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Business Model Innovation in the context of Industry 4.0

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Table of Contents

Index of Figures

Index of Tables

Abstract

The fourth industrial revolution is called Industry 4.0, and it is making it possible to connect information, objects and people due to the intersection of the physical and the virtual worlds in the shape of Cyber-Physical Systems and Internet of things. A phenomenon which has been proven to provide great benefits, however it remains to be specifically figured out how digitalization and business model innovation correlate.

This industrial revolution is breaking down the traditional barriers of businesses, and many academics are emphasizing the need to rethink the existing business models. However, the recent researches are mainly focused on the technological development and less on the business models that are affected through the integration of those technological revolution. The new industrial paradigm is transforming the current ways of value creation, value proposition, and value capturing. It has brought extensive challenges and opportunities not only in a production-technical matter, but also in organizational consequences.

Overarching research purpose of this study is to explore the characteristics of business models in the context of Industry 4.0 and digitalization. It is a question that is highly relevant for firms seeking to adopt Industry 4.0 related technologies. That will help them in identifying the required resources, activities as well as capabilities in order to embrace Industry 4.0. The key-drivers, opportunities, and barriers that Industry 4.0 cause regarding business model innovation, are to be determined.

The literature on business model innovations for Industry 4.0 is characterized by overlaps with literature on technological enablers like Internet of things, Cyber-Physical systems and Big Data. Hence, previous research studies and literature are reviewed and evaluated in order to gain a broad understanding of the topic and to create a framework that enables firms to gain insights into the impacts of Industry 4.0 on their business models. The expected business model characteristics for Industry 4.0 are gathered and structured according to the Business model Canvas (BMC) by Alexander Osterwalder. Then empirical data and use cases regarding Industry 4.0 are gathered and used in order to evaluate the theoretical framework.

Keywords: Business Model, Business Model Innovation, Industry 4.0, Digitalization.

Chapter 1 Introduction

1.1 Problem Background

Over the past two decades, the world has witnessed various industrial revolutions and currently facing the fourth industrial revolution. The first industrial revolution, which is referred to as Industry 1.0 happened approximately in the 1780s and it was mainly about the use of steam engines for production purposes. The second industrial revolution, Industry 2.0, happened around 100 years later and was related to the emergence of new technologies as gas, petrol and electricity. It allowed companies to develop continuous production lines as well as mass production. The third industrial revolution, Industry 3.0, emerged approximately at the middle of the 20th century, with the introduction of automation systems and digital programming. The fourth industrial revolution, known as Industry 4.0. was born in Germany when it was first emerged as a concept due to a project which aimed to bring automation and digitization into manufacturing. And then was introduced in 2011 at the Hannover fair (Drath & Horch, 2014).

Industry 4.0 is characterized by being able to connect information, objects and people due to the intersection of the physical and the virtual worlds. The main drivers, which will be further explained in chapter 2 are among others, Cyber Physical Systems (CPS), the Internet of Things (IoT), cloud computing and big data analytics.

Industry 4.0 has brought many technological possibilities. These possibilities enable firms to create and capture values in different ways as it is transforming the traditional ways of value creation, value proposition and value capturing. This revolution has not only brought technical development but also extensive organizational consequences and opportunities providing more cooperative environments, improved customer relationships, new product and services offerings. Consequently, new and adapted business models are needed.

Business model as a concept has gained a lot of attention over the last decade (Wirtz , Pistoia , Ullrich , & Göttel , 2016). Practitioners use it for the purpose of designing competitive business processes and strategic positioning. Academics perceive it as a concept to study firms’ performance, value streams and business innovation (Teece, 2010).

Some researches define business model as tool to describe how businesses operate. Others define it as a concept that consists of different components. Furthermore, it is necessary to point out the definition of a business model should be a result of its components being interacting rather than being individually acting since business model elements have to be studied for the purpose of completely defining the concept. (Wirtz , Pistoia , Ullrich , & Göttel , 2016) (Foss N. J., 2017)

According to a survey carried out by the associations (BITKOM, VDMA and ZVEI, 2013) on Industry 4.0. They were able to get 278 companies to participate in the survey, mainly from the manufacturing industry. 47% of the participants declared that they were already somehow engaged with Industry 4.0 and 18% of them said that they were still involved in research regarding Industry 4.0 however 12% said that they started already to put it into practice. Companies were asked about the main challenges related to Industry 4.0, and as a result, new business models came fourth in the list of greatest challenges as shown in figure 1. That clearly highlights the relevance of the research topic for firms seeking to implement Industry 4.0.

Figure 1: Results of survey on I4.0 trends (BITKOM, VDMA and ZVEI, 2013)

The business model as a tool has been evolving over years since many frameworks and ontologies exist. However, there is no agreement on its scope and nature. Business models for Industry 4.0 is a concern that has not been the main focus of many studies. Moreover, analytical frameworks or tools for the assessment of business models in the context of Industry 4.0 in have not yet been well identified and agreed upon. This research addresses the matter of integrate business model innovation and Industry 4.0 concepts.

Many challenges should be considered with regard to business model innovation, for instance, organizational inertia and rigidity (Chesbrough, 2010). The impact on value propositions, value creation and value capturing can be greatly disruptive. Managers lack comprehensive understanding about the potential changes, risks and new solutions (Rudtsch, Gausemeier, Gesing, & Peter, 2014). Therefore, the assessment of the actual changes in actual business models and considering possible future consequences in terms of operational and financial benefits may help to present an overview on the adoption of Industry 4.0

1.2 Knowledge Gap

When performing the literature review. A gap in existing research on Industry 4.0 was noticed as business models are barely mentioned. Even though many academics and practitioners are focusing on the need to rethink the existing business models, the literature on business model innovations for Industry 4.0 is inadequate and seems to be characterized by overlaps with literature on Internet of things, Additive Manufacturing, Big Data and other technologies related to Industry 4.0.

Furthermore, the literature regarding the concept of business model innovation usually link it to one specific technique such as Big data, Internet of Things, or cyber physical systems. there is a gap in the literature that cover the impact of Industry 4.0 on business models.

Research about the impact of implementing Industry 4.0 on business models is scarce. And Industry 4.0 is still yet not clearly defined in literature. Moreover, another challenge is that the business models usually expand from business unit level to inter-organizational and even ecosystem-level, which can bring even more complexities.

1.3 Research Questions

Overarching research purpose of this study is to explore the characteristics of business models in the context of Industry 4.0 and digitalization. In order to assist firms in identifying the necessary resources and capabilities for the same agenda. It is applicable to firms seeking to adopt Industry 4.0 whether they are willing to offer it to external parties, or simply perform it internally.

The major research question is: "How can the adoption of Industry 4.0 components affect business model characteristics?".

In order to give justified answer to the main question. Few sub-questions were answered in the process:

1. Which frameworks, methods and concepts should be taken into consideration in determining the impacts of Industry 4.0 on business models?
2. What are the key-drivers, opportunities, and barriers to business model innovation in the context of Industry 4.0?
3. What are the appropriate business model characteristics for Industry 4.0 ?

1.4 Research Design

This thesis has an exploratory nature. The literature related to business model, business model innovation and Industry 4.0 components especially Internet of things, Cyber-Physical systems and Big Data is reviewed and evaluated to show the current state of art. the key-drivers, opportunities, and barriers that Industry 4.0 cause regarding business model innovation are to be determined and then this would lead to the development of the framework.

The theoretical framework is then created to enable firms to gain insights into the potential impacts of Industry 4.0 on business models. The expected business model characteristics for Industry 4.0 are gathered and structured according to the Business Model Canvas (BMC) by (Osterwalder & Pigneur). The framework BMC 4.0 is a compact template that can be used as a metamodel to represent the impact of Industry 4.0 across different industries and firms.

The framework is a description of the characteristics that should be integrated by the new or adapted business model to embrace Industry 4.0. In order to check the functionality of this framework. It is important to explore real world cases using desk research to get empirical data about firms that are already implementing Industry 4.0. For this purpose, we have decided to include Bosch group as a reference case study to check the consistency between the BMC 4.0 as a theory and the real world.

Bosch is a leading company with regard to Industry 4.0, hence it makes sense to explore multiple use cases and projects that are currently happening in Bosch on their way to adopt Industry 4.0. Press releases, interviews, conference reports, annual reports, articles, online reports and many other sources were used in order to build this case study.

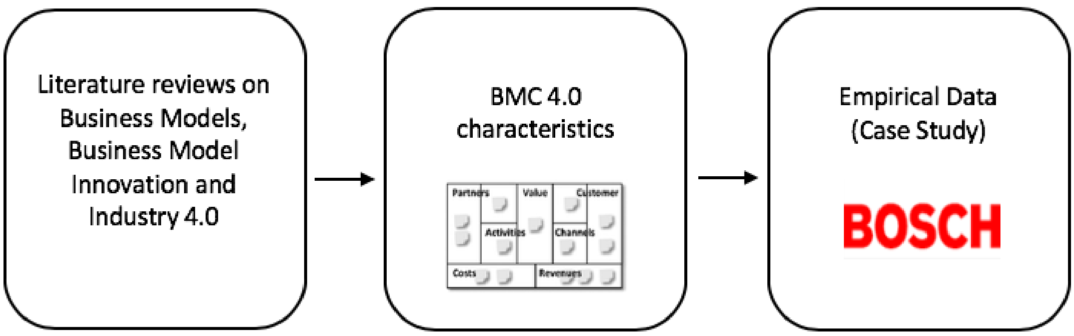

Figure 2: Research design

Chapter 2 State of the Art

The theoretical framework is created based on available literature sources. The different theoretical concepts and domains that form the basis of it are described in this section. Firstly, an introduction to the business model is provided besides an overview of available different definitions. After that, common business model ontologies and their usage in relevant research fields are described. Then, an overview of business model innovation, its triggers and the nature of change. Finally, the technological essence of Industry 4.0 and its basic components and concepts. In this section, the following sub-questions are answered*:*

> Which frameworks, methods and concepts should be taken into consideration in determining the impacts of Industry 4.0 on business model characteristics?
>
> What are the key-drivers, opportunities, and barriers to business model innovation in the context of Industry 4.0?

2.1 Business Model

2.1.1 Business Model definitions

One of the earliest definitions of business models was presented by (Timmm, 1998), who stresses the architectural elements: "a business model is an architecture for the product, service and information flows, including a description of the various business actors and their roles, a description of potential benefits for the various business actors, and a description of the sources of revenues". Based on this definition, a number of other definitions were then presented from different disciplines.

The concept business model is almost new. However, it first emerged in an academic article in 1957 (Bellman, Clark, G. Malcolm, Craft, & M. Ricciardi, 1957). Then it became popular at the end of the 1990s because of the expansion of the internet and e-commerce, and it has increasingly shaped a separate field of study with a huge amount of studies and articles published.

Academic literature state that a business model in general should be able to describe how a firm creates value (Zott & Amit, 2010). Many definitions of BM have been developed, for instance, (Weill & Vitale, 2001) define a BM as a tool to represent the relationships through a firm's network and distinguish the main flows of objects as well as the major gains to participants. This definition goes well with the e-business context.

Research in business models evolve over time. However, researchers should continue each other's work and findings extensively, they work separately. According to on an extensive literature reviews (Osterwalder, Pigneur, & Tucci, 2005) conducted. They presented five phases regarding the evolution of business model literature as shown in figure 3.

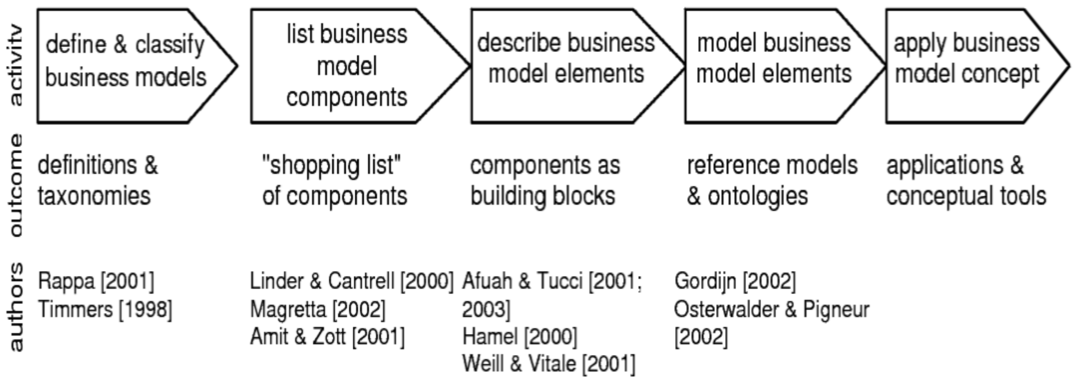

Figure 3: Evolution of the business model concept (Osterwalder, Pigneur, & Tucci, 2005)

(Afuah & Tucci, 2001) present business models as a combination of components such as value, financial aspects, implementation, resources and relationships, while (Mahadevan, 2000) emphasizes value creation, revenues and logistics. (Osterwalder, Pigneur, & Tucci, 2005) are more systematic in their approach to the concept of business models which focuses on the firm offerings their target , the key activities and how much is the revenue, they discuss four basic elements ,which are offerings, infrastructure management, customer interface and financial aspects.

Furthermore, another approach that is considerably used in literature is to categorise business model elements into value proposition, value creation and value capturing which in return would minimize the complexity and provide a perspective for business models (Johnson, Christensen, & Kagermann, 2008):

o **Value Proposition** which describes added value for particular customer segments from products and services offered by a firm.
o **Value Creation** which describes resources, capabilities and processes required to deliver the value including partner, supplier relationships and sales channels.
o **Value Capturing** which describes the cost structure and revenue formula in order to evaluate profitability and sustainability.

The theoretical foundation for the term business models comes from different backgrounds, among strategy management, the resource-based view, transaction cost and open innovation. Some researchers focus mainly on the sorting of BMs into specific sectors, while others focus on the strategic level considering value chains, also the use of BMS in the era of open innovation which causes different definitions of the business model according to the research fields and their different goals.

It would be inappropriate to fix one globally valid BM definition that can used for all cases, since one definition would lack specialty and lead to misunderstandings (Zott & Amit, 2013), it is important to state that to proceed further with this research, one definition for BM has to be set. Therefore, we decided to apply BM ontology (BMO) (Osterwalder, Pigneur, & Tucci, 2005).

(Osterwalder, Pigneur, & Tucci, 2005) lead a systematic review for BM literature and then came up the most common Business Model components in academic literature. They synthesized the models and the most often mentioned and tested academic literature. As a result, they developed a Business Model definition based on the concepts that has been presented to scientific Business Model literature. Moreover, their concept is comprehensive and includes a relatively high range of components (Wirtz B. P., 2016) which is critical for analyzing Business Models in a wide concept as possible. In addition, the BMO has been proposed in the context of information systems, which is critical for the Industrial internet of things (IIoT). For these reasons, it would be very appropriate to use their concept in this study.

According to (Osterwalder, Pigneur, & Tucci, 2005) a Business Model is a "conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams". Figure 4 illustrates the relationship between the nine elements constituting the BMO.

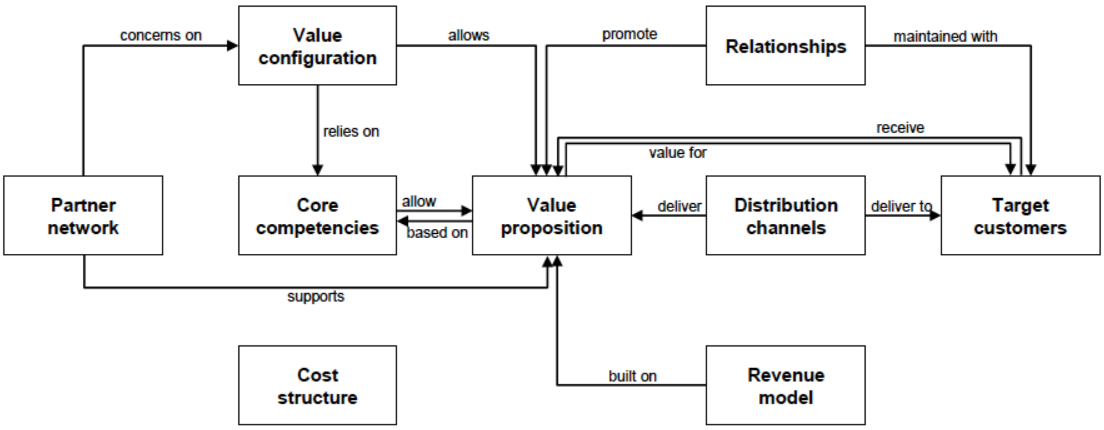

Figure 4: Relationship of BM components (Osterwalder, Pigneur, & Tucci, 2005)

2.1.2 Representing approaches for Business Models

Due to the conflict between how strategic management and Information systems literature propose business models, since the focus in strategic management is on how strategies are executed, however in information systems, the focus is mainly on the design process and its related approaches (Bouwman, et al., 2012). Therefore, it is necessary to identify and discuss different design approaches that are used regarding the information systems business models which are suitable in the context of Industry 4.0.

There exist many different representation approaches for business models design and structuring. Hence, we highlight the most common approaches with the purpose of deciding the most appropriate representation to be used regarding this study.

