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BUSINESS MODELS ENABLED BY INDUSTRIE 4.0 AND
INTERNET OF THINGS

BY

FABIAN LUDWIG

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

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UNIVERSITY OF RHODE ISLAND

2016

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OF
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2016

ABSTRACT

Industrie 4.0 (I.40), Industrial Internet and Internet of Things (IoT) are used today as generic terms to describe a vision that will connect all objects to digital networks, succeed in the digital transformation of existing business enterprise processes and fundamentally change the way of production and value creation. Many enterprises are confronted with a bundle of new market requirements in a more global and competitive environment. This may endanger their current market position and force them not only to reshape their product strategy but also to re-organize in parallel their entire company structure or even to search for new business models. The scope of all these efforts should be to create in time the improved or complete new business model that ensures or even better improves the profitability and market position of today's companies. Important strategic aspects out of I4.0/IoT-driven applications are to facilitate new business model initiatives with the purpose to sharpen the company's value proposition and increase the long term revenues and profits. This paper focuses on analyzing successful business models enabled by I4.0/IoT and identifying aimed core improvements, which can ideally be transferred to other companies and business sectors. It provides theoretical and practical grounded assistance to corporations that are today well-known manufacturers. A major scope of the study was to identify and present a selection of business models enabled or improved by I4.0/IoT. Finally, the thesis outlines the differences between the American and German companies in developing the I4.0/IoT business models.

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LIST OF ABBREVIATIONS

AR	Augmented reality
B2B	Business-to-Business
B2C	Business-to-Consumer
Bitkom	Bundesverband-Informationswirtschaft, Telekommunikation und neue Medien e.V.
BM	Business model
BMC	Business model canvas
BMI	Business model innovation
BMN	Business model Navigator
CPS	Cyber-Physical Systems
CPPS	Cyber-Physical Production Systems
ERP	Enterprise-Resource-System
GSM	Global system for mobile communication
GE	General Electric
HMI	Human machine interface
IIC	Industrial Internet Consortium
IIRA	Industrial Internet Reference Architecture
IoT	Internet of Things
IRB	Institutional Review Board
IT	Information technology
I4.0	Industrie 4.0

MES	Manufacturing execution system
OEM	Original equipment manufacturer
UMTS	Universal mobile telecommunications system
RAMI 4.0	Reference Architecture Model Industrie 4.0
RFID	Radio-frequency identification
ROI	Return on Investment
R&D	Research & Development
VDMA	Verband Deutscher Maschinen- und Anlagenbauer
Wi-Fi	Wireless Fidelity
ZVEI	Zentralverband Elektrotechnik- und Elektronik-Industrie e.V.

CHAPTER 1 – INTRODUCTION

With the expansion of the Internet and digitalization, many enterprises are confronted with new market requirements in a more global and competitive environment. Examples are significant changes in consumer behavior, increasing competition resulting from more market transparency and new competition due to lower market entrance barriers. This endangers their current market position and forces them to revise their complete business and product strategy and to re-organize their internal structures. The scope of all efforts must be to identify the necessary changes, activities and measures to maintain or to achieve a leading position in their field of action. Important strategic aspects of Industrie 4.0 (I4.0) and Internet of Things (IoT) are to identify new business models and service offers that will sharpen the company's value proposition and increase the long term revenues and profitability. Many of the business models enrich classical products with digital services to obtain new value propositions. This means that a traditional physical product can be extended with a sensor and connectivity to get the linkage to the internet and allow additional digital functions. This can be one important prerequisite to offer value-added services. Another I4.0/IoT business model approach is to evaluate which business models are successfully applied in the digital world that can be transferred to other industry sectors to achieve the desired revenues. Many of these new models use a completely new value proposition making them difficult to compare as they often target a new market. By implementing new business models in existing company structures various entrepreneurial risks can occur and should be ideally considered in advance. One

example can be new competition such as new market players when IT-companies, start-ups and investment companies try to gain market shares transferring their expertise from other areas of activity to a new business field.

1.1 Motivation

In the last five years, a lot of research was published in regard to topic I4.0/IoT and the related business opportunities that arise therefore for a large number of companies. The researchers recognize now what the German federal government and research union understands about cyber-physical systems (CPS), digitalization and smart factories and why a tremendous amount of research funds flows into the development of these technologies. This master's thesis sets the focus to another exciting topic, which deserves as much attention as the technical implementation of I4.0 and IoT. The thesis is about new business models enabled by the Industrie 4.0 and Internet of Things and the differences between the American and German business model approaches.

Siegfried Dais (2014), Chairman of the Steering Committee of the Platform Industrie 4.0 and Deputy Chairman of the Board of Management at Robert Bosch GmbH has recognized this:

- *"We have to think in business models! I am concerned that we are developing great technologies but other business will earn the success."*
- *"The development of the Internet shows us how primarily the American companies are extremely successful with transforming new technical possibilities into profitable business models."*

1.2 Problem statement

The main focus of the study is to investigate how I4.0/IoT-driven projects influence the existing business models in American and German companies and to evaluate which business model improvements and new business models are already implemented in practice. Table 1 shows the research questions of the thesis.

Main research question:	<i>What business model improvements and new business models can be enabled by Industrie 4.0 and Internet of Things?</i>
Sub-questions:	<i>What consequences are expected from I4.0/IoT technology for today's industry?</i> <i>What kinds of I4.0/IoT-driven projects are already implemented in practice?</i> <i>What are the differences between American and German companies in developing and implementing I4.0/IoT projects?</i>

Table 1: Research questions

1.3 Structure of the thesis

The thesis is structured in two main parts. The first part contains the literature review, including the theoretical fundamentals with definitions and explanations

related to the study. The second part provides insights about the chosen research method, the findings from a set of interviews with American and German companies, the identified use cases from industry and the conclusion.

Chapter 1 gives a brief introduction to the topic, states the motivation for the research, provides the research questions and presents the structure of the thesis.

The terms Industrie 4.0, Industrial Internet, Internet of Things and their differences are explained in Chapter 2. In the modern theory, Industrie 4.0 can be divided into different elements. I4.0 and IoT are based on two reference models, respectively.

Business models and business model innovations in theory are elaborated in chapter 3. The theoretical part covers aspects like from the definition over characteristics, main types of business models to frameworks from the practice. Digital business models as well as the transferability of business models are other aspects which are explicitly discussed in this part.

The impacts of Industrie 4.0 and the Internet of Things on business models is presented in chapter 4. This chapter is divided into the variants of Internet-driven business models, the emergence of new business model patterns and new opportunities of I4.0/IoT. The chances and risks as well as the challenges in implementing I4.0/IoT business models complete this chapter and the theoretical part of this thesis.

Chapter 5 covers the methodology of the study. It explains the reason for choosing this research method, the data collection technique as well as the type of analysis applied. At the end of this chapter the case companies who were interviewed are introduced.

Chapter 6 contains the cross-case analysis and results of the study. The findings were clustered in different categories, based on the structure of the questionnaire that was used. The end of this chapter shows the identified improvement of I4.0/IoT business models as well as the differences between the American and German approach.

Chapter 7 includes the conclusion which summarizes the main results of the thesis and provides recommended action for the future.

CHAPTER 2 – INTERNET OF THINGS AND INDUSTRIE 4.0

Experts involved in research and industry predict and expect the fourth industrial revolution, often named Industrie 4.0, Industrial Internet or Internet of Things, which is illustrated in Figure 1.

Figure 1: Industrial revolutions

These words are used today as generic terms and represent new opportunities for manufacturing companies. This new approach of network and connectivity means that machines, work places, sensors and IT systems can be connected along the whole value chain. These new connected systems, often called Cyber-Physical Systems (CPS), are able to communicate with each other and predict failures by analyzing the data. With digital networks based on I4.0/IoT technology it will be possible to collect and analyze data from machines with the goal of creating more efficient and flexible products at lower cost. In summary, the new industrial revolution will shift the whole

balanced model of competitiveness from firms and regions to an interconnected global model (Kagermann et al., 2013).

2.1 Introduction Internet of Things, Industrie 4.0 and Industrial Internet

In the world of tomorrow, the Internet of Things will influence almost every industry. This transformation is leading to the appearance of smart healthcare in the field of hospitals, smart mobility in field of transportation and smart grids in the field of energy supply. In the area of manufacturing, end-to-end engineering and vertical/horizontal integration across the value chain can result from the new ‘conditions/circumstances’ (Kagermann et al., 2013). The following sections provide the fundamental definitions for Internet of Things, Industrie 4.0, Industrial Internet and points out the differences between these concepts.

