third dimension is the optimization levels, from the simplest to the most complex one: machine, machine fleet or factory, suppliers or consumers, network or supply chain and finally, ecosystem.

Q2. Which are the trends related to these basic technologies?

After presenting the most relevant Industrial Internet related technologies, the trends of these technologies have to be explained in order to understand the huge dimension of the IIoT phenomenon. And it is that the advances and development of already existing and new technologies have made technically and economically possible the emerging of IoT and consequently of Industrial Internet and thus these trends play a crucial role in this study. Some drivers have been for example: breakthroughs in the performance and in energy efficiency of the sensors and batteries, highly compact low-cost computer processing power and data storage (which has made possible to have embedded systems in the products), cheap wireless connectivity and connectivity ports, tools for rapid software development and big data analytics. The latest trends in sensor technology for example are the miniaturization of the hardware, the widespread of multi-sensor systems and the increasing availability of radio wireless and autonomous sensors, the increasingly energy efficiency and the low-cost electronic circuits.

Q3. What is the impact of Industrial Internet related services (achieved by II related technologies) such as predictive maintenance to the BM´s of production line manufacturers?

In this study, the impact of II related services such as predictive maintenance to the BM of mid-sized production line manufacturers conforms one of central questions. Some of the factors that make Industrial Internet interesting and feasible for SMEs are the increasingly low cost of the sensor technologies as well as the cloud storage that were previously expensive and not affordable for small companies.

From literature review, it has been widely said that II will offer huge benefits to the manufacturing industry and that new business opportunities such as predictive maintenance services and new business models such as pay-per-use or rent instead of buy models are emerging due to the Industrial Internet implementation. However, Industrial internet constitutes a relatively young research area and it has been studied mainly from a technological perspective (Arnold et al., 2016) rather than business impacts. Another point that brings up the novelty of this thesis is that the case studies presented in the literature are mainly from large companies such as GE, Rolls Royce, Tesla, etc. (Agarwal and Brem, 2015; Porter and Heppelmann, 2015).

The interest of answering this question has been justified through the existing literature review and due to the lack of case studies from the mid-sized production line manufacturers’ perspective. In order to address this question, it has been used the BMC (section 3.3) from the literature review as a framework for one of the interview’s part after documenting and going through BM literature in chapter 3. The selection of this framework was based on the widely acceptance of it by the most relevant BM literature and also because of its simplicity and friendly way to present the nine different components that conform any business model.

From the empirical part, presented in sections 4 and 5, it can be summarized that the overall impact of the IIoT application will be huge in the industry's business models. Making use of the BMC framework during the interview the respondents went through the nine business model components and in all the cases an impact was perceived which means that when putting all of them together, the whole business model will get somehow impacted. Key partners, Value proposition and Revenue Streams have been identified as the most perceived impacted blocks while Key activities, Cost structure and Customer segments are perceived to have the lowest impact.

Q4. How do the perceived risks and opportunities related to the predictive maintenance achieved by II technologies impact the business of production line manufacturers?

This question also conforms one of the central questions of this study. During the literature review, the most cited risks and opportunities were pointed out and summarized in a table format in the section 2.1. This literature was kept in mind while designing the interview part related to risks and opportunities perception. During the interviews it was given a list of risks and opportunities to the respondents and they had to rate the perceived impact and give reasoning for every case since it is a qualitative study.

From the risks side, as expected, the common and highest concern within the three companies is the *security and privacy of the data*. Despite literature and experts have stated that security issues are not as a high risk as it may seem and there exist some risk mitigation methods, it is still the highest perceived risk for these companies. The ownership of the data is another concern that came up while talking about security issues. *Customer switching costs* is the lowest perceived risk but the reasoning of each company differs. From the interview analysis it has been identified that predictive maintenance, despite being very interesting and necessary, is not enough if it is offered alone to the customers. The benefits of it might be clear but their willingness to pay for it is not that clear. The other risks perception varies and it is not common for all the three companies.

From the opportunities perception side, *effective and efficient production planning and maintenance scheduling, reduce the breakdowns* and *improvement in customer relationship* are the three highest perceived opportunities in all the three cases. *Product differentiation* is also seen more as an opportunity than a risk in all the three cases. The other opportunities perception also varies depending on the case.