2.1.2.1 Business Model Canvas

Business model canvas (Osterwalder & Pigneur, 2010) is a very popular tool for business model structuring which considers different design variables and domains. It first came out when the author conducted a research on the inherent of business models (Osterwalder, Pigneur, & Tucci, 2005), then it became very common and widely used. The business model Canvas includes nine different elements as shown in the figure 5:

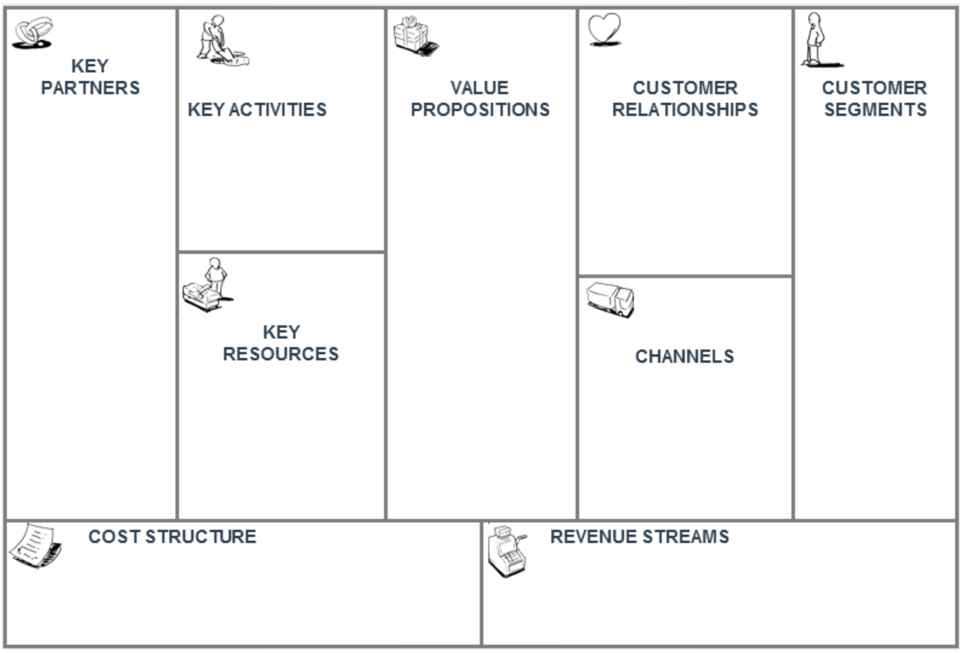

Figure 5: Business Model Canvas (Osterwalder & Pigneur, 2010)

BMC elements can be jointed together in four main sections:

- **Offerings** which includes the Value Propositions.
- **Customer Interface** which includes Customer Segments, Customer Relationships and Channels.
- **Infrastructure Management** which includes the Key Partners, Key Activities and Key Resources.
- **Finance Aspects** which includes the Cost Structure and Revenue Streams.

The main advantages of the BMC are that it provides a visual interface of the its components which make it easier to identify and discuss different types of business models in a firm. Also, it is simple, popular and used among different industries (Bouwman, et al., 2012) A drawback of the BMC, is requires interpretation and many iterations in order to reach consistency as there is no right order with which the canvas should be outlined, and it requires many jumps between sections while dealing with it.

2.1.2.2 Gordijn's E3-value methodology.

E3- Value Method is a tool which is used to represent the creation of financial and economic value of BMs and how this value can be exchanged and consumed in a network of many actors while providing the ability to offer complex products or services (Gordijn & Akkermans, 2001). It extends the viewpoint to the entire value chain and simulate the value flow within it. It is easy to use since it uses a popular and widely used programming language which is Unified Modelling Language (UML). E3-Value allows the creation of value through the exploitation of complementary assets besides the traditional way of creating value by bringing it to the input and trading in the output.

The E3- Value Method provides a better perspective than the traditional methods when it comes to the basics of an e- business models, operations and requirements, and is does so through quantitative scenario analysis which can be illustrated in a detailed pattern (Bouwman, et al., 2012). This ontology has a graphical representation that includes components and the value flows on which can be joined with added basic information by the user which can lead to initial business plans and financial spreadsheets.

This example from (Gordijn, Petit, & Wieringa, 2006) as shown in figure 6 explains this ontology in detail as following: "There are many readers that buy a newspaper (e.g. using a subscription) from a title they select. In this constellation, all the titles obtain services (e.g. printing services) from a publisher and pay a fee in return. The titles obtain also fees from advertisers, who pay for publication of their ads in the physical newspaper of a title. As the dependencies show, the amount of money to be paid by the advertiser to the title, relates to number of readers - as for each reader, money has to be paid for an ad. If we attribute the e 3 -value model with numbers, we can assess economic sustainability for each actor involved. Suppose now that we find that according to the best of our estimations, the profitability of the titles and the publisher decreases (in the long run)."

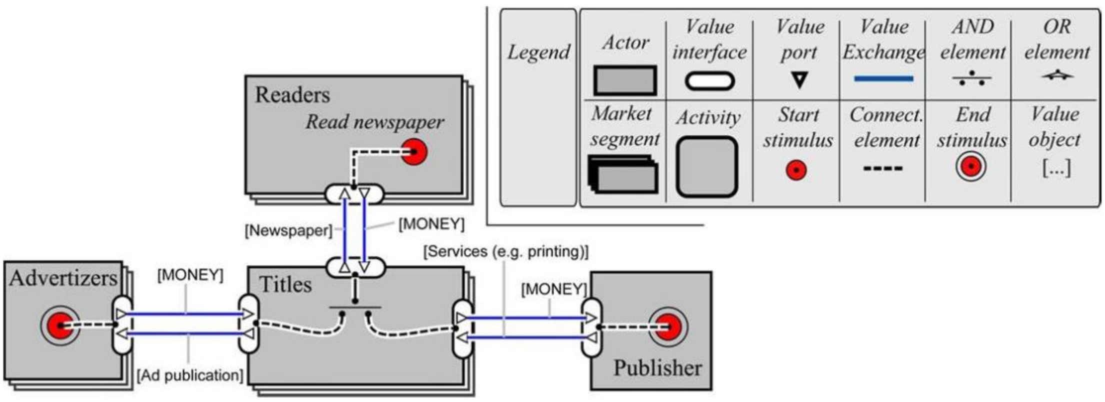

Figure 6: The E3-Value model (Gordijn, Petit, & Wieringa, 2006)

2.1.2.3 The STOF method

This method first came out as a designing tool for mobile service business models (Bouwman, 2008). It is consisted of four main domains: service, technology, organization and finance. It describes each domain specifically, while focusing on the interdependencies between them and the important design factors as shown in figure 7.

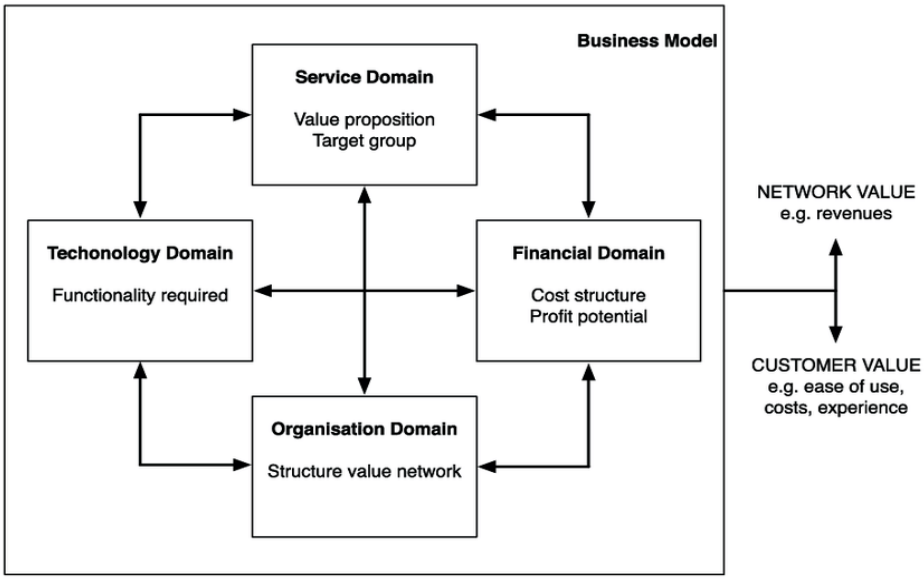

Figure 7: The STOF model (Bouwman, 2008)

Despite the fact that the research focus was mainly on mobile services as mentioned in the book Mobile Service Innovation and Business Models (Bouwman, 2008), the author believes that the STOF can be used in an extended way to include different fields. The STOF is a flexible method as the options for each design variable are open instead of restricted to a set of fixed options (Bouwman, et al., 2012).

2.1.2.4 The CSOFT model

The CSOFT model is a business model approach that focuses on the customer relationships. It is suitable to design joint business model as it represents the business model as a combination of different interrelated components with the nature of the customer relationship as a core element in contrast to other business models (Heikkilä, Heikkilä, & Tinnila, 2008).

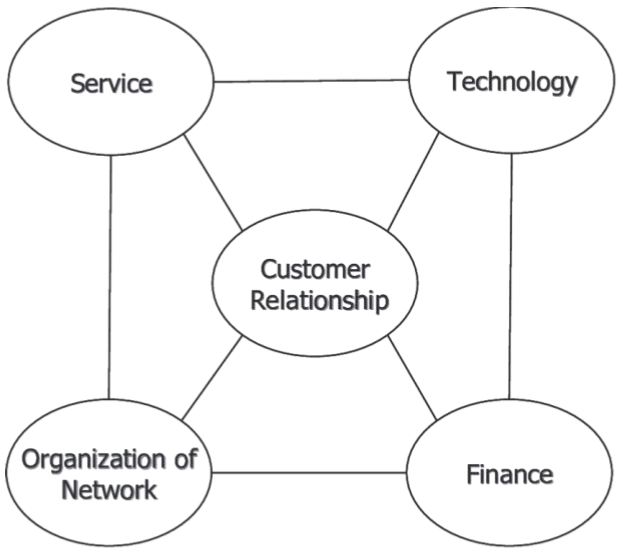

Figure 8: The CSOFT model (Heikkilä, Heikkilä, & Tinnila, 2008)

The components of the CSOFT model as shown in figure 8 are: Service, Organization of network, Finance, Technology and Customer Relationship. The CSOFT model is especially useful for networks that offer complex services since the main focus is on the customer relationship, it is also suitable for creating and evaluating the business models for start-ups. Moreover, it is possible to use it each time where there are new offerings by network for the customer (Heikkilä, Heikkilä, & Tinnila, 2008).

2.1.2.5 Magic triangle

Magic triangle is a method that was developed to represent existing business models and compare them to the new ones. It is used in the domain of internet of things which makes it related to Industry 4.0 (Gassmann, Frankenberger, & Csik, 2013). It illustrates the value proposition, value chain and revenue model while defining the target customer.

The Magic triangle helps identifying the promising opportunities and answering many questions in doing so, so it is mainly used to generate business models based on opportunities (Bilgeri, Brandt, Lang, & Weinberger, 2015).

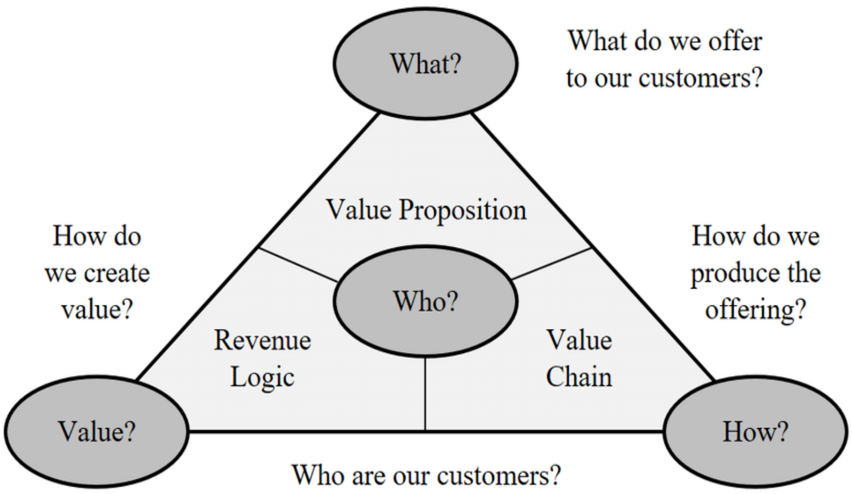

Figure 9: St.Galler Magic triangle (Gassmann, Frankenberger, & Csik, 2013)

It is mainly about answering questions as shown in figure 9. “What?” refers to the offerings done by the firm to its customers. “Value?” refers to the way the proposed value was created. “Who?” refers to the customer segments that the firm targets. “How?” refers to the production of the offerings. It also focuses on illustrating the Value Proposition, Value Chain and Revenue Logic.

After reviewing these different methods and ontologies, it is important to decide which approach to follow while going further in our research, and we have decided to apply Business Model Canvas by Osterwalder, for these reasons:

- It focuses on the value proposition as the center of the model, which is really important for the new technology brought by Industry 4.0.
- It is simple, clear and can be used by different types of businesses and organizations.
- It is the most frequently mentioned in literature reviews and the most widely applied and tested in business. (Gassmann, Frankenberger, & Csik, 2013)
- It was originally developed with respect to information systems (Osterwalder & Pigneur, 2010) which is the base for Industry 4.0.

2.2 Business Model Innovation

2.2.1 The Concept of Business Model Innovation

Business Model Innovation as a phenomenon was early descried by (Malhotra, 2000) as a paradigm shift, which demands a fundamental reassessment of the company itself instead of just modifying its processes and workflow. (Mitchell & Coles, 2003) thought about BMI as it happens when a company replaces its existing business model by a new one or even reinvent it by presenting new value propositions (Johnson, Christensen, & Kagermann, 2008) Moreover, (Casadesus-Masanell & Zhu , 2013) defined BMI as providing the ground for a competitive advantage which can maintain sustainability. Business model innovation means finding a new opportunity that can renew the existing system (Osterwalder & Pigneur, 2010).

Business model innovation can be described following (Wirtz, Göttel, & Daiser, 2016) as a design process for creating a novel business model, which goes together with an adjustment of the value proposition and results in attaining a sustainable competitive advantage. It is important to point out that firms don’t have to be inventors in order to innovate new ideas (Arthur, 2007), since business model innovation is more of an activity to improve the existing business model (Garud, Tuertscher, & Van de Ven, 2013).

From a business perspective, innovation can involve three types, which are: Product innovation, Process innovation, and Business model innovation. Business model innovation is challenging as it requires major changes and requirements. For instance, the capabilities or processes that make a company successful and profitable will need to be reconsidered. In some cases, these changes can threaten the company identity, structure and may cause conflicts with what a firm promised to deliver.

Start-ups have a superior advantage when it comes to BMI, since they are still in the phase of creating their business model, which would enhance their ability to try and change it; however, there are multiple large and stable organizations that have managed to add different resources or customer base and question their existing business model (Baer, 2017). Furthermore, literature research in this regard has implied that it is important to realize the difference between business model innovation and business model adaptation, in other words, as proactive and reactive business models.

The concept business model innovation includes two types: business model reconfiguration, and business model design. The reconfiguration refers to the adjustment of an actual business model, while the design means to create a new business model for new organizations (García-Gutiérrez & Martínez-Borreguero's, 2016).

2.2.2 Triggers of Business Model Innovation.

There is a resistance to change since it can be really costly when firms try to attempt innovation, and without any guarantees of success. The innovation concept doesn't involve high level of predictability, but in contrast ,it brings creativity (Beer & Nohria, 2000).

When companies perceive an idea or an event as a threat, there is a high chance to trigger adaptation. New technologies create opportunities for a different competition which can affect the market position of established firms or even challenge their technological capabilities (DaSilva , Trkman , Desouza , & Lindič , 2013). Moreover (Foss & Saebi, 2017) indicated that strategic orientation can have a significant impact on firms' likeliness to adaption.

It is important to identity clearly what is needed to be considered or to be achieved when thinking to change the current business model, for the sake of using this knowledge to guide the innovation process and to provide insights about the challenges that can be faced through the process. In general, there are several targets that a model can be changed for, such as fulfilling the needs no other firm does, introducing new technology to the market, presenting a better value proposition to the market, and creating a whole new business (Foss N. J., 2017).

2.2.3 The Nature of Business Model change.

Research in the area of innovation tends to define the phenomenon of innovation as disruptive or and to a radical degree. However, other researchers state that business model innovation can happen at different stages, which implies radical or incremental changes (Bucherer, Eisert , & Gassmann, 2012).

(Bucherer, Eisert , & Gassmann, 2012) defines radical business model innovation as an innovation that creates discontinuance of an Industry or a market or both. In contrast, incremental business innovation is a gradual incorporation of new means, such as technical capabilities or services, that does not result in discontinuance of an Industry or a market. This description of radical innovation has a lot of similarities with the description of disruptive innovation. Where disruptive innovation is the industrial replacement of a technology that has higher potential than its predecessor (Chang & Baek, 2010). This means that disruptive innovation is a crossroad of an industrial standard technology (Chang & Baek, 2010) versus radical innovation, which is the scale the innovation has been implemented or the impact the innovation has had on the individual firm (Foss & Saebi, 2017).

(Saebi, 2015) states that the nature of business model change happens through three distinct paths as following:

- First, business model adaptation as a process of alteration in the current business model in order to align it with its environment.
- Secondly business model evolution, as an incremental adjustment of the current model, effectively improving value creating, delivering or capturing activities.
- Thirdly, business model innovation tends to actively strive to disrupt the state of the current environment.

(Foss N. J., 2017) distinguish four types of business model innovation as shown in table 1. These types are defined by two different dimensions. Novelty, when the innovation of a business model is new to a whole Industry or new to a firm alone, and scope, when the business model innovation occurs on modular level or affects the architecture of a model.

The scope depends on the complexity of a business model structure, a firm that has a complex and intertwined model tends to affect the whole business model during the process of innovation. On the other hand, business models with less interlinked activities occur on a modular level, with smaller effects on other activities in the model. (Bucherer, Eisert , & Gassmann, 2012) stated that an architectural Business model innovation tends to be more radical and modular business model innovation suggestively occurs on an incremental level.