2.1.1 Definition of the Internet of Things

According to the definition from the German EU Presidency in 2007 the Internet of Things (IoT) is “[...] *the technical vision to integrate any kinds of objects into a digital network*” (Gabriel et al., 2010). Equipped with a unique identity, these objects are located in a ‘smart’ environment, which represents the connections between the physical world of things and the virtual world of data. So far only computers and other network devices have the possibility to connect with the Internet. However, a lot of everyday objects such as consumer goods, cars, healthcare equipment, power plants, or even clothes will be connected via the Internet and will be able to interact with each other, as depicted in Figure 2 (Gabriel et al., 2010).

Figure 2: Internet of Things

(Aria, 2015)

IoT is enabled by tiny, connected microprocessors, which are embedded in the objects and therefore invisible. By using integrated sensors, these small computers will be able to detect their environment, to process the gathered information, to communicate with other objects and even to trigger actions. Thus, things can ‘recognize’ where they are located, if other things are around and which activities happened already in the past (Gabriel et. al, 2010).

2.1.1.1 Value drivers of Internet of Things

An important driver for IoT applications is the value which they add to the world, and more precisely to a company or individual. Fleisch (2010) analyzed more than 100 existing IoT concepts and applications and identified four categories of value drivers (Fleisch, 2010):

Environment driver: For this driver, the system automatically triggers transactions when the physical distance of two sensors falls below a defined value. This technology is often applied to the in manufacturing and supply chain management environments. Whenever a product passes the scanned area, in other words leaves the inventory, a transaction like a replenishment order or alarm call is triggered (Vitzthum et al., 2008).

Sensor driver: This driver uses sensors to collect data. This method enables the possibility of constantly measuring the condition of the environment based on defined values. An example from practice is ‘Precision agriculture’, in which crops and plants are monitored by different sensors to obtain the maximum output harvest. To achieve this goal, sensors constantly measure the required sun brightness, temperature and amount of water. Besides this specific example, there are also a lot of other applications. They vary from condition monitoring in a production plant to early-warning systems for natural catastrophes. In summary, this value driver provides a cheap option to measure environment in detail.

Audio and visual feedback signal: The key aspect of smart things is to give feedback to individuals. While the sensors and devices are usually extremely small, they can give an audio beep or visual signal such as LED lights to the user who is interacting with them. From a manufacturing perspective, the audio and visual signals can help to broadcast information from a machine to an operator. Due to this technology, it is possible to improve production downtime and maintenance.

Mind changing feedback: This value driver results from merging “real” world with digital data. the merge between the real world and the digital world. This combination established a new level of human so it is possible to influence someone with a physical-digital feature. However, compared to the above mentioned drivers, it is not based on ‘new’ technical features of the Internet of Things. A possible example can be the electrical toothbrush that interacts with a superhero figure on the bathroom mirror to motivate the children to brush their teeth seriously. This trigger counts to the

phenomena ‘behavioral economics’ and will play a large role in the future (Fleisch, 2010).

2.1.2 Definition of Industrie 4.0

Industrie 4.0 is a collective term embracing a number of contemporary automation, information exchange and production technologies and can be seen as one part of the Internet of Things. It had been defined as a term for technologies and concepts of value chain organization which combine the elements of cyber-physical systems, cloud computing, RFID technology, cyber security and smart factory. The word Industrie 4.0 originates from a high-tech strategy project in 2012 called ‘Action Plan High-tech strategy 2020’ of the German government, which promotes the computerization of manufacturing (Friedemann et al., 2010). The German government thereby wanted to expedite the technological and social development in this area. Furthermore, the project should strengthen the collaboration between different market players and innovators. Together with the German associations VDMA, Bitkom and ZVEI, a cooperation agreement beyond association boundaries would be concluded which forms the ‘Plattform Industrie 4.0’. Nowadays the ‘Plattform Industrie 4.0’ is the leading driving force, with a goal of developing joint recommendations for the stakeholder, identifying relevant technology trends and setting standards for a uniform communication. The Plattform Industrie 4.0 defines Industrie 4.0 as: “[...] *the fourth industrial revolution with a new level of organization and the control about the value chain, including the entire life cycle of a product*” (Plattform Industrie 4.0, 2015). This cycle is based on rising individual customer wishes regarding the development, production and delivery of a product all the way to

recycling including related services. Industrie 4.0 enables the availability of all relevant information in real-time, and thus the ability to derive the optimal value flow from the data to any time” (Plattform Industrie 4.0, 2015).

2.1.3 Definition of the Industrial Internet

Industrial Internet is the American counterpart to Industrie 4.0 and was defined by General Electric (GE) as follows: *“The Industrial Internet draws together fields such as machine learning, big data, the Internet of things and machine-to-machine communication to ingest data from machines, analyze it (often in real-time), and use it to adjust operations”* (Lin, 2015). Hence, the Industrial Internet focuses on improving efficiency, big data analysis and better integration of humans into the production process. However on a closer look the two approaches have some differences, which will be explained in the following section (Lin, 2015).

2.1.4 Differences between the Industrie 4.0 and Industrial Internet

Industrie 4.0 describes a connected and integrated value chain that extends from procurement to the manufacturing and distribution and services. The ultimate goal is to reduce idle capacity and failures, improve efficiency and ultimately reduce total costs. In contrast, the Industrial Internet is considering the same process but is not limited to manufacturing. The core of both is that humans, machines and software should work all together hand in hand. Both concepts focus on improving efficiency, cloud computing, big data and human integration. Because the concepts follow the same objectives, it is fair to call them international siblings but on a closer look both

have some crucial distinctions, as described below (Plattform Industrie 4.0, 2014; Lin, 2015)

Key founders and stakeholders

Industrie 4.0 has three stakeholders: 1. the federal government which is represented by the Ministry of Economics and Technology and the Ministry of Education and Research, 2. the Plattform Industrie 4.0 which is represented by three associations: VDMA for machinery, ZVEI for electronics and BITCOM for IT and Research and 3. academia which is represented by the Fraunhofer-Gesellschaft, the German Research Center for Artificial Intelligence and the National Academy of Science and Engineering. In contrast the term Industrial Internet, defined by the firm General Electric, is an integrated approach of the Industrial Internet Consortium (IIC). The IIC was founded by the firms General Electrics, AT&T, Cisco, Intel and IBM in 2014 and is a nonprofit organization with the goal to “*catalyze and coordinate the priorities and enabling technologies of industry, academia and the government around the Industrial Internet*” (Industrial Internet Consortium, 2013). Furthermore, the IIC has many experts from the U.S. and Europe and is highly business-driven. It has 180 members including companies and research institutes from all over the world; the membership is open and the fees vary depending on the company size. Summing it up the IIC is a private consortium (owned by its members), whereas the name ‘Industrie 4.0’ was initiated and is owned by the German government.

Stages of revolutions

While Industrie 4.0 was named the fourth industrial revolution with four stages in its taxonomy (shown in Figure 1), the Industrial Internet taxonomy counts only three stages. For the Industrial Internet, the first was the industrial breakthrough of the Industrial Revolution, followed by the rise of distributed information networks also known as Internet revolution and lastly the Industrial Internet Revolution, including machine-based analytics and additive manufacturing (Industrial Internet Consortium, 2013).

Motivation

The Germany's initiatives supports the concept Industrie 4.0 in many ways. The ultimate goal for the Plattform Industrie 4.0 is: *"[...] to safeguard a sustainable competitive advantage of Germany's manufacturing base. On the one hand we must train German industry to build and install CPS, and on the other to make these remain competitive worldwide."* (Plattform Industrie 4.0, 2016).

The initiators for the Industrial Internet Consortium(ICC) is different. The objective is to enable the adoption of the Internet into different types of businesses, for instance the shop floor. In addition, the focus is the compatibility between different products and technologies, through so-called "testbeds". They can be described as platform on which experiments and analysis can be tested (Industrial Internet Consortium, 2013).

Technological Focus

Industrie 4.0 emphasizes manufacturing technology, such as automation, embedded systems and shop floor machinery. The Industrial Internet pursues a more general approach which is the attempt to connect as many things to the Internet, to obtain data, conduct analytics and ultimately increase efficiency. The scope of the IIC is much wider than the Industrie 4.0 approach because their focus is not limited to production and manufacturing topics (Plattform Industrie 4.0, 2014; Lin, 2015).