The differences in the risks and opportunities perception can be attributed to the fact that their level of understanding or experience in Industrial Internet is different, they are in different end-users industries and not all of them are as far in II application which can make them be more optimistic for example when thinking about the risks and opportunities. In an overall analysis, all the three companies are clearer about the opportunities than the risks which embrace the fact that Industrial Internet is perceived as a good opportunity for the industry.

Q5. What is the role of the Data & Information in the development of BM's of production line manufacturers?

This las research question has been covered by the empirical part. One of the three blocks of the interview structure was about the data and information available due to the Industrial Internet related technologies and its impact into the industry or the business of each company. All the three companies are in traditional industries and are mid-sized production line manufacturers and commonly to all of them, the impact of the data and information to the business hasn't happened yet. However, the general perception is that the new gathered and reliable data and information allowed by the II related technologies will play an important role, mostly for decision making based in algorithms, but also for creating new services and new business models.

6.2 Conclusions

The main purpose of this study was to understand and explore the impact of Industrial Internet to the business and the business models of production line manufacturers. In order to address this objective, the major ontological question was formulated and it was split into six smaller questions (research questions) in order to serve as guidance during the whole research process (see section 1.2). In the section above, these research questions have been answered by discussing the results of this study. Finally, putting together all the research questions, it is possible to answer to the main ontological question: *How major industrial internet related technologies are affecting the business and the business models of production line manufacturers?*

This thesis started with the literature review with the purpose of getting to know the most relevant existing literature related to the topics of the research: Industrial Internet and its related concepts such as IoT, Industry 4.0, CPS, Smart manufacturing, etc.; Major basic technologies related to Industrial Internet and its capabilities, functionalities and optimization levels; and the Business Model related literature. It was found plenty of literature about Industrial Internet conceptualization, background and related technologies. From the literature review, it has been widely said that II will offer huge benefits to the manufacturing industry and that new business opportunities such as predictive maintenance services and new business models such as pay-per-use or rent instead of buy models are emerging due to the Industrial Internet implementation. However, Industrial internet constitutes a relatively young research area and it has been studied mainly from a technological perspective rather than business impacts and the case studies presented are mainly from large companies such as GE, Rolls Royce, Tesla, etc. These facts motivated the present research in order to cover the gap by studying mid-sized companies from traditional manufacturing industries such as production line manufacturers in relation to the perception of the Industrial Internet related opportunities and risks and impacts to their business models.

The empirical part of the study was based on three interviews to three mid-sized Finnish production line manufacturers. The interviews were designed to cover the most important research questions: Q3, Q4 and Q5 so that combining the collected data with the literature review, it has been possible to answer them as it is explained in the results and findings section and the discussion section. The impact to the business model components because of the increase in information intensity is perceived as big one. Being *key partners*, *value proposition* and *revenue streams* the most impacted blocks and *key activities* and *cost structure* the less ones. In general terms, all the respondents perceived an impact in every business model component which brings the conclusion that Industrial Internet might have a high impact in the business models of production line manufacturers. Opportunities and risks perception was more heterogeneous but *security and privacy of the data* was the most and common perceived risk while *effective and efficient production planning and maintenance scheduling, reduce the breakdowns* and *improvement in customer relationship* are the three highest perceived opportunities in all the three cases. The differences in the risks and opportunities perception can be attributed to the fact that their level of understanding or experience in Industrial Internet is different, they are in different end-users industries and not all of them are as far in II application which can make them be more optimistic for example when thinking about the risks and opportunities. In an overall analysis, all the three companies are clearer about the opportunities than the risks which embrace the fact that Industrial Internet is perceived as a good opportunity for the industry. Finally, it has been demonstrated that the role of data and information in the development of BM of traditional industries such as production line manufactures hasn't happened yet. However, the general perception is that the new gathered and reliable data and information allowed by the II related technologies will play an important role, mostly for decision making based in algorithms, but also for creating new services and new business models.