Table 1: Business model innovation typology (Foss N. J., 2017)

	Scope		
		Modular	Architectural
Novelty	New to firm	Evolutionary BMI	Adaptive BMI
	New to industry	Focused BMI	Complex BMI

2.2.4 Business Model Innovation Barriers.

(Vorbach, Wipfler, & Schimpf, 2017) expressed that there are some challenges that firms need to overcome before managing the reconfiguration of a business. One of these challenges is overcoming internal inertia. There is a significant amount of studies that provide different insights on why some firms struggle to implement change due to conflict interests between agents and principals, (Doz & Kosonen , 2010) path dependency, cultural barriers (Cavalcante, 2014), the static nature of business model (Christensen, 2016) or the commitment to a strategic path (Foss & Saebi, 2017).

Other researches focus on the aspects such as the size, complexity, and embeddedness of firms and how these aspects can affect their capabilities and willingness to change the activities currently occupied in the business (Bohnsack, Pinkse, & Kolk, 2013), (Freeman & Engel, 2007). Moreover, one of the main challenges of business model innovation is managing uncertainties, such as finding the best design and making sure that the chosen business model is the most suitable one. For doing so, it important for firms to test the new business model before a full-scale launch. Even though the model is right, getting the market to adopt it is not a certain thing (Freeman & Engel, 2007).

2.3 Industry 4.0

2.3.1 The four stages of the industrial revolution

- **The first industrial revolution**: it happened between the end of the 18th century to the beginning of the 19th century. It was mainly about mechanization as the new foundation of the economic structure of society instead of agriculture as it used to be. The introduction of steam engine and coal extraction formed a new energy type that helped in developing railroads and other invention as forging and metal shaping. This revolution caused economic and society development (Sentryo, 2017).

- **The second industrial revolution:** about a century later, a new source of energy was emerged which is electricity. It resulted in making combustion engine to be set out to their full potential. And the demand for steal increased, so the steel Industry evolved as well as chemical synthesis as fabric and dyes. Then the invention of telegraph and telephone which revolutionized the way of communication. Moreover, transportation methods were also strongly affected due to the emergence of the automobile and the plane then at the beginning of the 20th century (Sentryo, 2017).

- **The third industrial revolution:** it happened in the middle of the 20th century with the emergence of a new type of energy which is nuclear energy. As a result, the world witnessed the rise of electronics with the transistor and microprocessor, along with the augmentation of telecommunications and computers. This technology has led to the production of miniaturized material which opened the door to space research and biotechnology. For industry, this revolution introduced the era of high-level automation in production due to major inventions such as automations and robots (Sentryo, 2017).

- **The fourth industrial revolution:** This fourth revolution is mainly characterized by merging technologies that connect information, objects and people due to the intersection of the physical and the virtual worlds. Figure 10 shows the four stages of industrial revolution as following.

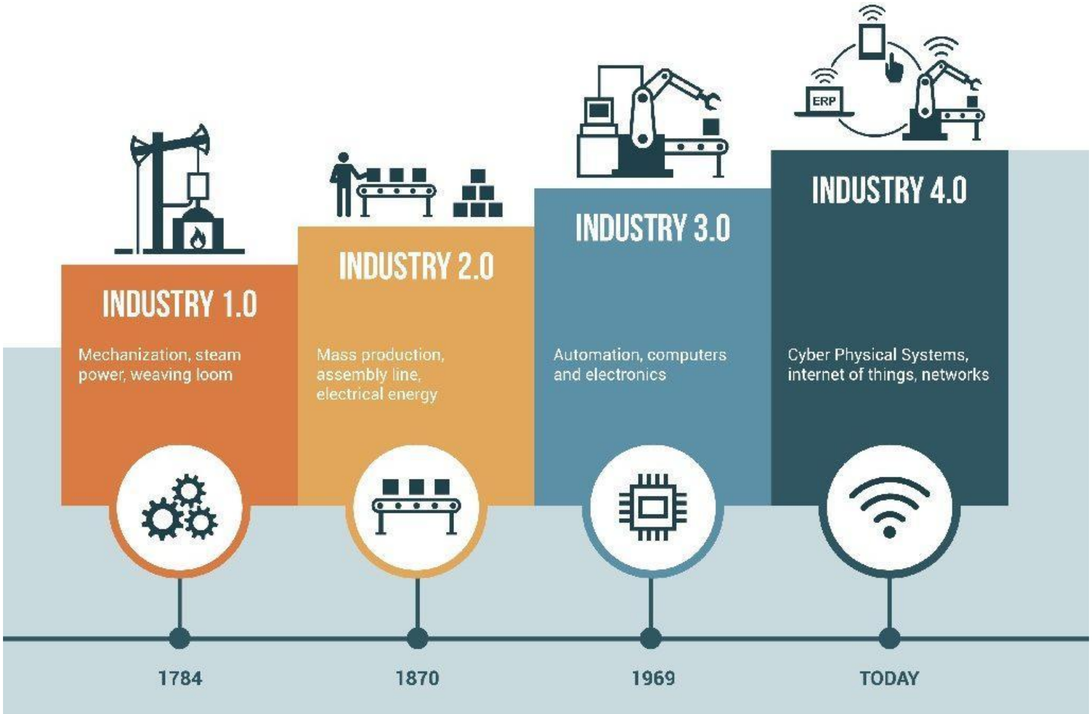

Figure 10: The four stages of the industrial revolution (Diaonescu)

2.3.2 Industry 4.0 as a concept

The fourth Industrial Revolution was emerged in Germany under the name of "Industry 4.0" in 2011 at a fair in Hannover called Hannover Fair, it was mainly about discussing how organizations and global chains will be affected by the arrival of the new technological concepts that tend to turn industries into smart factories.

Industry 4.0, introduces a completely new perspective to the industry. It enables the collaboration between the Industry and its new technologies to get maximum output with minimum resource in Manufacturing. Industry 4.0 is considered as an attempt to facilitate the complex manufacturing in this era. It is a combination of the current trends of automation technologies in the manufacturing industry. It includes many components such as the

Cyber-physical systems (CPS), Internet of Things (IoT) and cloud computing (CC) (Kamble, Gunasekaran, & Gawankar, 2018).

As stated by (Shafiq, Sanin, Szczerbicki, & Toro, 2015), Industry 4.0 can be defined as the combination of intelligent machines, processes, production and systems that shape an interconnected network which emphasizes the idea of linking and digitizing manufacturing units in a given economy. It is tending to virtualize the real world into a large network of centralized information system.

2.3.3 The Reference Architecture Model for Industry 4.0 (RAMI 4.0)

The definition of the concept behind Industry 4.0 is challenging. As a result, in Germany, where it was first introduced, several associations and institutions from the public and private domain collaborated to create a reference model for Industry 4.0. This reference model describes the fundamental aspects of Industry 4.0 and is supposed to help with the implementation of Industry 4.0 components (Grangel-Gonz, et al., 2016).

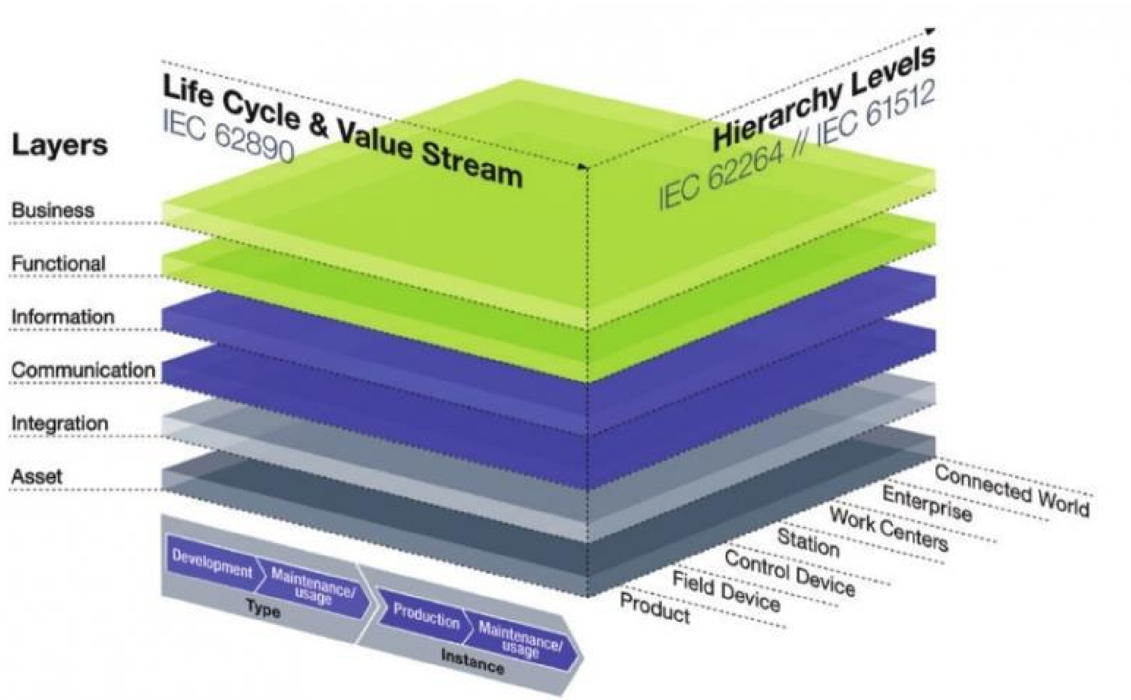

Figure 11: Reference Architecture Model for Industry 4.0 (P. Adolphs, 2016)

This reference model is called the Reference Architecture Model for Industry 4.0 (**RAMI 4.0)** and is shown in Figure 11. This model describes the connection between IT, manufacturers and product life cycle through three dimensions. The left vertical axis represents the side of IT projects, which can be complicated. Hence, they are usually broken down into various elements, such as information, assets, integration, communication, functional and business. The left horizontal axis represents the product life cycle with its main concepts: type and instance. The right horizontal axis represents the location of functionalities and responsibilities within a hierarchical organization. RAMI 4.0 builds upon existing Industry standards for data management during product life cycle (IEC 62890), enterprise control system integration (IEC 62264) and process control (IEC 61512) (P. Adolphs, 2016).

2.3.4 The basic components of Industry 4.0.

Industry 4.0 mainly depends on a number of new and innovative technologies. It does not revolve around a single new technology, but rather around various techniques combined that enable this industrial shift. We have decided to narrow this matter down by keeping an overview perspective on the basic components of Industry 4.0 and the main concept rather than structuring this research towards a detailed analysis of every single component. However, it is still important to define the basic components that previous literature found essential regarding this topic in order to create this framework and to be able to analyze the impact of Industry 4.0 on business models. It is important to mention that the components of Industry 4.0 can also be known as the “drivers” behind Industry 4.0. (Fatorachian & Kazemi, 2018) described these drivers as the “key technological innovations enabling Industry 4.0”.

2.3.4.1 Cyber-physical System (CPS)

Cyber Physical system (CPS) is an important component regarding Industry 4.0. it links the physical and the virtual world. Cyber-physical systems are integrating computational and physical processes. The development of CPS consists of three phases. The first one is the generation of the identification technologies as for example RFID tags, which can be used for identification and tracking purposes. The second phase is the generation of the sensors equipped with a limited range of functions. The third phase is then the generation of sensors that are connected to the network and are able to store and analyse data (Kagermann, Wahlster, & Helbig, 2013).

The technology behind CPS can be presented into multiple layers (Fleisch, Weinberger, & Wortmann, 2015) as following:

- A physical layer with added logical capability through sensors and actuators;
- A network layer that enables communication;
- A content layer which store data;
- A service layer for the functionality of the CPS.

2.3.4.2 Internet of Things (IoT)

Internet of Things (IoT) allows "things" and "objects" as RFID, sensors, mobile phones to integrate into unique connections, which can work together and also with other objects to achieve a common goal. It can be defined as a network in which CPS collaborate through unique links. The IoT can be utilized for many domains, for example, smart factories, homes or networks (Hercko & Hnat, 2015). IoT is defined as a "global environment where the Internet is the center of connectivity for all the intelligent devices" (Fatorachian & Kazemi, 2018). IoT means that machines are connected to each other and hence can communicate with real-time performance.

2.3.4.3 Cloud Computing and big data analysis.

Cloud Computing refers to a computing all over the world that can give all objects in a system the ability to process and send information by providing appropriate microelectronics, sensors, communication modules and computer power. These objects are used for various domains such as in the formation of smart production machines and intelligent products or services (Kainer, 2017).

Cloud systems are providing companies with the opportunity to store big amounts of data and at the same time offering the accessibility to this data anywhere (Fatorachian & Kazemi, 2018). This means that the communication between machines is monitored from the cloud and that all information coming from the machines will be stored there. This will provide the analysts with the ability to analyze this huge amount of data which can bring great benefits such as detailed forecasting and real-time problem solving (Fatorachian & Kazemi, 2018).

2.3.4.4 Smart Factories.

The Smart factory is also one of the main elements of Industry 4.0. Smart factories are where machines and robots are used to assist people to fulfil their tasks and where tasks are performed based on data from the physical and virtual worlds for instance, from the physical world they can get information about the location or the condition of the machine, and from the virtual world, they can get information as electronic documents or simulation models (Kagermann, Wahlster, & Helbig, 2013).

2.3.4.5 Internet of Services

Internet of service refers to providing a service through the internet. Services are then offered and integrated into the value-added network from different vendors. This approach allows different variants of distribution in the value chain (Hercko & Hnat, 2015). The Internet of Services focuses on creating a bond that simplifies all connected smart devices in a bid to make the most out of them by simplifying the integration process.

2.3.5 The basic principles of Industry 4.0

Industry 4.0 is mainly based on 6 principles (Hercko & Hnat, 2015). Here is a brief description for each one:

- **Interoperability:** A critical principle especially with regard to the concept of the CPS, IoT and Internet of Services. It means having people, machines and devices to connect easily with each other while exchanging data.

- **Virtualization**: The ability to control the physical processes through CPS. By using sensors, physical objects are then tracked in a virtual environment. This virtual world allows simulation models.

- **Decentralization:** Devices are allowed to make decisions and perform tasks. This leads to decentralized control system; this principal is essential considering the increasing market demand for products.

- **Capacities in real time**: Collecting and analyzing data in real time. In order to be able to respond in real time.

- **Service-orientation:** As a result of the connection between CPS and people through internet of things. Service orientation can be whether internal or external since it is possible to access those services through webs.

- **Modularity and reconfigurability**: The ability to adapt to changing requirements and to extend or change modules. Modular systems are flexible and beneficial especially for seasonal changes in the product specifications.

2.3.6 New opportunities and challenges in the context of Industry 4.0.

Industry 4.0 will lead to the development of business models and partnerships. This revolution will enable firms to meet individual and changing customer requirements. The new business models will provide new concepts such as dynamic pricing that takes into consideration the customers' and competitors' situations and guarantee the quality of the service or the product. Networking and cooperation between business partners will require the sharing of potential benefits fairly among all the participants in the value chain which in return requires data and resource sharing.

Detailed monitoring of processes in real time is critical in documenting procedures and system conditions to ensure that the contractual and regulatory requirements are satisfied. Moreover, business processes will be tracked at all times. It is predicated that Industry 4.0 will cause major global changes and will lead to highly dynamic environment (Kagermann, Wahlster, & Helbig, 2013).

In the context of Industry 4.0, factories will be able to get instant feedback on costs and performance. Cloud-based systems and software solutions will be used to optimise performance and resource usage. Computer systems supplies with machine-based learning algorithms will qualify robots to operate and perform tasks with limited human interactions. At the same time, the growing customer demand for smart and complex products makes smart technologies mandatory for industries (Andrews, 2017).

CPS will enable flexible and dynamic configuration of different business processes, for instance. Smart facilities will be able to continuously optimize their usage of materials and other resources. It will also lead to more agile engineering processes. Smart equipment will be used and characterized by high level of automation which in return will lead to flexible adaptation to work condition changes.

Industry 4.0 is to provide end-to-end integration in real time, resulting in early verification of design decisions and hence faster and more flexible responses. Industry 4.0 brings new ways of creating value and new methods of utilization. Data which is recorded and stored by smart devices can be analyzed and provide innovative opportunities. There are specifically huge opportunities for Small Medium Enterprises and start-ups in the area of business-to-business industry. Firms will be able to turn demographic changes to their benefit thanks to the interactive collaboration between people, machines and information (Kagermann, Wahlster, & Helbig, 2013).

It is important to mention that smart assistance systems will offer new opportunities with regard to organizational work. It will set new standards of flexibility and freedom in order to fulfil the requirements and the personal needs of employees. Organizations will need to be more flexible in order to cope with the growing need of employees to have a better balance between their work and their lives and also between individual progress and ongoing professional evolution (Kagermann, Wahlster, & Helbig, 2013).

Additive manufacturing technologies which is also recognized as 3D printing will be progressively used in different processes, it has been noticed that the costs of additive manufacturing are dropping in the last few years, at the same time additive manufacturing has provided strong advantages considering speed and precision. This technology enables the production of complex and customized products. Products in the context of Industry 4.0 will be produced in massive quantities but according to customers' individual requirements. It will also make it possible to provide the products for customers as fast as possible. Products will also be equipped with new services offering which in return will guarantee high functionality and transfer the ownership to the customer as part of new business models (Stock & Seliger, 2016).

The value creation networking in Industry 4.0 provides novel opportunities. It enables the effective collaboration of the product, resources , and data flows throughout the product life cycles and within different factories. The new offerings will take into consideration the whole life-cycle of the product such as multiple use phases beside remanufacturing or reuse in between. Industrial collaboration will be characterized as cross-company collaboration within different factories in order to achieve sustainable competitive advantage (Stock & Seliger, 2016).

Industry 4.0 offers new opportunities with regard to business models. Sustainable business models can expressively create more positive impacts for the environment or society (Bocken, Short, Rana, & Evans, 2014). Sustainable business model can contribute significantly by solving environmental issues.