Geographical Focus

The concept Industrie 4.0 focuses so far only on Germany. Unfortunately the industrial guidelines developed in Germany are limited to Germany and are not effective in Europe or other countries. One of the first policy papers about Industrie 4.0 reinforces this statement: *“The lead markets for Industrie 4.0 are German-based manufacturing companies.”* (Plattform Industrie 4.0, 2014)

The IIC concept is different and is primarily open to everybody who is interested in creating new businesses with the Industrial Internet. The more people and companies that join, the more they can learn from each other. In general, the Industrie 4.0 approach is more national and the IIC approach is more global (Plattform Industrie 4.0, 2014; Lin, 2015).

Improvement Focus

The Industrie 4.0 approach is particularly focused on optimizing production by reducing energy consumption, making the supply chain more flexible or decreasing

the operating costs. In contrast the Industrial Internet approach aims to improve every asset by looking for incremental increases to its return. In other words, it is looking of ways for optimization beyond the manufacturing perspective (Plattform Industrie 4.0, 2014; Lin, 2015).

2.2 Elements of Industrie 4.0

Figure 3 illustrates the elements of Industrie 4.0. According to the study from Wieselhuber & Partners (2015), Industrie 4.0 consists of the following elements (Wieselhuber & Partner GmbH, 2015).

Figure 3: Industrie 4.0 elements

2.2.1 Cyber-Physical Systems

Cyber-Physical Systems (CPS) are automated systems which connect the physical reality with digital infrastructure and virtual communication. Unlike traditional embedded systems, which are usually built as stand-alone machines, CPS focuses on

connecting several devices with each other. These ‘classes’ of highly connected and collaborative computer-based systems, which are dependent on sensors and actuators, bring advances in the current digital world as well as in the physical world. A more technical approach is to define CPS as a combination of computation with physical processes. Embedded computers and network monitor(s) control the particular steps, often with feedback loops, in which physical processes influence computations and vice versa (Poovendran, 2010). Nowadays, CPS applications are so powerful that they outshine the latest IT revolutions. Possible areas of CPS applications are business sectors such as automotive, aviation, medical devices, traffic control, communication systems, manufacturing and smart living. As an example, the automotive industry could improve safety and efficiency by implementing embedded intelligence into cars or by using smart robots to build a ‘smart factory’. To give another example, the entire process of payment in the retail industry could be dramatically revolutionized by using RFID or similar ‘new’ technologies. The economic impact would be massive. The CPS of tomorrow is expected to be embedded in almost every physical product or module, resulting in a higher degree of automation as well as a higher complexity for the system (Lee, 2008).

2.2.2 Cloud computing

Cloud computing enables a more decentralized approach for the allocation of information, services and entire business models. It can be used to execute different software or apps as well as provide a platform for storing all the data. Due to the fast development and the increasing demand of web-based networking between individual, machinery and objects, the integration of the virtual and real world is only one step

ahead. The fast advancement of the technology brings an incredible increase of data and information. To manage this growing data volumes, new approaches in terms of big data are required. Big data may be defined as extremely large data sets that can be analyzed by computers to reveal patterns and trends, particularly relating to human behavior and interactions (Lee et al., 2014). Big data therefore combines several options to store, manage and use large amounts of data. To handle the volume and variety of the data, new technologies and algorithms for data storage as well as for data analysis have to be developed. Further challenges in the future might be the transfer and adaption of conventional data analysis methods, such business intelligence to the big data approach. Additionally, new requirements arise in the information area. Cloud computing allows demand-driven data exchange with the Internet in real-time by shifting all local services and processes to the cloud (Wieselhuber & Partner GmbH, 2015).

2.2.3 Smart factory

Cyber-physical systems and cloud computing are the prerequisites for smart factories. The connection and interaction in a smart production line can be between human-to-machine as well as machine-to-machine. The network of the machine-to-machine application consists of data networks, backend servers, connecting points for the sensors and actuators as well as control components. The components for the interaction between human and machine are called human machine interfaces (HMI). HMIs may assist humans to understand the complex processes and help them to communicate with the CPS (Strategy&, 2015). Nowadays there are a lot of different applications for HMI interfaces available including virtual touchscreens- and finger

print recognition systems as well as audio voice- and language recognition systems. These data contain product-, process- or resource-related information. For instance, order data might be collected through the whole year and afterwards analyzed in order to improve the order process for the next year. Smart phones and devices offer completely new opportunities for the operators. A machine has a breakdown, but has the ability to inform the responsible operator on his smartphone. The machine can transfer the entire 'failure history' in order to potentially avoid the next breakdown. Another approach of smart factory is augmented reality (AR). AR is the integration of digital data with video as well as the user's environment in real-time. More simplified, AR takes an existing picture and projects new information into it. By the use of AR, a lot of processes can be simplified to save costs such as trainings for new operators could be done without interrupting the entire production line (Weiner et al., 2010).

2.2.4 RFID technology

The RFID (Radio Frequency Identification) technology enables new possibilities within the shop floor and is therefore one of the basic prerequisites for Industrie 4.0 applications (Gubbi et al., 2013). One example can be the communication between machines and machines or autonomous production control and scheduling through the manufacturing process. The main advantages of using RFID in terms of Industrie 4.0 are quality improvement, shortening delivery time and efficiency improvement

Due to RFID, the smart product knows itself the upcoming production steps, and it can communicate with the machine and collect new information. To enable this potential, the products have to be equipped with a mobile data medium or so-called tag. The tag consists of a chip, which include the unique identity of the product, an

antenna and information about the production process. This RFID tag represents the memory of the product and allows decision making in real-time. When a smart product arrives at a certain machine, the reader device detects the attached RFID tag and adjusts the associated machine to the appropriate process steps. Every production step can be written back and can thereby identify incorrect products immediately (Gubbi et al., 2013).

2.2.5 Cybersecurity

In the last years, many IT crimes related to industrial control systems or infrastructure have been reported. The most famous and recent example is Stuxnet, which had the aim to sabotage an entire Iranian nuclear facility. Nowadays, cybercrime is a serious threat and a reason why many companies still run on analog production and management systems. Cybersecurity itself focuses on protecting computers, networks, programs and data from unintended or authorized access or change. Elements of cybersecurity are information security, network security, disaster recovery and end-user education (Ten et al. 2010). Since the use of IT technology and computers contributes to the success of a firm, the topic of IT security becomes more important for individual departments as well as the entire company. The current industrial systems offer different attack possibilities for hackers. Plants equipped with Industrie 4.0 technology include a lot of different cyber-physical systems, which contain of plenty of electronics. To enable communication between these electronics and humans, the electronics have to be connected to several network connections e.g. Wi-Fi. Unfortunately the connectivity of the production elements provides many options to attack the system. For instance, the software can be compromised by viruses

or Trojans or even human operator can be attacked by social attacks such as phishing. The ultimate goal of IT security is to protect firms from these attacks, or more precisely prevent the production system from breakdowns that can result in physical damage (Sageghi et al., 2016).

2.3 American and German reference architecture models

The following section presents the two reference architecture models for the German Industrie 4.0 and American Industrial Internet approach. The section will describe the benefits of the models, the structures and the principles of data operations for the different model layers. These models can go hand in hand with specific norms and standards to sustain a certain workflow. Interestingly, the German ‘Plattform Industrie 4.0’ and the American Industrial Internet Consortium invented these two architecture models independently from each other.

2.3.1 Reference Architectural Model Industrie (RAMI) 4.0

Industrie 4.0 is a complex topic in which the standards and norms from the different industry sectors need to be combined with the particular technology protocols and specifications. The ‘Plattform Industrie 4.0’ invented subsequently the ‘Reference Architecture Model Industrie 4.0 (RAMI 4.0)’ shown in Figure 4 (VDI, 2015).

Figure 4: Reference Architectural Model Industrie 4.0

(VDI, 2015)

RAMI 4.0 is a 3D-layer model that compares the life cycles of products and goods with the hierarchy levels of Industrie 4.0 technology. It divides existing standards into manageable portions. The design of the model is partially built on the Smart Grid Architecture Model from the European Smart Grid Coordination Group (VDI, 2015). The vertical axis stands for the various layers such as asset, communication, information or functional. The axis terminology results from the IT industry where complex projects are often divided into manageable subprojects. The horizontal axis in the RAMI 4.0 model represents the product life cycle. This element indicates the actual status of the product in the value chain. The remaining axis defines the location of the functional hierarchy level, more precisely the responsibility along a product plant such as product, station, work units, enterprise or connected world (VDI, 2015).