Even though this thesis is limited to three cases studies, it can be said that this study has been successful in answering to the primary ontological question. However, the results cannot be generalized to apply to the whole mid-sized manufacturing companies.

6.2.1 Limitations and future research

After discussing the results and concluding the research, some limitations of this study and possible future research lines are discussed in this section. Limitations are common to be in all the research works and so do have this study.

In the first place, the six month timeline has been limitation has been present during all the research because of the wide scope of the thesis. Many different concepts have been covered by the literature review but some viewpoints might not have been covered in depth. However, covering all the possible aspects related to the impact of Industrial Internet in one study is not possible and this thesis has focused on providing an answer to the primary ontological question making use of the research questions.

Restricting the empirical part of this study to three cases companies is another limitation. This fact inhibits to generalize the findings and apply the conclusions to the whole mid-sized manufacturing companies and also make some statistical statements about the most impacted business model blocks for example. The access to the companies and the timeline for this study has contributed to this three case selection. However, the selection of the companies has followed an strategic criteria as explained in the subsection 4.2.1 in order to obtain valuable findings and provide an introduction to the emerging phenomenon of Industrial Internet.

Finally, the novelty itself of the topic has been a limitation either during the literature review that in some cases was limited and didn't covered some concepts in depth such as the literature related to the Industrial Internet impact to the SMEs and the empirical part. Designing an appropriate interview has been the most challenging part of the thesis because of the fact that not all the companies were as far in Industrial Internet understanding and this topic is too wide to obtain interesting results from generic questions. Therefore, a scenario was designed and provided to the companies in order to fix the starting point and to be able to compare the results.

This thesis leaves a lot of space for further studies. As mentioned in the conclusions, companies are not aware of what is the competition doing in relation to Industrial Internet implementation and it is of a high interest for all of them. In future researches and studies, the competition should be studied in detail making use of theoretical frameworks such as Porter 5 forces. Due to the level off maturity in Industrial Internet of the mid-sized companies, this aspect was not possible to cover at this stage, but in further studies it will be necessary to make research in this direction. Another further direction is to carry out more case studies about SMEs manufacturing companies in order to be able to generalize the findings.

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APPENDIX A: INTERVIEW GUIDE

INTERVIEW PURPOSE:

Analyse the threats and opportunities that arise because of increasing role of information due to Industrial Internet of Things (IIoT) based technologies and the impacts of IIoT based technologies to Business Models for Machine Builders in Finland.

SCENARIO:

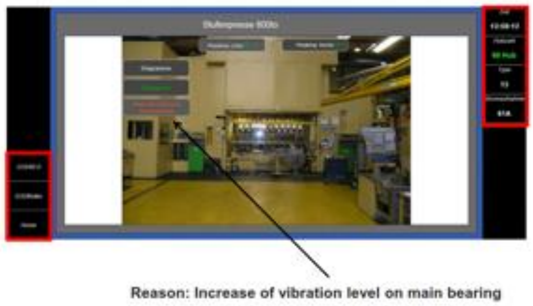
We presume that IIoT would be something in line with what we explain in this scenario below. And we expect that you answer the questions of the interview keeping it in mind.

Imagine if:

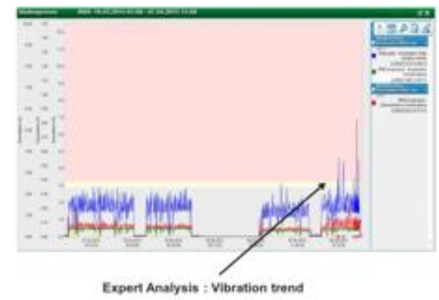
- There were no interruptions in your product (Production lines for example) because of failures
- You were able to predict 3-4 weeks prior to the actual failure
    - When the failure happens (Time)
    - Where it happens (exact location of the failure in the production line)
    - Which spare parts and tools are needed to fix the failure
    - Who might fix it (Which skilled maintenance personnel is needed)
- Because of the above implementation, the following changes would occur in your Business, Process, etc.:
    - Change in Inventory Management
    - Maintenance Personnel Management
    - Customer Value - Reduction of Downtime

SCENARIO ILLUSTRATION

Problem identified, visual display of the area



Detailed description of the problem displayed in the machine screen: high vibration of the main bearing



Change in the vibration trend of the machine, possible failure soon (prediction based on historical data)

Problem response, automatic purchase

Generic questions (Intro plus Generic Questions = 15-20 mins)

1. Which particular product or production line would be the first to adopt IIoT fully and take its capabilities towards predictive maintenance for example so that your customer sees the value already with that particular product?