Despite the potential benefits, Industry 4.0 has brought some challenges along the way (Bocken, Short, Rana, & Evans, 2014). At the top of these challenges is cybersecurity, since investing in smart factories would in return increase the risk of security attacks and since data is one of the main assets in the light of this new revolution (Andrews, 2017).

However, software technologies are in an intense rise within manufacturing facilities, a lack of IT security knowledge regarding relative threats is still an issue that has not been discussed properly. There is still no common agreement on the suitable level of security in different industries, but it is important to point out that the increases networking between different participants in the new concept of the value chain will require high level of confidence and trust in others' capabilities and competences (Kagermann, Wahlster, & Helbig, 2013).

Moreover, Implementing CPS solutions with real time capabilities highly demands the availability of suitable infrastructure by means of advanced technical aspects and data reliability. Factories will need huge investments in order to embrace Industry 4.0 through smart systems. That can be seen as a potential obstacle for many organizations. It will also be necessary for others to upgrade their existing systems with new technological capabilities . Firms to embrace Industry 4.0 will have to assess the trade-off between the additional resources needed to deploy CPS and the associated infrastructure along with the potential savings. These assessments should be done to help in making decisions regarding retrofitting production lines or building new ones and regarding the required level of automation (Kagermann, Wahlster, & Helbig, 2013).

Industry 4.0 will also cause a paradigm shift in the human- technology interaction. The role of operators will change, and machines will adapt according to the needs of operators, this paradigm shift will require different training programs and skills, it will bring digital learning to shop floors. The nature of work in the context of Industry 4.0 will bring out new challenges on the workforce with regard to managing complex dynamic work condition and problem-solving. This transformation regarding skills requirements can be a result of two trends. Firstly, the new role of the labour will be revolving around decision making coordination, monitoring and control. Secondly, it will be essential to organize this intercommunication between virtual and real machines, manufacturing systems and management systems (Kagermann, Wahlster, & Helbig, 2013).

Chapter 3 Business Model Canvas 4.0

This chapter presents the characteristics to be in a business model which is appropriate for Industry 4.0. These characteristics are arranged according to the Canvas Model (Osterwalder & Pigneur, 2010). It should be considered that even though the elements of the Canvas model are interconnected with each other, they are described separately for the purpose of simplification. In this section, the following sub-question is answered*:*

What are the appropriate business model characteristics for Industry 4.0?

Offerings

This section represents what a firm offers to its customers. Offerings should be more than the product itself and includes items that form additional value to the customer needs and desires.

3.1 Value Propositions (VP)

The value proposition is a critical business model block which is believed to be affected by the increasing fusion of Industry 4.0 and its related techniques since this phenomenon is breaking down the traditional concepts of value propositions.

Industry 4.0 can bring greater value due to the convergence of the physical and the virtual worlds in the form of Cyber-Physical Systems, Internet of Things, Cloud computing and big data analysis, these techniques results not only in a manufacturing-technical change, but also in extensive opportunities and consequences regarding the value offerings of a firm. Here are the main business model characteristics regarding Value Proposition:

Table 2: Value propositions for Industry 4.0

BMC 4.0 elements	Related Characteristics
1.Value Proposition	• Mass Customization. • Integrated product- service offerings. • Flexibility.

3.1.1 Mass customization

As (Davis, 1987) in his book “Future perfect” refers to the mass customization when “the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously they can be treated individually as in the customized markets of pre-industrial economies”. Mass customization has the competitive advantage of both the efficiency of mass production and the differentiation options.

Industry 4.0 is making it possible to connect information, objects and people and to use big data and feedbacks to analyze the customer needs and preferences while assuring optimization and efficiency. Along with the growing individualization of customer demand as well as the continuous need to decrease the cost and given the business attempts to be more responsive to customers. For these reasons, companies will have to embrace the concepts of customization and differentiation in order to address value proposition which is valuable. (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013) (Piller & Tseng, 2015).

3.1.2 Integrated Product - Service offerings

The product - service offerings refer to the complementarity between products and/or services that are offered by a firm, which results in a better integration with customer and partners along the value chain. Product service systems have been strongly linked to Industry 4.0 and CPS in recent literature. The idea of equipping products with sensors and connectivity to generate operational data about the product is referred to as "smart products" (Porter & Heppelmann, 2016).

According to (Kiritsis, 2011) a smart product includes sensing, memory, data processing, reasoning and communication capabilities at various intelligence levels. Organizations are competing by offering integrated product - service solutions throughout the product life cycle (Herterich, Uebernickel, & Brenner, 2015). These solutions are enabled by the collection, monitoring and analysis of data provided by Industry 4.0.

The integrated product - service offering can be carried out in various ways such as continuous monitoring and visibility with regard to the current status of the equipment which helps with identifying the problems and errors during operating and then solve them, operations can be optimized based on sensor data and support systems which can provide the needed information in order to achieve service efficiency, spare parts can be reordered automatically, maintenance and repair become more predictive and pre-emptive which results in more customer satisfaction and minimized downtime (Herterich, Uebernickel, & Brenner, 2015). The product – service offerings bring along other sub-values for customers such as (Onar & Ustundag, 2018), (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013):

- **lower responsibility for product life cycle,** as the main responsibility for monitoring is transferred to the producer.
- **functional guarantee and efficiency,** which refer to the possibility of making the operations faster, simpler while increasing its transparency and dependability in order to minimize the errors, provide better predictability and optimize the production as well as the usage of products and equipment.
- **Novelty,** as it refers to the new market, services and innovation that will be created due to IoT applications or through IoT platform itself such as AT&T Connected car that turns the vehicle into a Wi-Fi hotspot and let the car be connected to the network

even on the road. Users are able to do video streaming, browsing the web, and listening to Internet radio via Car's network.

- **Lock in,** the product-service offerings enable the firms to increase the transaction cost for existing customers and guarantee their loyalty.
- **complementarity,** product-service offerings are more valuable together.

3.1.3 Flexibility

Flexibility is provided due to the introduction of dynamic configuration of different processes, enabled by CPS and IoT technologies. Modularization is another key element for providing flexibility since it provides adjustable adaptations and make products/services easily editable for seasonal fluctuations or changes in the product specifications.

Industry 4.0 enables modularization of both products and services, as well as agile manufacturing which would make business scalable and would help to satisfy wider ranges of customer desires and at the same time guarantee short time to market . (Hercko & Hnat, 2015) (Kagermann, Wahlster, & Helbig, 2013).

The Customer Interface

The following part represents the customer interface section in the Canvas model, it includes customer segments, customer relationships and channels. By the introduction of Industry 4.0 technologies, new ways of interaction through improved channels are created, allowing a better understanding of customers' needs, and in return, greater customer experiences.

Table 3: Customer Interface for Industry 4.0

BMC 4.0 elements	Related Characteristics.
2. Customer segments (CS)	• Segmentation based on data analysis. • Expanded customer segments.
3. Customer Relationships (CR)	• Increased customer integration (Co-creation). • Long term relational nature.
4. Channels (CH)	• New marketing campaigns. • Digital sales. • Direct and digital communication. • Smart contract transactions (Blockchain).

3.2 Customer Segments (CS)

Customer segments defines the various groups of people or organizations the firm aims to reach and serve. Here are the main business model characteristics regarding Customer Segments:

3.2.1 Segmentation based on data analysis

Industry 4.0 allows data collection and analysis on a large scale due to the existence of big data, IoT and CPS. Accordingly, a greater and more accurate understanding of customers' real needs and problems is obtained which has a significant impact on the design of the added value of a firm. Therefore, it becomes easier and more efficient to position the customers according to these needs in order to guarantee satisfactory products and/or services. (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013) (Christian Arnold, 2016).

3.2.2 Expanded customer segments

Taking into consideration the powerful possibilities of Industry 4.0 to recognize the cultural and regional differences of customers and to analyze their habits, values and behaviour through the CPS, big data and product service solutions. Furthermore, Industry 4.0 involves many changes regarding the product's ownership, responsibility, availability and cost, since the provider/ producer remains the "owner", or at least holds some responsibility through the product life cycle which is an economic incentive to extend the product's lifetime.

For that, it is very likely for firms to be able to expand their customer segments to include new customer segments that they didn't know about before, not only within already served industries, but moreover beyond that. (Cong Cheng, 2013) (J.C. Diehl, 2015)

3.3 Customer Relationships (CR)

Customer relationships describes the types of relationships a firm creates with its Customer Segments. Here are the main business model characteristics with regard to Customer Relationships:

3.3.1 Increased customer integration (co-creation)

Customers are becoming more integrated into the design and the production phases of the products/services, and not only in the usage phase as it used to be. They are participating now as an important cooperative partner since they play a new role as co-designers and value co-creators.

The design for the integrated product service systems(PSS) offered by Industry 4.0 is quite different as companies now seek long- lasting interactions with the end-user and one of the main critical keys to do so, is to identify clearly the value proposition and maintain it relevant over time. Moreover, in order to manage the different needs, expectations and perceptions of stakeholders, designers have to be in long-lasting, close and steady communication with them and to integrate their demands (Valencia, 2014).

The co-design and value co-creation activities help searching new future directions, new partnerships, as well as new design ideas and solutions. Moreover, customers can play a protracted role in expressing their experience regarding the PSS and guarding it along the life cycle (Christian Arnold, 2016).

3.3.2 Long term "relational" nature.

Industry 4.0 facilitates direct and enhanced connections with customers, which leads to a stronger and long-lasting communication with the customer which would be related to the product performance due to capacities like shorter running time, better information transparency and interoperability of humans and machines (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013).

The marketing literature recommends a variety of customer relationships, ranging from discrete transactions to relational exchange (E. Penttinen, 2006) . Customer relationships in the context of Industry 4.0 will take a turn from short-term transactional relationship which focuses on the actual sales process for an item and goes well with the typical “product sale” context to more long-term “relational” one. This “relational” path can be created through operational linkages, strong information transfer, legal obligations and intensified collaboration activities (Kauremaa, 2009). Because of this relationship, customers will be more loyal and attached to the business and willing to cooperate more to maintain this long- term relationship.

3.4 Channels (CH)

Channels are referred to three types as following: communication, distribution, and sales Channels and they are important as they shape the company's interface with its customers (Osterwalder & Pigneur, 2010). Finding the suitable combination of Channels to comply with customers’ expectations and needs is crucial in bringing the value proposition to market. Here are the main business model characteristics regarding Channels:

3.4.1 New marketing campaigns

Following Industry 4.0, companies should have strong touchpoints with customers in order to raise awareness about the novel values offered by the new technologies as well as marketing campaigns to make the new offerings more appealing and attractive. Sales teams should engage with customers at the right time and to be able to highlight the new added values of the new system and explain how these values can be delivered. Doing so would require special training and readiness to change the sales mind-set (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013)

3.4.2 Direct and digital communication

Digital communication is another key characteristic regarding Industry 4.0 channels in order to help customers benefit from firm’s offerings and to be able to evaluate it through online platforms and easy-to-access performance metrics, it also helps with the post-sale services since it enables instant answers and reinforcements.

Digital communication can help in unifying customer information through single central database by adopting digital methods such as a document-sharing system while cooperating to create them, therefore the time needed to discuss and analyze the details will be dramatically decreased. (Auman, 2018). The enhanced connected information flow will enable former B2B businesses to connect with the end customer directly, while excluding intermediate entities of the value chain (Piller & Tseng, 2015).

3.4.3 Digital sales and enhanced collaboration

Providing a wide range of devices, web-based platforms and self-driven channels while assuring the coherence between them and defining clear pathways of collaboration is important to improve efficiency, reduce time and cost and start the sales earlier.

Another effect of going digital is that it demands less manpower, regarding contract negotiation and finalization. Channels are becoming largely data-driven, which helps managers to have access to information about their partners' performance, so they can efficiently deploy training and marketing resources to the right partners in the right locations (Deloitte , 2018) (Ibarra, Ganzarain, & Igartua, 2017) (Auman, 2017).

3.4.4 Smart contract transactions (Blockchain)

In order to achieve comprehensive digitalization, it is believed that smart contract (blockchain) will be integrated with Industry 4.0. it potentially cuts out the intermediary party regarding transactions through applications where people can buy things with virtual currency and store it. With this current development stage of technology, smart contracts can be programmed to perform simple functions and would enable the payment process to be automated. Blockchain allows the direct interaction between parties which implies decentralized sharing economy results, autonomy and security (Blockgeeks) (Pascal, 2018).

Infrastructure Management

The infrastructure section represents the supply side of the business model which is responsible for the value creation and its delivery to customers by covering the key activities, key resources and key partners.

Table 4: Infrastructure Management for Industry 4.0

BMC 4.0 elements	Related Characteristics.
5. Key Activities (KA).	• Data collections and analysis. • Product and process development. • Training programs and skills reinforcement. • Horizontal integration through value networks. • Supply chain agility. • Vertical integration of manufacturing systems. • Standardization and reference architecture. • Safety and Security procedures.
6. Key Partners (KP).	• Co-creation network (Eco-system). • Partnerships with legal experts. • Partnerships with education and training institutions. • Partnerships with IT companies.
7. Key Resources (KR).	• Digital infrastructure. • Qualified and adaptable workforce.

3.5 Key Activities (KA)

Identifying the key activities helps the managers to understand which activities need adequate attention while formulating and executing the strategy, therefore the focus should be on the essential activities instead of the generic ones. Here are the main business model characteristics regarding key Activities:

3.5.1 Data collection and analysis

Thanks to technologies like IoT, Big data and Cloud computing, physical objects can be involved into the information network and become active contributors in the business processes. These technologies make it possible to have advanced analysis and control over the industrial environment as they can be used to understand the machine’s behaviour, production processes, maintenance requirements and more. Consequently, expands today’s possibilities and opportunities for improving manufacturing process and products (Shrouf, Ordieres, & Miragliotta, 2014). (Lee, Yang, Ardakani, & Bagheri, 2015) suggested that considering the usage of data in CPS, there should be a framework which is consistent of five stages, namely 5C architecture.

- The first stage is the smart connection to manage local data acquisition and transfer it to the central server through sensors.
- The second stage is the aggregation and conversion of data to information by using intelligent algorithms and data mining techniques.
- The third stage is the cyber level which represents a central information hub in this architecture, information is being gathered in it from every source to create a cyber space.
- The fourth stage is the cognition, in this level, the implementation of CPS generates system knowledge, which provides the support regarding decision making by experts, quality assurance and human evaluations.
- The fifth stage represents the optimal usage of data within a CPS, which is the Configuration level where there is a supervisory control to make machines self-configure and self-adaptive and then apply the decisions which have been taken in the cognition level.

Accordingly, self- optimization and self- adjustable operations are possible. Companies have to develop and provide cloud computing services, big data analysts and CPS related applications to become proficient in data management, which plays an important role to gain useful knowledge and enable automated decisions making.

3.5.2 Product and process Development

Industry 4.0 focuses on the creating of smart products and production processes. In future manufacturing, companies will have to consider the need of product and service development and flexible production, also how to cope with complex environments. Given the provision of product-service offerings, companies should focus on activities along the different phases of the life cycle, these activities are performed before, during and after the product's usage phase since managing the product life cycle is essential in this matter.

During the usage phase of product-service systems companies can keep an eye on the product performance and identify the maintenance needed and plan it ahead, further examples for processes that should be considered through the integration between the product development and service development are: end-user centric design, end to end engineering, cost and quality control, product and resources traceability, process optimization, short time to market, rapid prototyping, feedback analysis, automated and real-time process, intensive communication as well as problem solving (Grönroos, 2010) (Arnold, Kiel, & Voigt, 2017) (Shrouf, Ordieres, & Miragliotta, 2014).

It will be essential to integrate new technologies into the old manufacturing systems. Modular simulations and modelling techniques will help managing this transformation and will allow decentralized units to flexibly improve products and accordingly enable rapid product development (Kagermann, Wahlster, & Helbig, 2013).

3.5.3 Training programs and skills reinforcement

The adoption of the technologies enabling Industry 4.0 within manufacturing surroundings can be a complex process with extensive changes. Industry 4.0 involves smart machines, advanced analytics and people working together. Hence, it is critical to have both technological as well as individual competencies.

Industry 4.0 will make it possible for tasks to be displayed on screens, machines performance and quality standards to be monitored by an automated systems and operations to be self-optimized and self- adjustable. However, operators will still have responsibilities and they will need a specific training to learn how to utilize digital devices and mobile devices of data analysis. In order for Industry 4.0 to succeed, training programs and employees' skills will have to be adapted to the new requirements (Vitria Marketing, 2018).

The focus should be on developing employees' competencies so that they are well-prepared to execute their new tasks, make better decisions, and manage future challenges since people and technology will be more interconnected in a complementary way. It will be important to provide ways to access science and engineering knowledge when needed, and to develop cooperative work design and lifelong learning measures (Kagermann, Wahlster, & Helbig, 2013).

3.5.4 Horizontal integration through value networks

Collaborative manufacturing and development become more important in Industry 4.0 especially for enterprises with limited resources. Collaborative networks can achieve risk balance while sharing resources, data and capabilities. It will allow the market to expand opportunities and organizations to exploit different capacities without further investments. (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

Horizontal integration in Industry 4.0 refers to the integration of IT systems that are used in the different stages of the manufacturing and business planning processes. It would require an exchange of materials, energy and data throughout the whole network in order to achieve optimization in a company and even beyond its boundaries and to deliver end-to-end solutions (Kagermann, Wahlster, & Helbig, 2013).

Smart factories with CPS are able to track manufacturing processes and objects through digital networks, resulting in more real-time horizontal integration along the value network. This integration will have the ability to maintain a competitive advantage since companies will focus on their core competencies while outsourcing others through collaborators. According to (Christopher, 2000), being able to be more responsive to the needs of the market through the usage of network competencies can lead to sustainable advantages.