2.3.2 Industrial Internet Reference Architecture (IIRA)

The Industrial Internet Reference Architecture (IIRA) is a standardized open architecture for the Industrial Internet. The goal is to reach high industry applicability to obtain interoperability as well as to guide the development and technology. To support these requirements the distribution and structure of the architecture have to be generic and possess a high level of abstraction. The design of the IIRA (shown in Figure 5) is proposed to exceed the available technology from today and to identify the current technology potentials or gaps (Industrial Internet Consortium, 2015).

*Figure 5: Industrial Internet Reference Architecture
(Industrial Internet Consortium, 2015)*

The American Industrial Internet Consortium developed the IIRA model based on the ISO/IEC/IEEE 42010:2011 standard. This international standard describes the prerequisites regarding a software, system and enterprise level architecture. If applicable, the standardization suggests identifying the viewpoints of the different stakeholders. In this case, stakeholders could be operators, users, vendors, owners or developer. The goal is to describe the system properties from their perspective. The

IIRA is a layer model that includes four various levels: business, usage, functional and implementation (Industrial Internet Consortium, 2015).

2.4 Economic impact on the current industry

In the last ten years the Internet and mobile devices (with App services) have significantly changed the private life of humans, especially their searching and buying behavior. New ‘data-driven’ companies like Google, Amazon and Apple have created completely new business models, are steadily increasing their revenues and are well-known to the majority of end users or consumers. These ‘big’ players continuously look for new business opportunities. They have identified new industry sectors, such as automotive with mainly B2B business, as their new focus area where they try to change the existing business with new disruptive innovations and thereby capture new markets. Before these disruptive technologies, these markets were completely ruled by the well-known OEMs. These circumstances shift the existing industry out of balance and allow new competitors to enter the market (McKinsey, 2016).

CHAPTER 3 – BUSINESS MODEL AND BUSINESS MODEL INNOVATION

The following chapter provides an overview about the definitions of business models, business model innovations and business model frameworks in practice and current digital business models.

3.1 Business model

Surprisingly business models are often studied without a clear and distinct definition of their source or concept. Moreover, the explanation of a business model (BM) in the literature refers to many diverse descriptions, such as an architecture (Osterwalder and Pigneur, 2010), a method (Tucci, 2010), a model or tool (Osterwalder and Pigneur, 2010), a pattern (Brousseau and Penard, 2006), or a framework (Afuah, 2004). The reason for the lack of uniform definitions is probably resulting from different perspectives and point of views (Zott et al., 2011).

However, the next chapters of the thesis will use and refer to the definition of Gassmann et al. (2015), which is: “*a business model defines who your customers are, what you are selling, how you produce your offering, and why your business is profitable*” (Gassmann et al., 2015).

3.1.1 Demarcation from similar terms

For further consideration the term business model should be demarcated from other related terms:

Business plan: The business plan is a detailed description (for a possible application) of a business model. In contrast, a business model can be applied to different types of business plans, for instance various price ranges. In general a business plan describes all elements in detail of a business model, such as target customer, revenues and costs (Osterwalder et al., 2005).

Business strategy: The literature provides different approaches to describe the combination between business models and strategy. Osterwalder et al. (2005) characterize business models as the link between the business process and business strategy prospect. Shafer et al. (2005) define both terms as different but complementary to each other. Although the business strategy contains in most cases the value proposition, and thus is one of the most important factors of a business model (Shafer et al., 2005).

Business concept: Hamel (2000) defined a business concept as a business model which is currently only available as a concept but not in the implementation phase.

3.1.2 Business model frameworks

A common technique to develop a simple business model even further is to divide the business model into individual parts. A business model framework allows this subdivision, from very simple to highly advanced models (Zott et al., 2011). The following paragraphs will present an overview about various frameworks from the theory.

Gassmann – Magic triangle

Gassmann et al. (2015) developed the ‘Magic Triangle’ to describe and visualize a business model. According to the authors, a business model consists of four different dimensions which are customer, value proposition, value chain and profit mechanism (shown in Figure 6).

Figure 6: Gassmann's Magic Triangle

The dimension customer characterizes which customer segment is relevant and which customers should get addressed. The customers are the core of every business model and therefore positioned in the middle of this model. The dimension value proposition describes the unique selling proposition for the customer as well as the drivers for the client value. The value chain contains all resources and capabilities for the business model as a relation from purchaser to the supplier. The profit mechanism specifies the cost and revenue structure for the business model (Gassmann et al., 2015).

Wirtz – integrated business model

In 2001 Wirtz invented a simple model, which has preferred application in the German-speaking regions. He divided a business model into various business model segments. Figure 7 presents his integrated business model including several segments.

Figure 7: Wirtz - Integrated business model

Wirtz distinguishes in his model the suppliers and demanders, where the demanders result from the offered products or services as well as the actual demand. This demand model gives a starting point for market segmentation to develop the ‘right’ marketing mix.

The value creation model describes the combination of goods and services in order to create a specific service offer. The value proposition is the core of the entire model, with the goal of having a customer-based value proposition and determining an optimal demand-offer-proportion. The capital model defines turnovers, costs and funding opportunities (Wirtz, 2001). Limitations for the Wirtz model are the unclear

arrangements and connections between the distinct model segments (e.g. value proposition, distribution model, etc.) and the neglect of costs (Weiner et al., 2010).

Osterwalder and Pigneur – Business Model Ontology

Osterwalder developed one of the first highly-detailed Meta models for business models and even implemented a XML based application. In 2004 he invented one of the most commonly used and first Ontology based models. This model is one of the most cited models for business model research and often builds the basis for further business model improvements. By comparing the model with the Wirtz model, Osterwalder focused more on relations between the particular elements and segments. Figure 8 presents the four main business model blocks customer interface, financial aspects, product and infrastructure management.

Figure 8: Business Model Ontology

The customer interface questions ‘Who?’ means who is the target customer, which distribution channel should be used and which relationship is required. The financial aspects block describes the revenues and costs, which result from the value proposition. The product or value proposition questions ‘What?’ and defines the type

of product or service which is offered on the market. The infrastructure management specifies the resources and required partner. It questions the problem ‘How?’ (Osterwalder et al., 2004). Limitations for this model are the small rooms for maneuvering and no proper value proposition for the single business model elements (Weiner et al., 2010).

Gordijn - e3-value™ Business Model Ontology

The e3 value model, shown in figure 9 is a value chain-based approach to model the consumption in the value chain graphically. Furthermore the model allows adding cash flows by using profitability tables. The model considers a business model as a tool for modelling and evaluation of a business idea.

Figure 9: e3-value™ Business Model Ontology

An actor may offer or request one value via one or multiple value ports. In general, one port stands for a value proposition or a request for a value. To display the trade or exchange, the model bundles all of the data in value interfaces. The link

between the single actors, defined as the value exchange can be displayed as edging on the lines and it may contain products, services, information or money.

The e3-value™ Business Model Ontology approach allows the implementation from the theoretical model into the e3 value –software. The advantage of this tool is modeling and evaluation of business ideas and business models with specific value chains despite the fact that the special focus is in creating the business idea and testing the transferability. It is particularly suitable for simple customer and market relations instead of large complex structures. If that is the case, the model can quickly get confusing (Gordijn, 2004).

Bouwman - STOF- Business Model

The STOF-framework, shown in figure 10 is based on four domains: service, technology, organization and finance which together form the service offer. It was actually developed for digital service offers and is one of the most detailed models in the literature.

Figure 10: STOF- Business Model

The service domain gives an overview about the service offering, the value proposition and the market segment. The domain technology provides an explanation of the necessary functionality to realize the service offer. A structure description for how to create the service offering and explain the company's position within the network can be found in the domain organization. The finance domain describes how a value network aims to create revenues from a specific service offer and how revenues and investments are divided among the different actors in the value chain (Bouwman et al., 2008).

3.1.3 Arguments for selecting Gassmann's 'Magic Triangle'

The above mentioned business model frameworks focus on different priorities. Due to the business model definition, the 'Magic Triangle' framework from Gassmann was chosen for the further procedure of this study. The reasons for choosing this framework were the self-explanatory design as well as the easy handling of the business model dimensions. Furthermore, this framework allows the simple modification of an existing business model, by changing one of the four business model dimensions.