1.1. Are the benefits from this clear for the customers?

2. What do you think is the growth of IIoT in your own business or in the industry you are in?

2.1. How significant is this change in business? Why?

3. How do you think has the role of data and information as a resource changed your business because of IIoT based technologies today?

3.1. Do you think that the role of information has increased in comparison with the traditional resources such as machinery, people, etc.?

Risks and Opportunities/Benefits related Questions (15 mins)

4. How important are the following risks and opportunities due to increase in data and information because of IIoT technologies (Scale 1-5)? Why?

<u>Overall risks/threats for your business</u>

- Product Differentiation

1	2	3	4	5

- Customer Switching Cost

1	2	3	4	5

- Because of the availability of information from IIoT, will you have new competitors for example, analytics companies, service companies, etc.?

1	2	3	4	5

- New capabilities (e.g. in-depth data analytics), will be required to acquire or develop within the company.

1	2	3	4	5

- Security and privacy of the data (What if the machine is hacked, can someone stop the production process, can someone introduce defects on the products, etc.?, What if the data is stolen?) From your perspective? And from your customer's experience?

1	2	3	4	5

- Difficult to demonstrate Benefits of IIoT investments to Customer

1	2	3	4	5

- New unexplored Business models

1	2	3	4	5

- Other Risks –

1	2	3	4	5

<u>Overall opportunities and benefits for your business</u>

- Product Differentiation

1	2	3	4	5

- Customer Switching Cost

1	2	3	4	5

- Effective and efficient production planning and maintenance scheduling

1	2	3	4	5

- Reduce breakdowns (improve global production efficiency) improvement of the product

1	2	3	4	5

- Start selling product + service (selling uptime) Product-Service System

1	2	3	4	5

- Cost savings because of the acquired data (Raw Material Costs, Personnel Costs etc)

1	2	3	4	5

- New options for a business model (e.g. selling some data to data aggregators companies or offer new models such as rent instead of buy or pay per use)

1	2	3	4	5

- Improvement in customer relationship

1	2	3	4	5

- Other Opportunities/Benefits –

1	2	3	4	5

Business Model Canvas Related Questions (15 mins)

5. How does the increase in *information intensity*[*] impact to the business in your industry/your products?

6. Taking as a reference the Canvas Business Model (see template attached below): How business model components are impacted because of the increase in *information intensity*[*] because of IIoT technologies (Scale 1-5)? Why?

[*]The increase in information intensity is referred to the increase of the valuable information

Key Partners

Who are your Key partners?
Who are your Key suppliers?
Which key resources are you acquiring from partners?
Which key activities do partners perform?

Key Activities

The most important activities in executing a company's value proposition

Key Resources

The resources that are necessary to create value for the customer.

- Physical
- Human
- Intellectual (brand patents, copyrights, data, etc.)
- Financial

Value Propositions

Collection of products and services a business offers to meet the needs of its customers and distinguishes itself from its competitors.

Customer Relationships

E.g.

- Personal assistance
- Self-service
- Automated services
- Co-creation (customer feedback)
- Communities (platform produces a scenario where knowledge can be shared and problems are solved between different clients)

Channels

Channels used to reach the costumers either for the clients awareness of the products, purchase, product evaluation (clients opinion), delivery and after sales service

Customer Segments

Which customers the company tries to serve.
How customer groups can be identified and segmented in the future because of the opportunities that the increase in information provide?

Cost Structure

Characteristics:

- Fixed costs
- Variable costs
- Economies of scale (↑ output → production cost ↓)
- Economies of scope (↑ variety of products → production cost ↓)

Revenue Streams

The way a company makes income from each customer segment.
Pricing model (e.g. adopting business models such as subscription fee, pay per use or rent instead of buy would change the revenue streams)