3.5.5 Supply chain Agility

Agility is defined by (Christopher, 2000) as "the ability of an organization to respond rapidly to changes in demand both in terms of volume and variety. Market conditions in which many companies find themselves are characterized by volatile and unpredictable demand". Hence agility goes hand in hand with the existence of Industry 4.0.

The agile supply chain implies that the supply chain can read and respond to real demand. Due to the recent progress regarding the use of information technology to capture data and engage with customers, organizations are being demand-driven rather than forecast-driven. Moreover, the use of advanced information technology creates a virtual supply chain which is information-based rather than inventory-based since it is possible to share data between partners and to track objects. The inventory levels and lead times within the value chain have to be reduced to enjoy the flexibility advantage of the network and to achieve optimized flows (Christopher, 2000) (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

Integrated engineering along the value chain using developed methods of communication and virtualization offers considerable optimization opportunities. Partners among the value chain will be able to access real-time data and control processes, the material and work flow, as well as manufacturing cycle time from product development to engineering, production and services (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

3.5.6 Vertical integration of manufacturing systems

Vertical integration in Industry 4.0 refers to the merging of IT systems in various hierarchy levels on both production and corporate scale. It is a key element in creating the physical cyber system. Factories within Industry 4.0 will be highly flexible and reconfigurable due to the full integration between production, and the corporate planning systems (Gehrke, 2015).

The structure of smart manufacturing will not be fixed and predefined as before. Instead, it will be more flexible and based on cases which are automatically built by IT configurations and contain all the corresponding requirements in terms of models, data and communication. Products will be simulated in the network and the manufacturing processes will be consist of steps where products will have a clear path along the manufacturing stages. Machine to machine communication and decentralized control systems will lead to optimized and flexible production flow. (Kagermann, Wahlster, & Helbig, 2013)

Within the extent of vertically integrated systems, the operator will be part of the planning process, and will help with tasks such as process development and quality control. In order to achieve vertical integration, it is important to implement modularization, end-to-end engineering and full integration of actuators and sensors across different systems. (K.Chukalov, 2017)

3.5.7 Standardization and reference architecture

Industry 4.0 will deliver collaboration and integration of different partners through the Eco-system and networking. This collaboration will require a set of common standards to be identified and developed, as well as a reference architecture in order to assure common comprehension of these standards and to guide their implementation. It is important for companies and partners in the value network to agree on this framework since it includes their different business models and different perspectives. The purpose of this reference architecture is to provide a common work approach that will guide them through structuring, developing and operating technological systems linked to Industry 4.0. This framework can be software applications and services (Kagermann, Wahlster, & Helbig, 2013).

3.5.8 Safety and security procedures

Safety and security are extremely critical in smart manufacturing and considered to be two of the main challenges in adopting Industry 4.0. Modified safety and security strategies are needed to provide some guarantees and precautionary procedures and to make sure that production facilities as well as data are secure.

There is a need to position strong safety and security architecture and to protect data, which is believed to be one of the most valuable assets in Industry 4.0, against cyber-attacks and unauthorized access. Integrating security and safety aspects in the design process along with providing solutions for security issues should be highly considered. Security and safety procedures should protect the digital processes, intellectual properties and data through new strategies, secure IT technologies and legal support. It is also necessary to develop methods that will provide better assessment of the risks related to Industry 4.0 (Kagermann, Wahlster, & Helbig, 2013).

3.6 Key Resources (KR)

The key resources are the assets needed to make the Key Activities possible. Here are the main business model characteristics regarding key Resources:

3.6.1 Qualified and adaptable Work force

Innovative technologies as collaborative robotics and additive manufacturing highlight the need of having advanced capabilities in order to achieve the utilization of big data and IoT. These technologies will need qualified and skilled workforce to deal with the new machines, materials, customers and particularly, data (Gehrke, 2015).

The industrial internet of things necessitates the technical talents and qualifications of the workforce with respect to software development, information systems and data analysis. Therefore, companies will need a workforce with capabilities to develop and run advanced manufacturing technologies and systems, to analyze the data received from machines, consumers, and other data resources, as well as to manage the new working environment (Shrouf, Ordieres, & Miragliotta, 2014) (Gehrke, 2015) .

Moreover, employee's role is predicted to be changed from operator to controller and problem solver since IoT provides automation and optimization in monitoring, operating and maintenance through intelligent assistance systems with optimized human- machine interfaces (Arnold, Kiel, & Voigt, 2016) (Gehrke, 2015).

Industry 4.0 hasn't only brought technical and production changes, but also extensive organizational consequences. Such changes will require significant organizational and cultural transformations. People will have to be able to adapt to the new working environment which is predicted to be more open and creative work space. Hence it will be necessary to develop personal skills regarding the ability to change, ambition for continuous improvement and learning, social and communication skills in order to facilitate this transformation (Cook, Bhamra, & Lemon, 2006).

3.6.2 Digital infrastructure

The production environment in the context of Industry 4.0 demands information technologies, intellectual resources and security measures, and it will not be possible to adopt Industry 4.0 Without flexible and scalable IT infrastructures.

For companies willing to implement Industry 4.0, it is significantly critical to build an infrastructure that enables high-volume and high-quality data exchange through sensors, huge servers, data centers and trusted security systems. The implementing of CPS solutions will need network infrastructure in terms of space, technical quality. Therefore, creating an enhanced digital infrastructure as well as broadband internet infrastructure and having them expanded on huge scale, is highly recommended to guarantee the reliability and quality of the service. (Kagermann, Wahlster, & Helbig, 2013)

Manufacturing systems have their own intelligent features of controls, sensors and actuators, as well as communication interfaces. However, data needs to be exchanged between these individual systems, besides they require distinct identification and communication in order to lead to a standardized and uniform data exchange process.

Established technologies (hardware, software) from the IT domain can be used in new domains such as production processes and logistics chains. (Kagermann, Wahlster, & Helbig, 2013). Meanwhile (Lee, Yang, Ardakani, & Bagheri, 2015) suggested that in order to be able to implement the CPS, companies should provide two fundamental elements: “the advanced connectivity that enables real-time data streamlining from the physical objects to cyber space and feedback from the cyber space; and intelligent data analytics that constructs the cyber space”.

3.7 Key Partners (KP)

This section describes the network partners that make the business model work. Here are the main business model characteristics regarding key Partners:

3.7.1 Co-creation Network (Eco-system)

(Perks, Edvardsson, & Gruber, 2012) defined the Co-creation as following: ‘Co-creation involves the joint creation of value by the firm and its network of various entities (such as customers, suppliers and distributors)”.

A value network is a network of engaging actors who focus on co-creation solutions that includes customers, suppliers, partners who are willing to collaborate for any type of exchange, such as competitors, and indirect influencers such as media, government and regulatory agencies (Frow, Nenonen, Payne, & Storbacka, 2015).

This network engages through engagement platforms. It shares goals and responsibilities and cooperates through organizations and technologies to perform specific forms of co-creation which include (Frow, Nenonen, Payne, & Storbacka, 2015): “co-conception of ideas, co-design, co-production, co-promotion, co-pricing, co-distribution, co-consumption, co-maintenance, co-outsourcing, co-disposal, co-experience and co-meaning creation”.

These co-creation forms result in more competitive offerings due to customer’s engagement, decreased cost due to the co-production of the core product, and also shorter time to create and launch new products. Furthermore, the co-promotion can result in raising the product awareness (Schau, J. Arnould, & M. Muñiz Jr, 2009) (De Luca & Gima , 2007) (Frow, Nenonen, Payne, & Storbacka, 2015). It is important to mention that this network will involve several different partners, so it will be necessary for partners to enjoy a high level of confidence and trust in each other's competencies and reputation (Kagermann, Wahlster, & Helbig, 2013).

3.7.2 Partnerships with legal experts

One of the main challenges that Industry 4.0 has brought is data security. It will be essential for companies seeking to adopt Industry 4.0 to ensure that legal experts are involved. This partnership would provide a competitive advantage and should be done from an early stage especially within R&D departments. Moreover, new contract models, practical guidelines and clauses will be required to guarantee the business protection and make sure that the value generated is shared fairly, and that will require a clear definition of the partners' roles through the network (Kagermann, Wahlster, & Helbig, 2013).

3.7.3 Partnerships with education/training institutions

Industry 4.0 will require fundamental development to the way IT experts are trained and educated. They should be able to identify application requirements in different industries and run development partners. The large-scale potentials created by Industry 4.0 imply that the standardized education programs will not be enough. Therefore, it will become important to develop a partnership between businesses and education/training institutions to ensure the continues engagement and dialogue in order to manage the new requirements and challenges (Kagermann, Wahlster, & Helbig, 2013).

3.7.4 Partnerships with IT companies

In the context of Industry 4.0, partner selection will be Intensively according to the need of competencies and activities needed to be done. Partnerships with companies that have strong competencies and advanced capabilities in the area of information technology, cloud computing, big data, machine learning and artificial intelligence will be necessary in order to enhance the value by boosting the traditional products and processes and manage the dynamic environment (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013).

Financial aspects

This section represents the financial part of the business model which includes the cost structure the revenue streams.

Table 5: Financial Aspects for Industry 4.0.

BMC 4.0 elements	Related Characteristics.
8. Cost structure.	• Cost optimization . • Economies of Scale. • Economies of Scope. • Network economies. • Initial cost of installation
9. Revenue streams.	• Financial adaptations due to longer payback period. • Unconventional pricing models. • New opportunities for augmentative revenue streams

3.8 Cost Structure (CS)

This section describes the most important costs incurred to operate a business model. Here are the main business model characteristics regarding Cost Structure:

3.8.1 Cost optimization

Industry 4.0 technologies such as Big Data and Cloud Computing allow real-time simulations of every step within the firm and to identify their impact on production. This simulation will include manufacturing processes, inventory levels, distribution logistics and maintenances activities. Which in return will provide the ability for high level of simulation regarding costs incurred in the firm and the ability to optimize the consumption of production resources and energy besides assessing relevant risks and environmental impacts.

Industry 4.0 will deliver a distinctive advantage regarding resource productivity and efficiency by monitoring the amount of resources that are used and then it will enable product set-up costs to be simulated and optimized. Cost can also be reduced due to the reduction of the internal operating costs as a result of the end- to-end engineering and integration (Kagermann, Wahlster, & Helbig, 2013).

3.8.2 Initial cost of installation

One of the key challenges for Industry 4.0 will be the establishment of the additional resources due to the installation of Cyber-Physical systems and the associated IT infrastructure, the wireless networking, as well as the purchase cost for the software, including costs for administration and support services since this installation will require large initial investment (G. Pateli & M. Giaglis).

It is important to mention that firms should calculate the trade-off between the additional resources needed to be involved in their infrastructure with consequential costs, and the potential gains delivered (Arnold, Kiel, & Voigt, 2017) (Kagermann, Wahlster, & Helbig, 2013).

3.8.3 Economies of Scale, Economies of Scope and Network economies

Adopting Industry 4.0 involves new fixed costs for investing in its technologies, even if these costs may change according to the business plans. This investment means that the business will later on benefit from a reduction of variable costs and accordingly average unit costs.

Mass customization offer product variety which can then lead to reduction of average unit costs especially considering the changeable nature of market demand over time, as it enables a faster response to demand and then reduce the inventory level and create great opportunities for achieving customer satisfaction and fast production. Moreover, Mass customization offer economies of scale and economies of scope (Büchi, Cugno, & Castagnoli, 2018).

Furthermore, economies of scale can be achieved due to the technical efficiency and automation in logistics and administration work, while results in increasing turnover. Network economies can be achieved because of the interconnection between different companies within the value network (Eco-system) and the enhanced cooperation between them resulting in resource sharing and co-creation of products without further investments. Economies of learning and experience can be achieved by training the workforce and also by the automation and integration of the processes. In addition, Economies of Scope can be guaranteed thanks to the larger scope of operations and using resources to support a variety of products and services (Büchi, Cugno, & Castagnoli, 2018).

3.9 Revenue Streams (RS)

This section represents a description of the revenue model a company generates from Customer Segments. Here are the main business model characteristics regarding Revenue streams:

3.9.1 Financial adaptations due to longer payback period

Taking Into consideration the new product-service offerings, the shift in their ownership and the long partnership between the customers and the business, companies should make financial and accounting adaptation actions, since the time range of financial flows changes noticeably from an almost instant return to a long usage time period. Companies then should seek financial support through their partners (Mont, 2002). It is important to understand from a financial point of view that the payback period of the value offerings is usually longer than the payback period of physical product sales (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013).

3.9.2 Unconventional pricing models

The new value propositions offered by Industry 4.0, as well as the ability to access real-time and historical data require considering new pricing models, and to find an efficient way to charge prices on the activities and products offered to the customer. These models should accommodate various price levels and payment frequencies. It is important to consider the shift from discrete product life cycles approach (traditionally a one-off payment) to one based on a continuous flow of data-driven service innovation. There are a variety of pricing models that can be appropriate, for instance (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013) (Arnold, Kiel, & Voigt, 2017):

- **Dynamic pricing** for products or services based on the market demands and as function of supply and demand at the time of consumption.
- **Value-based pricing** to ensure the customer is satisfied as they pay for what they received. It depends on the customer demand and their willingness to pay.
- **Performance-based pricing** to place prices on the performance of products/ services especially in case of a measurable outcomes. It requires legal support with clear metrics and clear terms.it can results in powerful long-term relationships and bonds.
- **Pay per use** where the customers pay only for the actual usage, with no further commitments and not like as it used to be where customers paid for a service whether they were using it or not.

A firm can use several pricing models for Industry 4.0 implementations in parallel to address different customer groups and it is important to mention that in order to determine which pricing models are appropriate, the firm needs to identify clearly its customers, suppliers, and other potential partners. (Abudi, 2012)

3.9.3 New opportunities for augmentative revenue streams

The revenue streams within Industry 4.0 are predicted to be more indirect and extensive since they exceed the product sales to include potential opportunities for increasing the revenue. The point-of-sale becomes more of a point-of-service that lasts for a long time, for example there is a tendency towards selling performance of machines instead of the machines themselves and to consider contracts that allow for leasing, maintenance and repair services, renting, process optimization, licensing, modelling and subscriptions (Smith, 2013) (Ehret & Wirtz, 2016). Generally, the cost differentials are predicted to form lower costs and higher income and accordingly, greater profit in the context of Industry 4.0.

After defining the recommended characteristics that should be involved in business models with regard to Industry 4.0. They are then gathered and placed in each element according to the Business Model Canvas as shown in Figure 12.

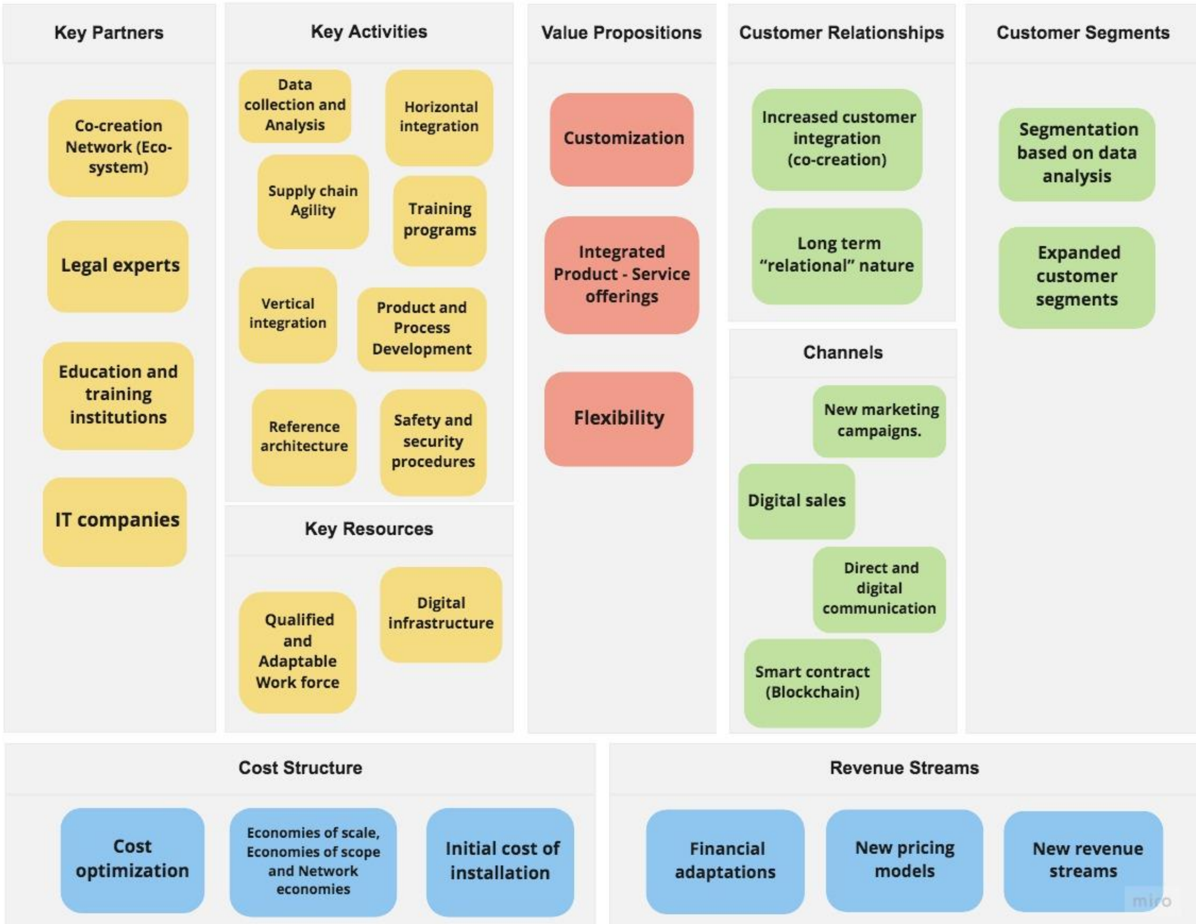

Figure 12 Business Model Canvas 4.0

Chapter 4 Case study and discussion

While many organizations still question Industry 4.0 and might be in denial about its impact on their business models or may be still trying to find out how to best adopt its technologies. Several others are already implementing changes today and preparing for a smart future where Industry 4.0 can help their businesses. This chapter represents the empirical data aimed at uncovering Industry 4.0 impacts on business models, since at this stage of the research, it is important to check the consistency between the theoretical framework and the real-life use cases.