3.2 Business model innovation

This section describes the definition of the term business model innovation (BMI). Mitchel and Coles (2003) defined business model innovation as the allocation of new products and services towards customers. The development of these products and services can be characterized as a process. Labbe and Mazeet (2005) characterized the term business model innovation as a change of at least one component to obtain a

new composition of the business model elements. Markides (2006) defined business model innovation as an optimization process in which the different business model elements are changed. Furthermore, he describes the BMI as a completely new business model but with the old business model borders. It is focused on other objectives as well as follows different rules for implementation. New regulations, technological changes and market shifts can be potential triggers for new BMI demand (Cavalcante et al., 2011; Demil/Lecocq, 2010). Osterwalder and Pigneur (2010) defined BMI in a different way than their colleagues. Their definition is not based on the past or the competitors, in fact they defined it as “*a mechanism to create more revenue and gain more profit by satisfying the customer demand*” (Osterwalder and Pigneur, 2010). One method for identifying BMIs is to analyze existing business models, try to find patterns in the models and formulate these in an abstract way. With this approach, it is possible to enrich existing business models with new features and elements (Fleisch et al., 2014; Gassmann et al., 2013). Ultimately, the implementation of BMI can have a big impact on the success of a company (Fleisch et al, 2014). However, only a few studies were published so far about the BMI tools and methods.

3.2.1 Approaches for developing new business ideas

Many different theoretical constructs/methods can be found in the literature. The upcoming sections present two widely-used frameworks for developing and testing business ideas.

3.2.1.1 Business Model Canvas

The Business Model Canvas (BMC), developed from Osterwalder and Pigneur (2011), is nowadays one of the most commonly used approaches for developing new business ideas, not only in theory but also in practice. The BMC consists of nine different components (shown in Figure 11). It consists of value proposition, key activities, key partners, key resources, customer relationships, channels, customer segments, cost structure and revenue streams. The advantage of this model is the possibility to describe every component in a detailed way and view the relationship between them.

The business idea development process can be divided into five phases:

- *Mobilization*: definition of the project goals, establishment of a multi-disciplinary team
- *Understanding*: conducting analysis and research
- *Design*: brainstorming, ideas generation
- *Implementation*: implementation of business model prototypes
- *Execution*: adaption to the market, continuous improvement process

The BMC is developed from practice, so it is more applicable than a lot of other theoretical frameworks. One limitation of the model is the restricted scope of action (Weiner et al., 2010).

Figure 11: Business Model Canvas

(Osterwalder and Pigneur, 2011)

3.2.1.2 St. Galler Business Model Navigator

Gassmann et al. (2015) developed the St. Galler Business Model Navigator in close collaboration with different international firms. The study showed that nine out of ten new business models are developed by recombination of already existing business models. During the research the authors identified 55 business model patterns, which can be used for the development of new business models. The development process is based on a more abstract basis. It is based on four dimensions which form together the ‘Magical Triangle’ (already mentioned in 3.1.2). These four dimensions can be described with Who, What, How and Value; the cornerstones of these elements are customer, value chain and revenues (Gassmann et al., 2015).

Figure 12: Business Model Navigator

(Gassmann et al, 2015)

The business model navigator can be also separated into different phases of procedure. Figure 12 shows the different steps from initiation phase, ideation phase and integration phase to implementation phase.

The first phase ‘initiation’ analyzes the business idea and its environment accurately. The examined issues are based on the previously described ‘Magic triangle’ and its process of ‘Who – What – How – Value’. The second phase is the ideation. The goal is to transform the current business model into a new innovative business model by adapting the 55 business model patterns from Gassmann et al. (2015). Gassmann et al. (2015) recommends therefore an iterative process. The third section describes the ‘integration’ phase. The goal is to achieve an integrated consistency regarding the internal and external conditions. According to Gassmann

(2015) the last step, the implementation, is the most difficult task. The reasons are the resistance from the market, the staff and partners. Together with the Stanford University, Gassmann et al. (2015) invented a 3-step-cycle approach to simplify the implementation process. It includes the steps test, adapt and market introduction and can be used to test a business model about its potential.

3.3 Digital business models

The first publications related to digital business models emerged in the 1990s. Following Venkatraman (1994), he defined that a business model is considered as ‘digital’ when digital technologies have a significant impact on the business operations as well as the revenues. Today almost every industry sector (automotive, aviation, energy, retail, etc.) use IT technology. Due to the increasing amount of products and services sold through online platforms, the demand in understanding digital business models is increasing. However, for many years there was no clear assignment for when a business model should be called digital. Al-Debei et al. (2008) defined that if the core of a firm’s business is digital, the company is assigned to the IT/digital industry (Al-Debei et al., 2008). Several ‘digital’ business models have been only applied in the digital world until now. By implementing and using new I4.0/IoT technology, the borders and boundaries between the IT and manufacturing industries will shift and thereby create new collaborations (Kagermann et al. 2013).

3.4 Transferability of business models

Nowadays a lot of competitors try to copy successful business models and transfer them to new business sectors. That raises the question: under which circumstances can

the transfer of a business model from one to another business sector be successful? Each business sector has individual characteristics which should be considered in a new business model. A business model is more than the dimensions customer, unique value proposition, value chain and profit mechanism. In fact, successful business models depend also from soft factors like humans, their values and company culture. To conclude transfer of successful business models to other business sectors is not as easy and requires endurance as well as specialist expertise to make it successful (Dottore et al., 2010).

CHAPTER 4 - INFLUENCE OF I4.0/IoT ON CURRENT BUSINESS MODELS

This chapter will provide an overview how I4.0/IoT can affect business models and also which new business models can arise from the new industrial revolution. The goal of this chapter should be to get a better view of the I4.0/IoT business model combinations as well as a solid outlook about upcoming business model (Weiner, 2010).

4.1 Variants of Internet-driven business models

Figure 13 presents the three different variants of Internet-driven business models. The following paragraphs will explain them in detail (Fleisch et al., 2014).

Figure 13: Internet-driven business models

Each Internet revolution has led to new business models

The first business model patterns resulting from IT occurred in the years between 1995 and 2000. These patterns used the first generation of the Internet, often called Web 1.0, to strengthen their business and reach new customers and markets. Gassmann et al. (2015) defined the Web 1.0 as supporting business infrastructure, which helped firms to offer their products and services through a new channel. Possible business model examples of this time were e-commerce or open source software. In 2005 a new era of the Internet (Web 2.0) emerged. The significant difference was that the users were now also responsible for the content, not only the providers. Thus, new business models such as crowdsourcing, crowdfunding or long tail, summarized by the term social media, were created and appeared in the former market. Today's generation will approach the next era soon. The next step is that sensors and systems can autonomously add and change content. Possible consequences could be the shift from product to more service-oriented business models (Fleisch et al., 2014).

IT technology as key for changes in business models

Fleisch et al. (2014) identified three central roles in which the Internet can affect a business model by analyzing the 55 business models from Gassmann et al. (2014):

No effect: Internet is completely irrelevant for the business model and does not influence the business model. A common example could be the business model 'Ingredient Branding'.

IT as value-add: Some business models were known and used before the introduction of the Internet, but not so easy to implement or control. However, since implementation of IT, the complexity of these business models is drastically simplified.

IT as prerequisite: Without the use of IT, the business models were not conceivable. Fleisch et al. (2014) defined them explicitly as digital business models, for instance E-Commerce.

Overall trends for business models with IT as prerequisite

According to Rutsch (2014), almost every IT-affected business model follows at least one of the following trends (Rutsch, 2014):

Service-oriented: Due to the increasing demand of customer support, IT is often used by companies to keep in contact with their customer, before and also after the transaction. Nowadays, the majority of customers prefer a complete product package including the actual product plus additional services, instead of just the product itself. To take advantage of these behavior patterns, business models such as ‘Freemium’, ‘Add-on’ or ‘Rent instead of Buy’ emerged.

Customer integration: By using the Internet, firms can easily integrate customers into their value creation process to improve their customer satisfaction through transferring tasks from the producer to the client’s side, such as ‘Open Source Development’ or ‘E-Commerce’.

4.2 Emergence of new business model patterns

The literature provides a few studies about I4.0/IoT business models and their applications. Fleisch et al. (2014), for instance, did a study in which they compared the applicability of the 55 business model patterns from Gassmann et al. (2015) to the Internet of Things. The goal of this study was to identify business models patterns, which can be applied to the I4.0/IoT. The following business model patterns represent an extract of the identified business patterns (Gassmann et al. 2015, Fleisch et al., 2014):

Digital Add-on: Digital Add-on represents a business model in which a physical product is sold very cheap, resulting also in low profit margin. In addition to the physical good, the customer can purchase on top different digital services. An example would be a purchase of extra power for a vehicle, e.g. 30HP more for a weekend trip.