4.1 Case study design

It is relevant to mention that the Business Model Canvas 4.0 Framework consists of multiple levels of analysis and aggregation. It comes from multiple theories and it can be applied to different industries and organizations. The main purpose of this case study is to test the content validity of the framework and to investigate into real life projects and use cases regarding Industry 4.0 in order to check if they can be characterized into the theoretical framework BMC 4.0. The case study selection is based on this following criterion:

- It has to be a business model that is currently operating since the analysis will be more effective when a single business unit is in mind.
- It has to be an asset owner company, which means that they have their own factories where they are implementing Industry 4.0 technologies since the framework is expected to be more suitable for asset owners rather than service or technology providers.
- It has to be a global and large sized company since the framework includes the impact of different key drivers of Industry 4.0 not only a specific one or two, and since Industry 4.0 is still not completely implemented by many companies. We believe that a large company will give more correlated results.
- Availability of sufficient data on business models, ongoing projects and investments through publicly available documents and interviews with the companies' employees.

The empirical data in this case study is gathered through a desk research. Press releases, conference proceedings, online documents, online interviews, articles, reviews, annual reports and many other sources were used for the construction of this case.

4.2 Bosch is committed to Industry 4.0

The Bosch Group is a leading international supplier of technology and services. It was established in Stuttgart in 1886 by Robert Bosch. They are operating in four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology.

Bosch offers connected solutions for many sectors. It benefits from its experience in sensor and software technology in order to be able to provide the customers with innovative solutions from one single source. Bosch operates in almost 60 countries. They enjoy a strong network of global manufacturing, engineering and sales that nearly cover every country in the world. Bosch has around 64,500 associates in research and development across 125 locations globally (Bosch , 2018). Smart manufacturing is a critical element in the Bosch IoT strategy. They are working on making all their electronic devices to be intelligent by 2020.

The international Boston Consulting Group predicts that companies will manufacture **30% faster and 25% more efficiently in a connected industrial world.** Bosch is playing the dual strategy of being a leading supplier and user at the same time. This strategy helped Bosch to increase its industrial technology sales **by 7.7% to 6.7 billion euros in 2017** (Bosch group, 2018).

Bosch offers new offerings that can improve its own competitiveness and their relationship with customers. This can be done in many ways, for example with connected sensors, advanced software applications, internet-enabled drive and control systems, as well as with APAS production assistants. Since Industry 4.0 is already a reality at Bosch and for the reasons mentioned above. Bosch is a great candidate for a case study that would help us getting some empirical insights on what is happening in the real world regarding Industry 4.0.

4.2.1 Smart factories

Bosch's factories are recognized as smart factories where people control and observe the production lines, and data supplies the required insights with robots. These robots are providing support and preforming repetitious tasks. Manufacturing and logistics are more advanced and optimized due to digitalization. Smart machines interoperate with people in order to perform the required work collaborative way. They also help people with monotonous tasks and ergonomically difficult movements (Bosch group, 2018).

"People are the creative element, the vital link between machines and data" says Rolf Najork, head of Bosch Rexroth, one of the leading companies in drive and control technology (Bosch group, 2018).

4.2.2 New qualifications for workforce

The digital transformation brings new requirements with regard to employees and their ability to manage highly dynamic manufacturing conditions. Bosch has recognized this reality and became responsible of providing these requirements; for instance, **the Drive and Control Academy at Bosch Rexroth** supports academic training providers and universities through training courses and advance media technology developed to enhance the skills required for Industry 4.0 (Bosch group, 2018).

Bosch just established its first Innovation Center in 2017 in the Chinese town of Chengdu. This center provides courses on topics such as quality control, production, logistics, and Industry 4.0 related technologies. There are over 20 different programs from which participants can decide which one to join (Bosch group, 2018).

Bosch invests around 250 million euros yearly with regard to training programs for its associates as reported in a press release in January 2019 (Bosch , 2019). There are around 19,000 different programs that their associates can choose to join. Bosch's main goal is to improve skills and empower associates with skills that make them ready to enter new business areas. Furthermore, the Bosch Learning motivation gets through employees' daily routines thanks to various techniques such as video lessons or learning applications on the continuous traditional training programs.

4.2.3 Data collection and analysis

Bosch supports manufacturing with data and communication applications. This combination delivers great opportunities. For example, associates can get the access to data whenever needed, also they can proceed with data analysis and visualization. It is now possible to avoid errors from the beginning. And if any issue occurs, associates will be able to react fast enough. This would in return, reduce machinery break down time and would cause increased output in an impressive way.

"Experience from internal Bosch projects shows that by using intelligent software we can increase at some locations the productivity every year by up to 25%. While also reducing stock levels by up to 30%" explains Dr. Stefan Abmann, who is the head of Bosch's connected Industry business unit (Bosch group, 2018). Bosch can now become even more economical and effective with regard to its use of resources and also to proceed with having more sustainable manufacturing processes. **An example for that is happening at the Bosch factory in Homburg, Germany**. They are using the central IoT software platform to determine when a sector is active based on the presence or absence of associates and then immediately adjusts the heating and air conditioning correspondingly (Bosch group, 2018).

Bosch has brought its software along with The Nexeed Connected Manufacturing solutions. Firms can facilitate the daily working routines of their employees and also plan their production and logistics operations to be more effective, more adaptable, and more cost savings with regard to resources usage.

4.2.4 Fast integration and Flexible configuration in manufacturing

Fast integration and flexible configuration enable the implementation of Industry 4.0. Ad hoc modifications to configurations can be done easily and quickly through some software commands since everything is connected. Software tools facilitate the commanding, integration, and reconfiguration. It also supports the maintenance of all elements. Hence machines and manufacturing equipment are easily adapted to the new flexible requirements and conditions.

It is not required for operators to have wide knowledge in PLC programming but basic knowledge on how to use a smart device. They also can select new tasks on their control panel and the production would adapt accordingly at the manufacturing line. Bosch control the information flow between enterprise resource planning systems (ERP) and machines through Bosch software solutions (Bosch, 2018).

Bosch software solutions for Industry 4.0 show their worth on a daily basis in Bosch's international manufacturing locations. Bosch modular software portfolio is convenient for making ready and connected for Industry 4.0. These software solutions connect people, products, machine, and systems horizontally and vertically. They are used to mainly improve processes, reduce costs, increase productivity, and provide total transparency. Moreover, Bosch IT Shop floor solutions provide modularity and scalability for the smart factory.

4.2.5 Horizontal and Vertical networking

For Bosch, the new perspective of processes with regard to Industry 4.0 is critical with regard to the level of networking and collaboration. It is about connecting all the value creation processes such as making orders, delivery, manufacturing, supplying and supporting activities along the company and even across the country brooders horizontally from the supplier to the customer and vertically from the accounting team to the RFID-tag on products as shown in figure 13.

The extensive exchange of data is well organized and maintained along both hardware and software interfaces. Currently SAP connects with the Programmable Logic Controllers without conjoined technology which would allow strong networking with no barriers between automation and information systems, documentation and decentralization are extremely important concepts for Industry 4.0 to go on. Obviously, the existence of open standards is very critical in order to make things work together since data is provided and offered everyplace through open interfaces with real time (Rexroth Bosch Group , 2016).

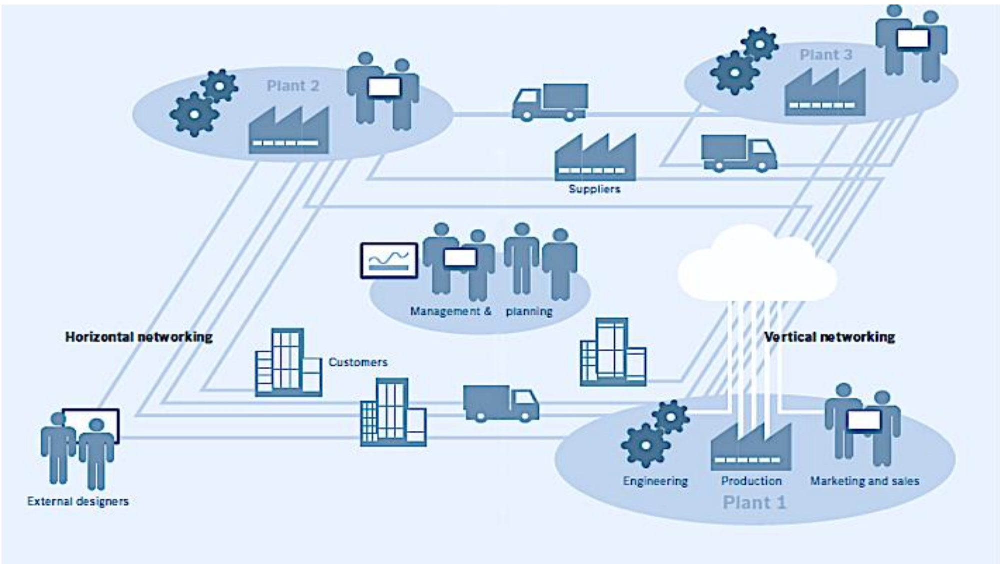

Figure 13: Bosch value stream network (Rexroth Bosch Group , 2016)

Bosch uses open architecture and open core engineering to guarantee quick simulation and optimization regarding production processes. Through the open core interface, reliable processes can be done directly. This can offer technological uniqueness and a competitive advantage (Rexroth Bosch Group , 2016).

Bosch's Open Core Engineering enables the integration of software technologies into machines to be done easily and quickly. It sets new standard engineering freedom and allows **the horizontal and vertical networking in industry**. Open Core Engineering is a solution to provide software tools in order to increase the engineering efficiency. The connection of PLC automation with the new IT technologies can be integrated into one single solution through open standards, pre-programmed software, functions for machine monitoring and Open Core Interface technology. It is also important to mention that the open core engineering provides direct function access to all control and drive processes. Using the Open Core Interface, users are able to create their own individual functions in a broad range of information technologies and internet high-level languages.

The Open Core Engineering in Bosch consists of three elements:

- The Function toolkits which simplify the engineering of complex machine processes and enables the fast integration of new machines functions.
- Software tools to cover the entire work flow .
- Open standards to provide the core for future automation.

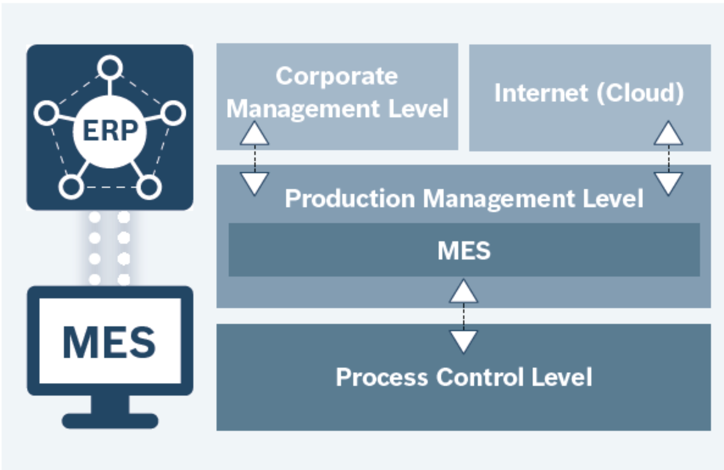

Figure 14: The open architecture of Bosch Rexroth's automation platform (Rexrouth Bosch Group, 2016)

The open architecture of Bosch Rexroth's automation platform as shown in figure 14 enables the direct communication between the Manufacturing Execution System (MES) and distributed control systems, and hence permits the real-time monitoring of manufacturing processes, and production functions. It also provides the access to the actuators and sensors.

4.2.6 Virtual tracking of supply chains at Bosch

On the path to connected production processes, the main focus until now has been on optimizing the production and supply chain activities. As a result of the newest IT technologies, it's currently attainable to represent production processes and physical flows by means of virtual reality techniques. With the assistance of **Kanban system and RFID technology**, product status and condition are recorded accordingly at Bosch. The data flow takes place in real time and goes beyond company borders to enable **end-to-end optimization of supply chain**.

Bosch is operating in many factories around the world using high-frequency labels (HF technology) and Kanban systems. Today, these technologies control the quality and are applied inside the Bosch group factories for various supply chain applications.

The Kanban system is mainly controlling the final phase of production, for example, if the level of stock in the final phase of production is less than the required minimum value, a notification is then sent to the upstream production unit so that new goods can be prepared. Moreover, Kanban cards are used to ensure that information about consumption is passed on and when a material is used up, the card is then located in a collection box. These cards are gathered and distributed on a regular base to the locations where the required material is prepared. In the past, the physical flow of material required great time and effort because it was monitored by an IT system manually. Errors occurred at very high rate and the data was never up to date, there was no synchronization between the information and the material flow. Nowadays, supply chain activities are performed differently due to the use of **the RFID technology and software-based data exchange** (Bosh software innovations , 2017).

In 2017, Bosch reported 30% reduction of stock in processes and 30% efficiency increase in processes due to the logistics with RIFD (Bosh software innovations , 2017).

4.2.7 Secure and safe value creation network

Safety and security procedures are major concerns for Industry 4.0. This includes the protection of people from machinery-related hazards and the protection of production facilities and IT from outsider attacks and flaws. Since data is a critical element in Industry 4.0, it is extremely important not just to protect it but also to prevent any potential malfunctions. The upgrade from the value-adding chains to intercompany and interregional value-creation networks that has been brought by Industry 4.0 require data exchange across the whole value chain. Participants will have to apply the same standards and processes in order to make the common network safe and secure (Bosch, 2018).

Bosch is a working member of many initiatives handling these issues and currently is participating in defining necessary standards. These outcomes are being executed persistently into all components, systems, and solutions Bosch offers. At Bosch, Security Engineering is an essential part of the product life cycle management. It aims to ensure the finest possible IT security from the very beginning (Bosch, 2018)

4.2.8 Blockchain technology

Blockchain technology is used wherever data is needed to be tracked. Bosch are researching many possible solutions to gain benefits from the blockchain technology, since it provides some advantages such as transparency, security, as well as efficiency. Blockchain is seen by Bosch as a decentralized system that stores a written record of assets and transactions across an end to end network. (Gessmann, 2017)

4.2.9 Bosch Eco-system

Bosch relies on a strong ecosystem when dealing with Industry 4.0. They understand that no single company can exploit the new opportunities alone. Figure 15 shows Bosch eco-system which involves smart things as they are the base for the new services, third party developers in order to use and deliver innovative applications, users as their roles are not limited to the use of the services or the products but extend further to contribute in order to provide enhancements through generated data, and partners are to participate and contribute to add value along the entire ecosystem (Bosch group, 2018)

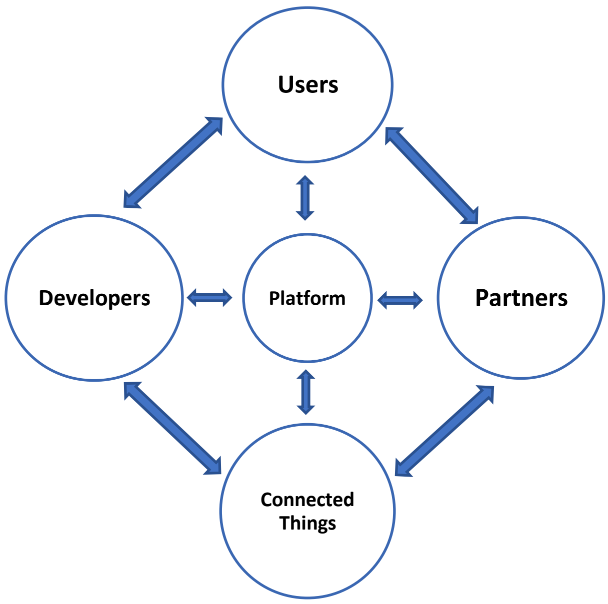

Figure 15: Bosch Eco-system.

Bosch partner selection can be characterized based on three elements which are diversity, openness and new ideas. They have partners in many sectors such as cloud strategy partners, technology partners who aim at developing integrated software solutions, consulting partners who would bring their expertise for the purpose of shaping the digital. Transformation and expanding the common view of the IoT world, open source partners, partners in the field of semiconductor technology who implement the products of Bosch software innovations in their technology and hence create benefits for the customers, implementation partners, consortial engagement partners who define IoT standards together with Bosch as well as consulting partners. (Bosch group, 2018)

4.2.10 Connectivity infrastructure with fast internet

A key success factor for a productive implementation of Industry 4.0 is a superior connectivity with fast broadband internet. After all, an oversized variety of sensors, actuators, and different devices are all connected with each other in the industrial plant. This accordingly will create smart systems which are then characterized by a high degree of efficiency, and flexibility (Bosch group, 2018). Bosch became a sort of a software company with the development of its own cloud-based IoT platform Called Firmware Over the Air (FOTA).

Bosch currently believe that the fifth generation of wireless mobile technology (5G) will play a key role, since its rate is more than ten gigabits per second, which is ten times faster than the 4G mobile phone technology. This remarkably will increase the quality of data being exchanged as well as its reliability along with real-time competences (Bosch group, 2018).