Digital Lock-in: The business model pattern digital lock-in is similar to the Razor and Blade business model which means that only original parts are compatible with a specific system. Digital lock-in in physical goods refers to a digital handshake that is used to ensure warranties and to restrict the compatibility.

Freemium: This business model describes a physical product and a free digital service, which are sold together, such as a digital manual, which is added to the product. In a long-term perspective, some customers will choose premium services that go beyond these free services and are willing to pay extra money.

Object Self Service: Object Self Service means that products have the ability to place orders independently. A common example would be a smart heating system,

which automatically reorders oil, as soon as the level of oil in the tank reaches a certain restriction.

Condition Monitoring: This type of business model means that products or goods can collect, analyze and transfer data independently about their own status in real time. Due to that feature, it is possible, for instance to detect errors in a production line earlier and create countermeasures.

4.3 New business opportunities enabled by Industrie 4.0 and Internet of Things

Business model improvements or business model innovations are mostly triggered by new technology opportunities. Industrie 4.0 and Internet of Things are an excellent example here. The digital transformation of existing processes and businesses helps to speed up the operational improvement and changes completely the value creation in a company. Three examples of greater range of IoT opportunities are selected and explained in the next section.

4.3.1 Big data and analytics

Big data and analytics can be applied to customer data of a company as well as to production and processing data from plants/companies.

I.40/IoT business models are expected to be more customer focused and more often designed as B2C offerings. When analyzing and using data from direct customers the offers can be better tailored, priced and delivered to customer.

Production and processing data

Industrie 4.0 stands in Germany for establishing cyber-physical production systems (CPPS). CPPS are networks of microcomputers, sensors, actuators connected through the internet and embedded in materials, devices or machines. In addition new camera/scan devices available at affordable prices can be added to the production lines. Huge amounts of data often real-time data can now be gathered, structured, stored and analyzed by data specialists. These specialists for the smart data analysis will be required to identify achievable process improvements in the company. Professional data analysis can also help to improve the product quality. Defective parts can be detected and sorted out early in the production process (Bitkom, 2015).

A complete new business model enabled by I4.0/IoT is 'Predictive Maintenance'. Smart devices and connected machines/production lines are a pre-condition for this new in-house service. The aim is to collect all relevant machinery and tooling data (with maximum run-time), to enable planned maintenance, to optimize the maintenance schedules in the plants and avoid unplanned stops and downtimes in the production lines. Some companies are investigating if this service can be offered to third parties as a new business model. Furthermore, the increased data availability/analysis can be used from managers makers for more profound decisions.

Data can also be used to identify and eliminate redundancies in the entire supply chain. This can lead to significant efficiency improvements and thus to a clear competitive advantage (Bitkom, 2015).

4.3.2 Additive Manufacturing

Companies have just started to use additive manufacturing, such as 3D printing, to produce prototypes or individual parts. In today's production often huge investments are required for the tooling (costs); these expenditures must no longer be considered. Additive manufacturing will be used to produce small batches of customized products, often with advantages in construction and design. By implementing these processes the transport distances and the stocks on hand can be reduced significantly. This additive manufacturing service enables complete new business models. For example the customers can choose and buy between different license packages for technical drawings, depending on this need. For this reason, additive manufacturing will have a large effect on the innovation and business model process (Piller, 2015).

4.3.3 Transformation of the value chain

Horizontal and vertical system integration is important pillars of the IoT-driven enhancement. Most of the IT systems today from companies, suppliers and customers are not linked with each other. Even in one company engineering, production, sales/marketing and service departments use different sub-systems. With I4.0/IoT companies, departments, functions can be linked in networks. Common platforms as services on a cloud can be created for example for design, manufacturing collaboration (Deloitte, 2013). By shortening the complete value chain significant cost savings can be achieved; they can be used to increase the company's earnings or to make the company's product/service offers more attractive (Rudtsch et al., 2014).

4.4 Chances and risks with Industrie 4.0 and Internet of Things

Recent publications draw a diverse picture of the chances and risks from I4.0/IoT. They show that the I4.0/IoT 4.0 will generate job losses, especially for small and medium-sized companies. This phenomenon emerged first in the field of consumer electronics and telecommunications where it eliminated 80 percent of all jobs in Germany within 15 years. On the other hand this new technology can also generate new jobs, revenue and profits. The firm Siemens, for instance, estimated already 50 percent savings in material via new optimization and advanced simulation software. The software enables the simulation of machine tools for machine operations in advance. This results in cost and time savings. Another Industrie 4.0 study from the consulting firm Strategy& (2015) predicted an overall efficiency improvement by 18 percent across all firms and industries (Strategy&, 2015). There is no clear predication of what will happen in the future but one thing is clear: the world will significantly change (Brynjolfsson and McAfee, 2014).

4.5 Challenges in implementing Industrie 4.0 business models

Different challenges can arise for companies while implementing I4.0/IoT business models. One challenge can be to define the right balance between product offer and service business. The more the world is changing towards digital technologies, the more likely that products have to include a service, as the digital part of a product offer is always a service. However, service business differs completely from products business since services cannot be stored and are difficult to monetarily assess. Another challenge is the variable use of product development. While it takes many years, long processes and high investment to develop a new, innovative physical

product, digital services can be established in a short time period and agile development processes. Furthermore, product failures can be mostly repaired by an (digital) update, for almost no cost and within a very short amount of time, often on the order of days (Fischer, 2012).

CHAPTER 5 - METHODOLOGY

This chapter will explain in detail how the research was conducted. In a first step, the reasons for selecting the qualitative research will be described. In a second step, it will be declared how the data was collected and lastly how the data was analyzed.

5.1 Choosing the research method

The following sections will explain the qualitative and quantitative research methods that could be used for data collection and analysis. Moreover, it will describe their differences and explicate why qualitative research was selected for this study.

5.1.1 Discussion on qualitative and quantitative research

Quantitative research methods are typically standardized procedures, trying to measure phenomena by figures and testing hypotheses through fixed variables. Due to their standardized measures this type of research is applicable for extensive samples and allows the finding of common data. Disadvantages of quantitative research methods are that some phenomena are simply not quantifiable by figures, statistics or random samples. In these cases, quantitative research might limit the chances of investigating certain aspects of these phenomena. (Silverman, 2013) In contrast, qualitative research aims to gain a deep understanding of underlying opinions, reasons and behaviors. Therefore the emphasis lies on in-depth understanding of words, thoughts and experiences rather than on figures. Furthermore, qualitative methods are focused more on the individual opinion rather than the general opinion. The disadvantage of qualitative research is mostly based on validity and reliability.

Moreover, qualitative research might be perceived as rather subjective. However, generalizing to a population is not the key goal of qualitative research. Qualitative research targets understanding and exploring a certain circumstance and context. The selection of research methodology depends mostly on the type of research question. For explorative studies such as this study, qualitative methods are a more suitable choice. Instead of measuring a phenomenon by figures and statistics, this study uses a survey with open questions to explore the interviewees' views and opinions (Strauss and Corbin, 2007).

5.1.2 Verification of qualitative methods

Regardless of the research method selection, it always seems advisable to consider the concepts of validity and reliability. Reliability is demonstrated if multiple different researchers come to same study result. Achieving reliability is very difficult in qualitative research. Taylor and Bogdan (1998) claim: *"it is not possible to achieve perfect reliability if we are to produce valid studies of the real world"* In addition, they state qualitative research highlights validity and they *"are intended to ensure a close fit between the data and what humans actually say and do"* (Taylor and Bogdan, 1998). In qualitative interviews, reliability often constitutes a challenge because the gathered data are a reflection of the conditions, under which the interview was executed. Repeating the same interview could lead to different outcomes as a result of the changing circumstances. However, it does not mean that qualitative researchers ignore reliability. Silverman (2013) suggests possible methods in order to conduct a reliable qualitative research study, which are included in this thesis. He proposes that researchers should explain and show their research procedure as well as their chosen

theory in a transparent way so that the proceedings can be followed, understood and reproduced by subsequent researchers. Moreover, he states that readers of research studies should be able to gain insight about concrete observations made, not only summaries or overviews. According to Silverman, this was applied by audio-recording and transcribing the interviews and including direct quotes from the transcripts into the analysis part of the thesis. Additionally, pre-testing the methods and questionnaire, such as the interview guidelines, can improve the reliability and has been applied in this thesis. Another important element in research is validity. The question of validity is the question of whether the research precisely measured what it proposed to measure (Silverman, 2013). In qualitative research, and particularly in research including exploratory research design, the answer to this question is less straight forward than in quantitative studies. Therefore, for the validity of a qualitative study it is essential that the observations made, fit the theories are upon which they are based. In other words the research should be well grounded conceptually, meaning that the quality of the procedure through which a study was planned and executed affects the validity of the research. In addition examples should be given, which support the meaning of the data and, as with reliability, the background with which the data was collected needs to be considered (Bryman, 2008).