“5G Alliance for Connected Industries and Automation” (5G-ACIA) is a recent initiative that has been able to bring together more than **40 companies** including Audi, Ericsson, Huawei, Siemens, Sony and Vodafone. **Among with research institutions** including German Research Centre for Artificial Intelligence, for the purpose of shaping fifth generation of wireless mobile technology from the very start so that it will be effective regarding the needs of Industry 4.0. It is also very unique to find representatives of the automation and manufacturing industries joining forces together with others from the ICT Industry in a world-wide phenomenon and cross Industry collaborations as they believe that not a single company will be able to obtain the benefits of the connected world alone.

4.3 Use cases within the Bosch Group regarding Industry 4.0

Use case 1: Bosch adopts the interoperation between human and robots (APAS)

APAS is a technical device by Bosch that has applications in a wide variety of industrial fields. Bosch analyzes the collected data and uses it further in improving the technical assistant. **APAS allow humans and machines to work safely together without the need for a safety barrier.** The robot automatically stops without any contact at all when a worker comes too close since it is supplied with comprehensive safety mechanism (Bosch Rexroth AG).

Figure 16: APAS assistant at Bosch (Bosch Global)

The APAS assistant offers multiple advantages such as modular designs, efficiency, flexibility and mobility. APAS assistant has many configurable settings and software. There is no need for a fixed positioning for the assistant at the work place. The flexibility of the APAS assistant extends to the fact that robots with different kinematics can be integrated and connected on several configuration levels through the open architecture of Bosch Rexroth's automation platform. It is also applicable to monitor the robots directly with standard programming in PLCopen, high-level, or script languages.

Real life success story: Retrofitting without line downtime at Bosch Homburg

Since June 2017, Bosch Homburg have been using two APAS assistants in the production of Diesel injection systems for utility vehicles. They have been performing the previously manual tasks of joining and aligning magnetic cores and tubes, and also tasks related to the insertion of components into a welding laser. These two robots **increase the productivity of the entire line**. Furthermore, they are collaborating with employees to take over the monotonous tasks at an ergonomically difficult workplace.

“The automated production assistants are ideally suited to upgrade existing lines” says Stefan Betz, who is the mechanical design manager at Homburg. The APAS assistant is equipped with a sensor skin, which surrounds the robot arm, and that makes it not necessary to have a safety enclosure which requires space. So, it was clear that the APAS assistant is a better solution than supplying the line with a second conventional shielded welding system for the purpose of increasing the capacity (Bosch APAS, 2018).

The Homburg line uses two APAS assistant, one to remove the magnetic core and sleeve from the washing frames, and the other is used to insert the joined parts into the laser welding station. It is important to mention that the magnet assembly line was able to produce and continue operating along the entire modification process. **One weekend was enough for modification and start-up instead of 4 weeks of downtime in the case of implementing a conventional robot with safety fence since it needs major modifications.** That highlights the short realization times and straightforward implementation that the APAS can offer. (Bosch APAS, 2018)

Use case 2: software solution Process Quality Manager (PQM) at Bosch

The Process Quality Manager (PQM) can control and document manufacturing processes safely and accurately. It gets data from machines and devices on the shop floor at the factory and works through WIFI connectivity It can cancel out any deviations or error from the standard process immediately, being able to avoid producing defective parts can save money and offer full control of manufacturing processes and eliminate errors from the beginning. PQM gives notifications when any fault in the manufacturing process occurs. This can help experts to optimize production processes. This will lead to achieve zero defects, clarity in production, and maximum output possible. Data may then be kept in clouds which provides worldwide availability of data in addition to advantages like scalability and reliability. (Rexrouth Bosch Group, 2016)

Data analysis has been the focus of enormous production firms that operate their own IT infrastructure and use over one hundred fifty tightening systems. It currently additionally offers possibilities for SME especially firms that outsource the process as well as the IT infrastructure maintenance and only operate on a small number of tightening processes.

Figure 17: Process Quality Manager in Smart Tightening (Rexrouth Bosch Group, 2016)

One of the most significant advantages of cloud solutions is that they do not require any initial investment virtually nor any commitment with regard to how long they have to be in operation before paying off. This cloud model can provide companies with the ability to integrate manufacturing sites worldwide in stages in order to centrally monitor tightening processes and make decentralized use of expert knowledge.

AT Bosch Connected World Conference 2016. Bosch reported that within the first year of using the PQM. These results came out:

- **Down time reduced by 10%.**
- **Failure costs reduced by 10%.**

Real life example: the manufacturer of sports car seats.

A firm that is producing sports seats for cars and which has 150 employees. This firm has 20 tightening systems on its assembly line with a rate of producing one tightening operation every two seconds. Their usage of the cockpit in the cloud does not need more than a normal DSL connection (Palm, 2016). The provider manages the installation of patches and associated processes and maintenance. This in return leads to cost savings for users each month.

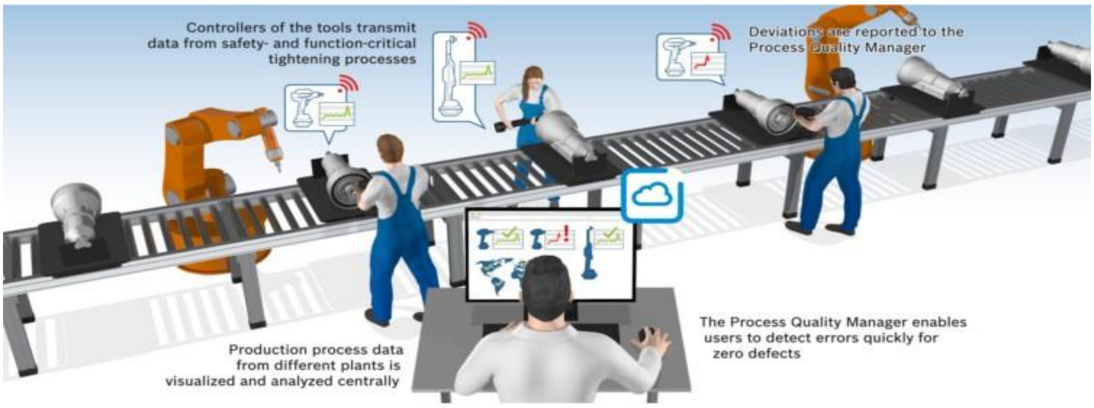

Figure 18 Using the PQM to visualize and monitor the quality of tightening processes (Palm, 2016)

New Pricing Models such as Pay-Per-Use are applied regarding this case. The manufacturer can pay for the process monitoring services based on the number of the tightening processes applied. Moreover, the manufacturer can control the number of tightening systems linked to the process monitoring service at any time, as they want or need since they are not obliged to use a specific number of systems which highlights the **flexibility** advantage in this case.

Use Case 3: Homburg plant, Networking of machinery and products

A pilot line is recently integrated into the “Bosch Production System” (BPS) at the Rexroth plant in Homburg, Germany. This line enables the semi-automatic production of disc valves for tractors in 6 main types and more than 200 variants.

RFID and connectivity allow devices, products and people to contact with each other for flexible and economical production of customized offerings. Smart tool carriers labelled with RFID tags are used to find the desired product alternative and contact the required materials and processes to the production line. Each station checks these tags and show the relevant information to the worker on screens to **reduce the time and to enable optimal usage of resources.**

Operators and decision-makers within the Production communicate through the platform which facilitates the fast initiation of the required production processes. That accordingly reduces **breakdown periods and provides more productivity**. Moreover, this platform can immediately provide the operators with the required solutions and information. Each workplace immediately adapts according to the specifications of their associated operators due to using Bluetooth tags with operators’ profiles. These profiles are obtained by every worker and then figured out by the assembly station. For example, the font size and language of the monitoring are changed consequently. And also, the data extent is adjusted on the screen according to the specifications of the actual operator then. The active Cockpit production data system developed by Rexroth repeatedly gathers, evaluates and show production data (Rexroth Bosch Group, 2017)**.**

In 2017, Bosch reported some results regarding this line as following (Robert Bosch GmbH , 2017):

- **30% stock reduction with no setup.**
- **10% output increase.**
- **cost savings up to 0.5 million € /year/line.**

Use Case 4: Odometer fraud in motor vehicles using Blockchain

As a result of the partnership between Bosch and the University of St. Gallen, ETH Zürich. Bosch IoT Lab team figured out this use case regarding using blockchain to prevent odometer fraud (Gessmann, 2017).

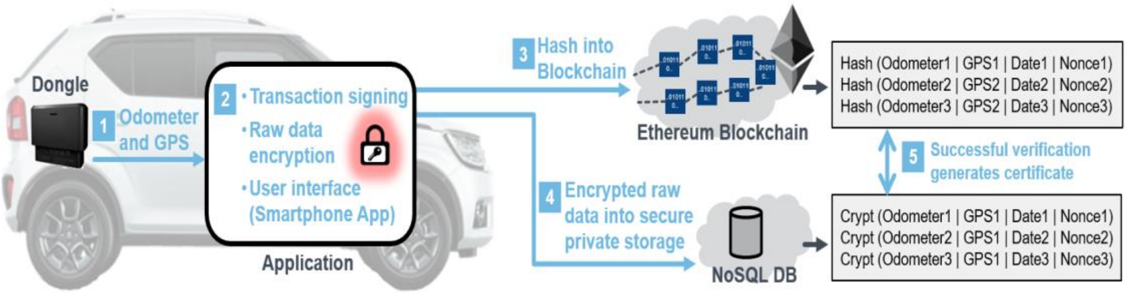

Figure 19: The prototype architecture of Odometer Fraud detector (Wortmann, Chanson , Bogner, & Fleisch, 2017).

A general overview of the prototype design is shown in Figure 19. Odometer values are restored from the car using a dongle that can also record GPS values. These values are sent to the main application running in the vehicle. The application sends the data to the public Ethereum blockchain which is a worldwide accessible and secure database. This dataset is encrypted regionally and saved through a cloud. Only the vehicle owner can check this data and guarantee the data privacy all the time since Data cannot be hacked without having to hack into most of the remain computers among the network that store precisely the same data, too (Wortmann, Chanson , Bogner, & Fleisch, 2017).

The customer interface in this use case would be a smartphone application and it receives information from the main application. Customers can have a digital certificate that tells the truth about the miles history and they may pass the data to a third party if they want (Gessmann, 2017). A screenshot from a smartphone application is shown in figure 20.

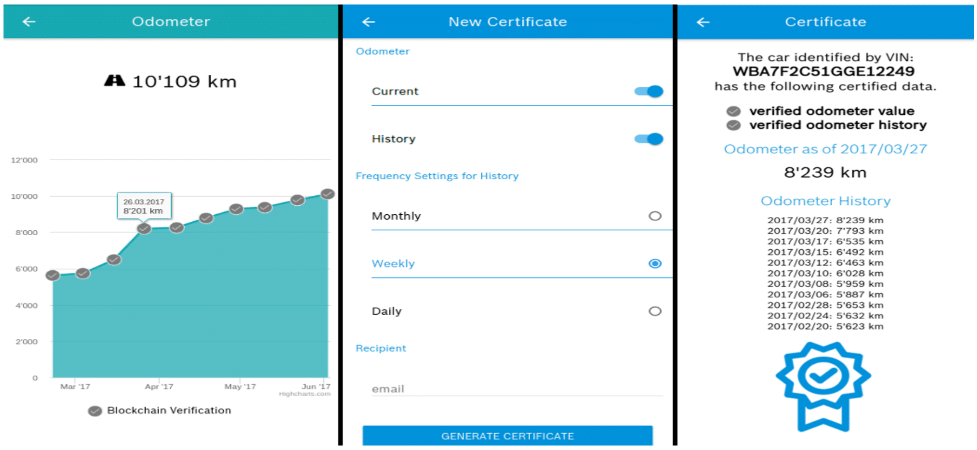

Figure 20: Screenshot from the smartphone application shows Three months of the odometer history (Wortmann, Chanson , Bogner, & Fleisch, 2017)

Due to the cooperation between IBM and Bosch, blockchain solutions were established within 3 months, by a tiny team as announced by Josef Maichle, Head of Advanced Analytics at Bosch at the "The Genius of Things Summit, 2017". According to him There is a high probability for productive usage of Proof of concept, and many other use cases within Bosch are being evaluated such as Logistic chain, sharing economy, spare parts authentication and Health care. Which highlights the advantage of this use case to be extensible to other business cases and to be used by Bosch itself and their customers, in other words economies of scope.

This innovative idea can be a solution for the fraud issue in the automotive market which has been a widespread problem. It enables the users to be the data owner and to be completely responsible of the data they generate and empowers them to use it the way they want without the need for intermediate platforms or parties.

Use case 5: Business models for mySPIN smartphone integration solution

mySPIN is a new set of offerings by Bosch to integrate the mobile devices and the vehicle into a single infotainment system which can help the drivers and provide them with a new level of accessibility. It allows the user to get to their applications and data while driving. It is easy to use applications on other two-wheelers now which provides a very different experience and good safety. Since mySPIN is known for being white tag product, it can be renamed according to the customers' needs and desires, which highlights **the customization offerings by Bosch** (Bosch SoftTec**.** In the future, it will be possible to use real time data to warn drivers of hazards such as traffic stop.

mySPIN solutions are available globally, and that also include China and India. Bosch SoftTec used this successful application from the automotive market and presented it at EICMA 2016 to the two-wheeler industry. Bosch SoftTec welcome partners all over the world to be part of their world of mySPIN 2W and in order to make their application as compatible as possible with the **Bosch eco-system**.

The relationship with customers does not need to end at the sale point but moreover can be extended throughout the whole lifecycle of the devices and this can cause more value for the users and enhance **the long-term relationship with customers.** OEMs can customize these applications with regard to the portfolio, home screen and functionalities with little efforts. Moreover, OEMs can also develop applications that would work on their two-wheeler only. It is also noticeable that in this case the monetization potential can be extended **throughout the entire lifespan of the vehicle and adds additional value for the driver.**

Some **new pricing models** can be used with this application such as add-on for an existing app or service, hence two general modes can be differentiated here: In-app purchases and Premium version. The first one allows the mode and other extensions to be added to an app through the app purchase. The last one allows the user to download the premium version of an app in order to use the connected mode.

There are almost no marginal costs for the smartphone integration solutions, especially if the license is sourced on a flat rate basis. Then the end customers can decide, **how much they want to pay for the smartphone integration of their vehicle.** This customer centric pricing mechanism lead to **better customer satisfaction, higher revenues while marketing awareness is created for free**.

Moreover, it can be either provided as a separate subscription model or used as an added-up service to an existing **subscription model** for OEMs digital services. Clearly, one of the most significant advantages of such a model is the constant cash flows. That cash flow is created throughout the whole lifecycle of the vehicle. This model also enables the engagement with customers through various touch points.

This case highlights the strong relationships with the customers since it guarantees their loyalty and satisfaction especially regarding the downtime and long term relational nature. It is also possible to use the collected data to get some insights into the product real performance and then enhance maintenance and reduce cost especially with regard to R&D spending and inventory.

Use case 6: conventional power tools into intelligent power tools with new target groups

Bosch Power Tools is bringing new values due to the use of sensors in impact drills and rotary hammers to manage and reduce the risk of injuries caused by the kickback. Bosch is working on increasing their connectivity as they believe it will offer various possibilities for additional growth. They are transforming traditional power tools into smart ones which can provide customers with much more satisfaction and productivity.

Bosch already provides a wide range of smart and connected tools such as angle grinders and remote-controlled lasers. These connected tools bring two major advantages along; customization and transparency, for instance notifications are being sent in case of overheating or in case of calibration errors, troubleshooting is being provided at the same time any problem happens which can enhance the remote diagnosis.

Bosch has been **expanding their measuring tools segmentation** with regard to the Zamo laser measure, which is an economic and easy tool that is available for everyone. The recent generation of tools is not a traditional laser measure, for example, it will become a global household measuring tool. With recent different adaptations, customers will be able to measure flexible and different shaped objects. Bosch is working on reaching new target segments which is also driven by meeting user needs. They are working to bring Bosch power tools to new sectors and areas of life not just the DIY enthusiasts (Bosch Power Tools, 2018).

Bosch recognizes strong potential in **emerging markets**. Emerging markets require availability but also affordability and that can happen with Industry 4.0. Bosch is expanding their existence in emerging markets as in 2018, they are offering nearly 50 professional tools for customers in those markets. In Africa, Power Tools will concentrate more on its sales units from now on. they are expanding their logistics network. In the last two years, Bosch Power Tools units were placed in 6 African countries. (Bosch Power Tools, 2018)

Use case 7: Bosch is enabling IoT into the world of Agriculture

The problem in this case was that the quality of asparagus mainly depends on the soil temperature. Traditionally, farmers would use a foil sheet to check the temperature, this sheet has two sides; the black side which increases the heat of the asparagus bed using sunlight, and the white side is to cool the bed down since it reflects the light.

Farmers have to measure the temperature of every field at least once every night, in order to be able to decide which side should be used and that can be inefficient and time-consuming. Then Bosch was able to provide them with an IoT system that measures the temperatures of the bed at different levels, collect and analysis the data and keep it accessible in the cloud while providing them with insight through a front-end interface.

The IoT enables Bosch to reach a totally new customer group that they had nothing in common before. In April 2015, Bosch established 10 prototypes for 7 farmers with getting asparagus advisors involved in the project. Then based on an intense collaboration between Bosch and asparagus farmers, they were able to develop that system further and to come up with 4 application updates . 12 weeks later, Bosch supervised the growth of 225,000 kg of asparagus and managed to gain some deep insights into the new customers' needs and desires. (Lasarczyk, 2015)

They were able to run the first prototypes within 3 weeks of planning and internal discussions and just 3 weeks of implementation. The solution would be as following; Temperatures data are sent to a smartphone, so that farmers can keep track of any temperature change which would result in providing optimal growing conditions and predicting the optimal time for the harvest (Denner, 2015). The monitoring process of Asparagus using IoT services by Bosch is shown in figure 21.

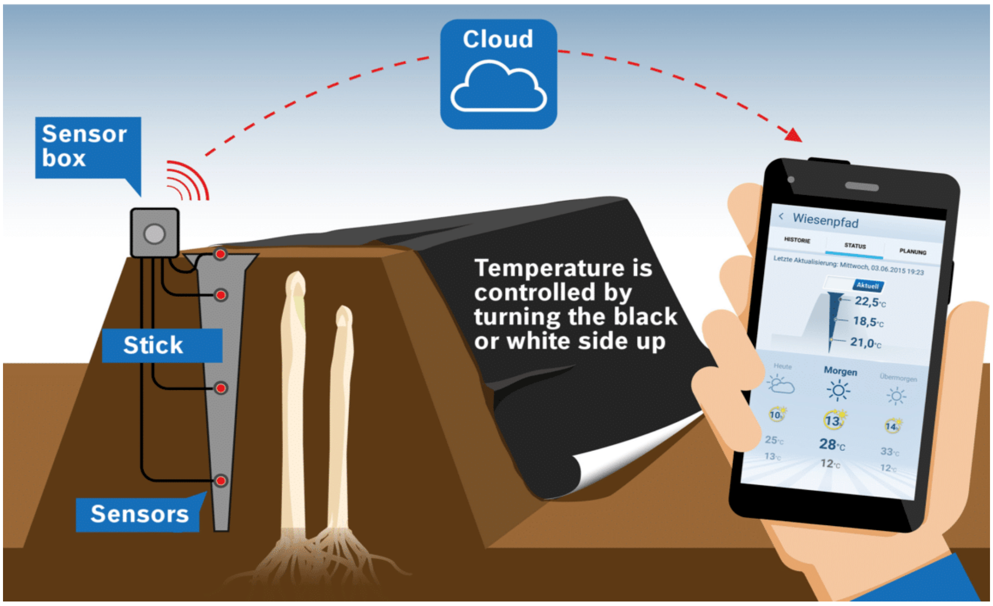

Figure 21: Asparagus-Monitoring using IoT (Lasarczyk, 2015)

Bosch did not only provide them with connectivity solutions and an easily scalable IoT platform. But also, with a lot of consulting through insightful market studies and purchasing support with the help of expertise in user experience. Bosch clearly is moving forward to target new customer segments as they have a new goal to become a global supplier of IoT services in agriculture. (Lasarczyk, 2015)

This solution has already been tried out with regard to the asparagus case, but the principle can be implemented for other crops and different cases. They have applied their market and customer expertise to the platform, in order to facilitate using it for other cases and customers. Bosch are currently examining the marketing of this new system and the possibilities of using in more comprehensive way. (Lasarczyk, 2015)

4.4 Discussion

Looking back into the characteristics of BMC 4.0 which is presented in chapter 3 and into Industry 4.0 at Bosch. We decided that in order to be able to validate the theoretical framework, it is important to come up with the main characteristics within each use case in order to be able to observe if there is any matching. Table 6 highlights the matching characteristics in each use case. We can clearly observe consistency between what theory recommends as appropriate characteristics that should be involved in a business model for Industry 4.0 and what is adopted in reality and especially in the Bosch Group.

Table 6: Matching characteristics within the Use cases.

Use Cases	Matching Characteristics
Use case 1	• Safety and security procedures. • Training programs. • Data collection and analysis. • Product and process development. • Flexible offerings. • Integrated product- service offerings. • Cost optimization. • Digital infrastructure. • Qualified and adaptable workforce.
Use case 2	• Data collection and analysis. • Cost optimization. • Product and process development. • Vertical integration. • Digital infrastructure. • Horizontal integration. • Economies of scope. • New pricing models. • Flexible offerings.

Use Case 3	• Mass customization. • Flexible offerings. • Cost optimization. • Data collection and analysis. • Reference Architecture. • Digital Infrastructure. • Qualified and adaptable workforce. • Product and process development. • Supply chain Agility. • Vertical integration.
Use Case 4	• Partnerships with education and training institutions. • Smart contract transactions (Blockchain). • Direct and digital communication. • Increased customer integration. • Long term relational nature with customers. • Data collection and analysis. • Safety and Security procedures. • Partnerships with IT companies. • Economies of scope.
Use Case 5	• Customized offerings. • Flexible offerings. • Eco-system networking. • Long term relationship with customers. • Integrated product- service offerings. • New pricing models. • New marketing campaigns. • Data collection and analysis. • New revenue streams • Cost optimization.

Use Case 6	• Integrated product- service offerings. • Digital infrastructure. • Expanded customer segments. • Customization. • Segmentation based on data analysis. • Product and process development. • Cost optimization. • Flexible offerings.
Use Case 7	• Increased customer integration. • Expanded customer segments. • Integrated product- service offerings. • Long term relationship with customers. • New marketing campaigns. • Direct and digital communication. • Data collection and analysis. • Digital infrastructure. • Eco-system networking. • Economies of scope.

Chapter 5 Conclusions and Recommendations

This chapter shows the conclusions of this research which can be presented in two parts. Firstly, conclusions with regard to the design of the framework. Secondly, conclusions upon the case studies within the Bosch group. Then recommendations for further research are provided.

5.1 Conclusions upon the Business Model Canvas 4.0

The available literature did not provide a specific framework to determine impacts of Industry 4.0 on a business model. This research was conducted in order to provide a framework which includes the appropriate characteristics of a business model in the context of Industry 4.0. In order to develop such a framework, it was necessary to identify the key drivers, potential opportunities and challenges of Industry 4.0. in the end, an appropriate business model for Industry 4.0 should have the following characteristics:

- High level of customization and flexibility with regard to the product or the service offered. In addition to integrated product- service offerings, while taking into account that the level of complementary between products and services needs to be determined. Product- service offerings in the context of Industry 4.0 will implicitly offer additional values such as novelty, functional guarantee and high efficiency;

- Data collection and analysis with regard to business processes and the use of this data for the assessment of production conditions and for product or service development. Process development in order to cope with the new conditions and challenges;

- Horizontal integration through the value network with the exchange of materials, energy and data along the whole network through an agile supply chain. Vertical integration of manufacturing systems in various hierarchy levels on both production and corporate scale;

- A value network of engaging participants among customers, suppliers, partners who are willing to share goals and responsibilities and to cooperate wherein co-production and co-development can be established. Along with partnerships with legal experts, education and training institutions and IT companies;

- Developed digital infrastructure which is flexible and scalable and equipped with advanced connectivity that enables real-time data streamlining. Besides qualified and Adaptable workforce;

- Increased customer integration through long term relationships and along the different phases of product life cycle since they play a new role as co-designers and value co-creators;

- New marketing campaigns to raise awareness about the new offerings, direct and digital communications as well as smart contract transactions in order to unify customer information through single central database and eliminate unnecessary intermediate parties;

- Expanded customer segments based on data analysis which leads to greater and more accurate understanding of customers' real needs and desires;

- Data-based new revenue streams with dynamic pricing models. Financial adaptation due to longer payback periods;

- Adaptation of training programs and employees' skills to meet Industry 4.0 new requirements. Advanced safety and security procedures to provide some guarantees and better risk assessment methods. A well identified standards and reference architecture in order to assure common comprehension through the network;

- Initial costs and investments due to the establishment of the additional required resources and infrastructures. Cost optimization due to real time simulation regarding costs incurred in the firm and the ability to optimize the consumption of resources and energy. Economies of Scale, Economies of Scope and Network economies.

Business models are expected to witness significant change due to the existence of Industry 4.0. The potential for the development of new and profitable business models is unlimited. Industry 4.0 will also give rise to cost benefits, for instance as a result of optimization and simulation or increases in productivity . Business models in the context of Industry 4.0 are characterized to be data driven due to the wide utilization of data in order to provide innovative offerings. This evolution is believed to lead towards more sustainable business models.

The proposed characteristics are shown in figure 22. The theoretical framework has a comprehensive nature since it can be implemented within different industries and firms, besides, it is mainly based on Industry 4.0 different key drivers. It shows the impact of the basic components of Industry 4.0 as it is not restricted to a specific technology or driver. It describes the characteristics that should be integrated by the new or adapted business models in order to embrace Industry 4.0.

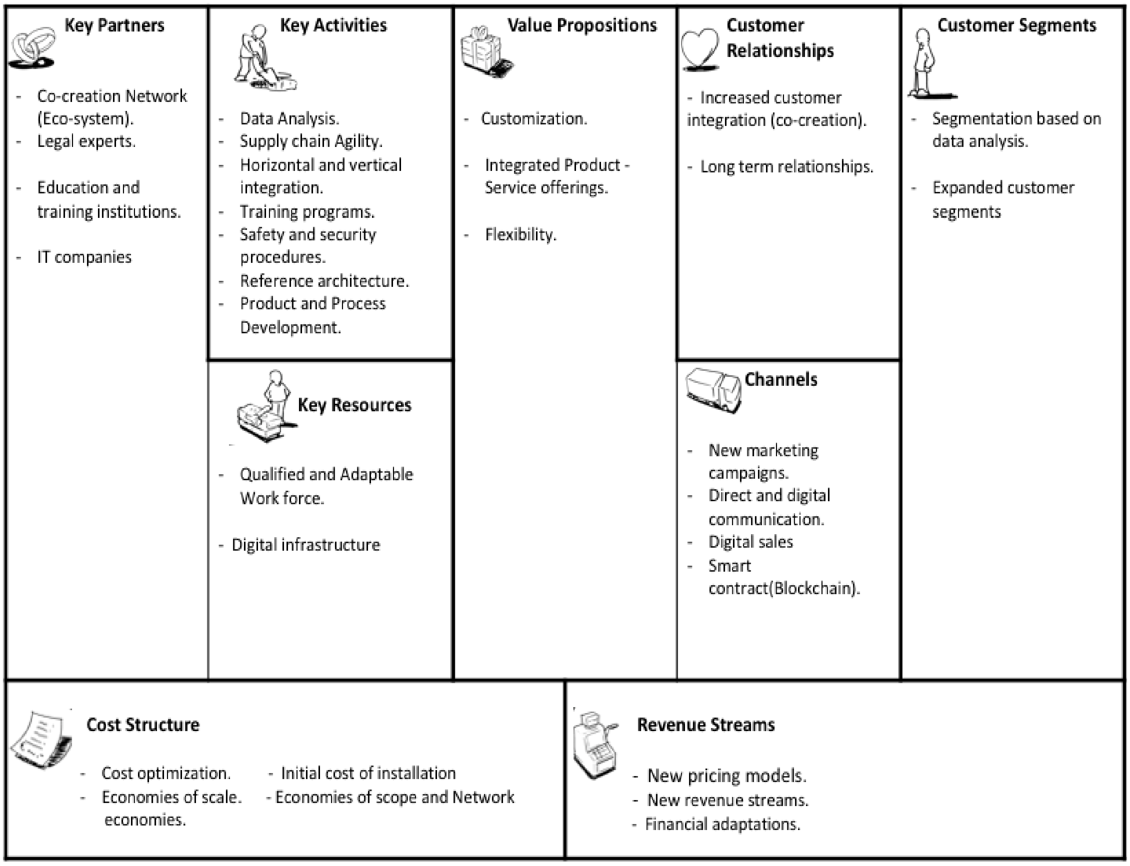

Figure 22: Characteristics of BMC 4.0

The BMC 4.0 framework is based on multiple levels of analysis and aggregation. It comes from multiple theories and hence it is extensive and can be used by firms who are seeking to adopt Industry 4.0. Firms can easily determine which characteristics suit their business and should be adopted based on their current business model and the desired development which will highly depend on the level of engagement these firms have with regard to Industry 4.0.

It is also expected that the different characteristics of the framework would have different relevance and importance among firms with different business contexts and organizational properties. Furthermore, it is important to point out that the recommended characteristics can be implemented on different scales. Organizations are no longer competing as individual entities but rather as a network. Those who can build, organize and manage the relationships with their partners in a network will enjoy a sustainable advantages and better customer relationships.

Business model innovation in the context of Industry 4.0 can de due to the fusion of technological innovations into business processes which would require the design of an appropriate and more suitable business models in order to get the benefits of these technologies, and due to obtaining new values as a result of the reconfiguration of resources and capabilities.

Industry 4.0 can provide business models with competitiveness on the long run by means of providing product service offerings instead of selling only tangible products. Traditional businesses in all sectors need to innovate their business models. For instance, product companies are looking at how to integrate services into their products to deepen their relationship with customers beyond the purchase of the product and offer more values. Business to Business companies are looking at how to move to direct Business to Customer companies. Firms are investigating to add digital services to their portfolios. Industry 4.0 brings along many advanced technologies with intense automation, yet people are still a key player.

5.2 Empirical findings within the case study

Several impacts of Industry 4.0 have been identified within the Bosch group and the associated use cases as following with regard to each element of the Business Model Canvas:

1. **Value Propositions**: Bosch clearly is offering customized flexible products, product-service offerings and novel solutions while monitoring the product life cycle thanks to the dynamic configuration of different processes. Bosch is also providing their customers with more functional and efficient products;

2. **Customer Segments**: Bosch is appealing to new target groups as derived from user requirements and thanks to Industry 4.0, they are able to provide new solutions into new areas of life and new markets that previously didn't have much in common and yet the results are very positive;

3. **Customer Relationships:** Bosch has an intense long relationship with its customers. the increased customer integration can be observed through many products and projects Bosch offers. Customers are value co-creators and they are cooperating in many ways to enhance the provided offerings and maintain this long-term relationship due to the nature of the integrated product-service offerings;

4. **Channels:** Bosch enables the digital sales and they have strong touchpoints with customers in order to raise awareness about the novel values, they conduct a lot of seminars every year as well as marketing campaigns with regard to their new products. Direct and digital communication is easily applicable through software applications, document-sharing systems and online platforms. Bosch can reach end customer directly, while excluding intermediate entities of the value chain as for example the case of Odometer fraud in motor vehicles thanks to the usage of smart contracts like Blockchain;

5. **Key Activities**: Bosch is already implementing all the key activities that were suggested by the framework, such as data collection and analysis within their daily working routines ,production and logistics operations and to get insights into real-time performance. Horizontal and vertical networking through software solutions

and platforms. Training programs through their new innovation centres and learning initiatives programmes. Supply chain agility, safety and data security procedures through comprehensive safety mechanisms and IT security. Open standards with reference architecture as well as process and product development;

6. **Key Resources**: Bosch has the required digital infrastructure by the means of scalable IT infrastructures and intelligent machines. They are investing more in enhancing their connectivity and broadband internet infrastructure. And for the qualified and adaptable workforce, they have taken on the responsibility of having the required qualifications and skills by engaging with education and training programs while empowering universities by means of training courses, training systems, and modern media technology designed to cultivate skills relating to Industry 4.0 and opening new innovation centers;

7. **Key Partners**: Bosch is involved in a strong eco-system network which can be noticed in many of their projects and offerings in different industries and even with research institutions. they are convinced that in order to success with regard to Industry 4.0, it is important to collaborate with partners. Bosch eco-system regarding IoT includes players such as: users, developers, smart things and partners. They have a large network of partners in many sectors as following: Consortia Engagement, Implementation partners, Semiconductor partners, Cloud Strategy partners, Technology partner, Consulting partner and Open Source. Bosch also in the middle of many partnerships with education and training institutions as a matter of fact and for example, Bosch IoT lab is established thanks to the cooperation between the University of St. Gallen, ETH Zürich, and Bosch;

8. **Cost Structure:** Bosch is strongly obtaining cost optimization due to the increase in productivity and automation. They are able to reduce time and cost in many facilities and obtain optimal usage of resources. For instance, in use case 2: they reported that within the first year of using the PQM, they could get downtime reduced by 10% and failure costs reduced by 10%. Considering use case 3: they reported some results regarding the Homburg line in 2017 that indicated 30% stock reduction with no setup, 10% output increase and cost savings up to 0.5 million euro/year/line. Bosch is achieving short realization of new technologies which increases the productivity

as was mentioned in use case 1. They also reported in 2017, 30% reduction of stock in processes and 30% efficiency increase in processes due to using RFID within logistics. Bosch also enjoys Economies of Scale ,Economies of Scope and Network economies;

9. **Revenue Streams:** Bosch provides solutions with new pricing models as pay-per-use, dynamic pricing, and add-on for existing applications or services. The revenue streams within Industry 4.0 are indirect and extensive since they exceed the product sales to include potential opportunities for increasing the revenue through subscriptions, consulting and data processing to gain insights into the real-life product use;

Bosch obviously has the required qualifications for Industry 4.0 by means of products, systems, people and software, from automation on the shop floor level to integrated hardware and software solutions with regard to manufacturing and logistics. They also embrace the idea of networking and are empowering companies in order to turn their ideas into connected reality in an economical way.

Based on the empirical results from the seven use cases, it was observed that each use case includes some of the proposed characteristics, but all cases combined with the activities and investments done by Bosch with regard to Industry 4.0 as mentioned in chapter 4 show that the majority of the BMC 4.0 characteristics are happening in reality. Moreover, it was observed that with regard to financial aspects there was no mention of financial adaptations due to longer payback nor initial costs of installation as was suggested by literature. there was also no mention of any partnerships with legal experts as recommended by theory.

5.3 Recommendations for future research

Several recommendations for further research can be proposed as following:

- Applying a scale model on the recommended characteristics in order to determine the different impacts on business models and assess these characteristics' relative importance and frequencies since the level of relevance and intensity varies between different firms and industries.

- Testing the appropriateness of the framework on other case studies within different industries and companies since the different nature of operations is expected to require different business characteristics. There are particularly significant opportunities for Small and Medium Enterprises to develop services for Industry 4.0 and it is expected to get a different level of correlation if this framework is applied on Small and Medium Enterprises or start-ups .This hypothesis is yet to be verified by future research.

- Further research for the purpose of identifying different characteristics to update the framework given the fact that the market demand is changeable, and that Industry 4.0 potentials and technologies are not yet fully realized.

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