5.2 Gathering the data

In order to collect data and information answering the research questions, a appropriate research method needed to be identified. The following paragraph explains the choice for semi-structured interviews and how the interviews have been executed.

5.2.1 Choosing the adequate technique

Qualitative research offers several techniques which can be applied such as focus groups, interviews, and ethnographic studies. Interviews seem to be an appropriate technique for this study because they facilitate the option to ask open ended questions to a small sample and collect individual views or experiences regarding the researched topic (Bryman, 2008). On the other hand, it has been found that qualitative research is conducting more frequent and flexible interviews. Unstructured and semi-structured interviews mostly concentrate on the interviewee's view and experience, extracting detailed and in-depth data. Moreover exploratory research need to be less structured than supporting research.

For this thesis the semi-structured interview approach, is an appropriate technique because it allows structuring via interview guidelines and made it possible to keep orientation during the interview execution. In addition, the guidelines ensured that important theoretical issues were covered in the dialogue and it supported the analysis according to categories. Therefore, complete semi-structured interview guidelines could have inhibited the possibility to catch relevant side information from the interviewees. But as with any other methods, interviews also have their boundaries. Interviews are mostly subjectively designed, and thus dependent on the respective interview situation. They are based on a subjective opinion of an individual with expertise in this area, so it cannot be expected that they would always uncover the correct view or truth (Bryman, 2008).

5.2.2 The Interview guidelines

The existing literature was studied intensively before executing the interviews. Important theories or related themes to the topic Industrie 4.0, the Internet of Things and related business models were collected and analyzed to subsequently develop the appropriate questions. Based on these formulated questions, interview guidelines were created as shown in the appendix. In order to ensure fluent interviews, the questions were divided into four different categories. The first category are introductory questions asking about the interviewee's background, his current role in the organization, and the recent tasks or projects that he has worked on.

The second category of the questions addresses the first element of the research question that is the business model. The intention for these questions is to receive an overview about the business model and the process of business model design in the company. The answers to these questions will be translated to the business model of the company. The questions in the third category are aimed to explore the situation regarding Industrie 4.0 and Internet of Things and the advancement process of the firm. Finally, the questions in the Industrie 4.0 business model category address the Industrie 4.0 business model creation in the firm as well as the implementation process. In addition to the mentioned intentions, the questions also try to evaluate the mutual perceptions of management and IT specialists regarding each other's fields. Thus, the order of questions in the interview guidelines was not strictly followed during the interviews. The experience showed that better outcomes resulted when the interviewees answer the questions in an unconstrained way, and more precise when they mentioned everything that came into their mind. The interview guidelines helped

function as a tool to support orientation during the interview and to ensure that all areas of the research topic were covered. Moreover, as all of the interviewees had different academic and professional background, possible misunderstandings regarding the interview questions had to be considered. For this reason, clarifying questions was permitted whenever it seemed required to check how the interviewees understood the questions or if the interviewer understood their answer correctly. A pre-test was executed after developing these interview guidelines, in order to double-check the interview questions, the interview guidelines and the analysis technique. This pre-test resulted in some minor changes, for example small adjustments on the wording of the questions (Silverman, 2013).

5.2.3 Conducting the interviews

For the purpose of this thesis, 18 participants were interviewed. They were identified through literature and market research, selected by their organization and role and contacted via different channels. Some of the experts were personal contacts from the author or from the supervising professors; others were contacted by using the social business platform such as LinkedIn or Xing, or were approached at relevant trade shows and conferences. All participants held management positions with regard to I4.0/IoT or business development to ensure that only informed and valuable answers and feedback. The interview durations were between 30 and 60 minutes long and were conducted via telephone, Skype or face to face. A couple of times interviewees involved other colleagues with special I4.0/IoT or business model knowledge to fulfill the interview questions. All interviews were recorded and transcribed in a pre-structured Word-file. In addition the interviewees occasionally

provided supporting documents such as organization charts, process descriptions or internal studies published by their own company. All interviews have been conducted in English or German. In addition the interviewees were promised anonymity and gave permission to audiotape the interview, in accordance with an Institutional Review Board (IRB) approved protocol.

5.3 Qualitative content analysis

After executing the interviews they were transcribed in order to process them for the planned cross-case analysis (in chapter 6). An appropriate technique here is the qualitative content analysis by Mayring (2011). The qualitative content analysis is an approach to analyze and compare conversations in a systematic way. It is built on the strengths of quantitative analysis, e.g. following reliability and validity. The technique then modifies these strengths in a reasonable way for the analysis of qualitative data. To execute qualitative content analysis, the source data needs to be defined first. This means stating who was interviewed, how the sample was chosen, what the basic conditions of the interviews were and how the text to be analyzed was generated. In order to analyze and interpret the data, the research question as well as the theoretical background must be methodically defined and described. Furthermore, the tools and methods for qualitative content analysis can never be completely standardized; they definitely have to be connected to the research questions and individual data. Mayring (2011) highly recommends to test the technique in advance with a pre-test.

In general there are three basic forms of interpretation in qualitative content analysis, which are structuring (data filtering), summary (data reduction) and explication (exploring further material) (Mayring, 2011). For this thesis the

interpretation form filtering is the most appropriate way to analyze the interviews. By defining specific categories or clusters, the interview transcripts can be reviewed and analyzed in detail. It is important to define the categories very carefully and to look in parallel for potentially important data outside these categories, as there is a risk to miss interview statements which do not fit into the defined categories. Every category was divided into numerous sub-categories and for each sub-category certain variables were developed. After developing these categories the text was coded. The contents corresponding to the particular variables were collected in an Excel spreadsheet and structured afterwards (Mayring, 2011).

5.4 Introduction to companies interviewed

Nowadays, new business opportunities enabled by Industrie 4.0 and Internet of Things can be found in every industry sector and in many different countries. The goal was to obtain a wide picture of the opportunities from various I4.0/IoT activities, therefore the companies interviewed were selected from different industry sectors. They comprise a selection of American and German well-known machine manufacturers, digital cloud-computing service providers, complete solution providers and consulting firms with I4.0/IoT activities already in place or in ramp-up status only a few of the companies were regarding I4.0/IoT activities in a ‘wait and see’ mode. Most of the selected companies currently have a B2B business whereas some of the firms distribute their products directly to the consumers (B2C).

In total 18 experts with profound I4.0/IoT background accepted to be interviewed. As requested by some companies, the gathered data has been anonymized with the Greek alphabet. Table 2 gives a general overview of the companies interviewed and

their number of employees. In addition the date and duration of the interview has been added to the table.

	Origin	Industry sector	Workforce	Interview date	Interview duration
Alpha	Germany	Industrial automation	2,400	5/24/2016	48 min
Beta	Germany	Sensor technology	3,000	5/23/2016	53 min
Gamma	Germany	Consulting firm	360	5/9/2016	43 min
Delta	Germany	Hydraulics, electric Drives and assembly tech.	38,000	5/10/2016	55 min
Epsilon	Germany	Electronic motors and fans	11,000	5/23/2016	50 min
Zeta	Germany	High-pressure cleaning devices and systems	11,000	5/20/2016	45 min
Eta	Germany	Robotics and automation technology	140,000	4/24/2016	43 min
Theta	Germany	Air Solutions and Compressors	400	4/26/2016	55 min
Omicron	Germany	Industrial automation	5,000	4/26/2016	42 min
Pho	USA	Industrial automation	13,000	6/9/2016	40 min
Iota	USA	Cloud computing services	-	5/23/2016	63 min
Kappa	USA	Cloud computing services	19,000	6/9/2016	38 min
Lambda	USA	Consulting firm	5	5/31/2016	38 min
Nu	USA	Cloud computing services	378,000	5/19/2016	30 min
Xi	USA	Cloud computing services	10,000	4/27/2016	33 min
Rho	USA	Automotive supplier	170,000	6/1/2016	45 min
Sigma	USA	Industrial automation	22,500	6/15/2016	50 min
Tau	USA	Health Care	2,200	6/17/2016	34 min

Table 2: Case company information

CHAPTER 6 – CROSS-CASE ANALYSIS AND FINDINGS

This chapter highlights the findings of the study based on the interviews executed and enriched with supplementary information from the theory. The interviews were analyzed with the technique ‘qualitative content analysis as explained in chapter 5. One important goal of the study was to cluster the I4.0/IoT use cases mentioned, discover the underlying specific characteristics and to find the commonalities of the cases. Another goal was to identify what improvements are expected from the started I4.0/IoT activities and to picture in which phase of implementation they are. A final goal was to discover/identify the different approaches between the American and German company when introducing new business models to the market. For the purposes of the study, the companies interviewed have been clustered into six categories or industry sectors.

It is important to notice that the calculated figures in this study corresponds only to a small sample size and is therefore not statistically representative and utilizable. However, these figures will be used as indicators for the qualitative evaluation. The defined company categories will be used during the whole chapter.

Figure 14: Case company clustering

Figure 14 presents the case companies categorized by industry sectors. The clustering of the firms establishes a basis for the cross-case analysis and provides better starting points for examination. As a result, six industry sectors could be formed. Alpha, Beta, Omicron, Pho, Sigma and Eta belong to the industry sector industrial automation. Rho and Delta are in the automotive supplier industry while Iota, Kappa and Nu form the cloud computing industry. Theta, Epsilon and Zeta could be summarized in the compressor, electronic motor and air solution industry. The healthcare industry contains Tau and the consulting industry has two firms Gamma and Lambda.

6.1 Findings about the interviewee's background and understanding

The entrance questions in the survey were related to the interviewees' job position, their experience with I4.0 and IoT and the I4.0/IoT based business models. This section summarizes the results of these questions.

Companies and experts interviewed position

Table 3 shows the job positions of the experts interviewed.

	Industry sector	Position
Alpha	Industrial automation	I4.0 Manager
Beta	Industrial automation	Senior Expert I4.0
Delta	Automotive supplier	Project Leader
Epsilon	Compressors, electronic motors...	Vice President Big Data
Eta	Industrial automation	Corporate R&D Expert
Gamma	Consulting	Principal
Iota	Cloud computing services	I4.0 Project Leader
Kappa	Cloud computing services	Senior Expert IoT
Lambda	Consulting	CEO
Nu	Cloud computing services	Platform Manager
Omicron	Industrial automation	CTO
Pho	Industrial automation	I4.0 Senior Expert
Rho	Automotive supplier	Innovation Manager
Sigma	Industrial automation	Business Development Manager
Tau	Health Care	Senior Manger R&D
Theta	Compressors, electronic motors...	Sales Manager
Xi	Cloud computing services	Innovation Manger
Zeta	Compressors, electronic motors ...	Vice President Sales

Table 3: List of interviewees

Table 3 highlights that only I4.0 and IoT experts have been selected for the interviews; the job positions varied from senior expert to CEO. The interviews showed that the firms interviewed assign different manpower, project structures and priorities to the I4.0/IoT activities and the creation of new business models. While some bigger companies have decided to establish large project teams with clear meeting structures, other companies have a ‘one man show’.

Definitions and difference between I4.0/IoT

The expert interviews provided I4.0 and IoT definitions and differences between Industrie 4.0 and Internet of Things. Almost every interview participant concluded the same view about the term comprehension, even though some American interviewees were not familiar with the term Industrie 4.0.

- *“These smart things include tiny sensors, which collect information about their use, their environment and their users. This network of connected physical things can include almost every device, vehicle, building or item.” (Lambda)*
- *“In my point of view, IoT is the idea that just increasingly more things become connected to the Internet, which can be also less valuable things than computers or smartphone” (Delta).*

According to the expert from ‘Iota’, Internet of Things is not limited to a particular industry; it has consequences for almost every business sector.

- *"Things, in the IoT sense, can refer to a wide variety of devices such as biochip transponders on animals, heart monitoring implants, smart robot application in the assembly line, electric appliance in seaside waters or even intelligent thermostat systems in buildings.” (Iota)*

At the same time, these embedded things should assist people and operators and increase their production. According to the interviewees, the Internet of Things enables things to be sensed and controlled remotely across existing digital infrastructure. It also opens new channels by integrating the physical world into the digital world which lastly results in improved production efficiency and quality.

In contrast, Industrie 4.0 is described as one specific element of the Internet of Things. It is primarily referring to manufacturing topics. The experts stated that Industrie 4.0 is comprised of the following the elements: cyber physical systems, smart factory, cloud computing, IT security and robust networks.

- *“Industrie 4.0 describes the convergence of the Internet of Things and the shop floor that affects every business area. It enables smart self-controlled products and production systems.” (Rho)*
- *“Industrie 4.0 is not only limited to smart factory, it affects also different other areas such as cloud computing or IT security.” (Theta)*

Definition of a business model

Although the development of I4.0 or IoT business models is a very important issue on most business agendas, the definition of a business model itself already showed a diverse picture and different understandings. Depending on the particular background and point of view of the interviewee, the definitions for a business model reached from strategy formulations, to process descriptions and complex illustrations. However, the interviewees agreed on the conclusion that the dimensions ‘customer’ and ‘value proposition’ of a business model should be always in focus.

- *“I am not familiar with the theory, but I am interested with which value proposition we make money in the future - and if that means we are selling signals, instead of our conventional sensors, then it is a new business model.” (Omicron)*

6.2 I4.0/IoT in the interviewee's industry

The second part of the survey consisted of questions like 'How dynamic is the interviewee's industry sector?' What relevance IoT/I4.0 elements have for the company and what is the status of current implementation for their I4.0/IoT projects?

Market dynamics in the industry sectors

Market dynamics are changes between different market factors, such as pricing, demand or supply. It determines how customers will react to price increases or how suppliers will react to changes in demand (Decressin and Fatas, 1995). The dynamics can vary significantly, depending on the industry sector. The interviewees had to decide within a scale from 1 (low dynamics), over 3 (medium dynamics) and up to 5 (high dynamics).

Figure 15: Dynamic of the industry

Figure 15 shows the differences in dynamics of the industry sectors, with the healthcare industry at the lowest (low dynamics) and the automotive suppliers at the highest level (high dynamics).

Relevance of I4.0/IoT business models

Industrie 4.0 and Internet of Things related technologies can be applied to almost every business sector. Almost every industry will be affected somehow by the IoT/I.40 key features explained in the theory; therefore all experts are convinced that these transformations will have a significant impact on today's business models. When asked '*How important is the topic IoT or Industrie 4.0 in your company*' the interviewees had to respond with 1 (low importance), over 3 (medium importance) to 5 (high importance).

Figure 16: Relevance of I4.0 and IoT

The emphasis on I4.0/IoT topics in the analyzed companies is very unequal up to now only the “big players” believe in new business opportunities and have thus established project teams to create new business models. Every company and interviewed expert understood that I4.0/IoT will significantly change their current business. However, many firms have no clear understanding that they have to take the initiative rather than wait to react on the expected I4.0/IoT market changes.

- *“The companies have to run ahead - otherwise they will be overtaken by their competitors.” (Sigma)*

Figure 16 points out a low value for the I4.0/IoT relevance in the industrial automation industry. One of the main reasons, according to Gamma’s expert, is that this industry area still has a lot of day-to-day business, especially for small and medium-sized businesses. These companies are mostly specialized on certain products and own a high expertise in this specific area. This industry sector has not so much competitive pressure as the others, yet.

- *“Fortunately, we still have a lot of daily business - nevertheless, we have to start now, otherwise we will lose our position.” (Gamma)*

On the other hand, the automotive industry shows the highest value. In accordance with the responsible experts, the automotive and the supplier industry is already in the I.40/IoT transformation process and triggered spacious programs, such as in-vehicle devices connected with the Internet.

The remaining industry sectors such as healthcare, consulting, electric engines as well as cloud computing rated this topic as having ‘medium’ importance. According to some press publications the healthcare industry has a huge growth potential through I4.0/IoT in terms of diagnostics. However, this was not reflected in the interviews that were conducted.

Implementation status of I4.0/IoT projects

This section is providing the findings about the current implementation status of the I4.0/IoT projects in the companies interviewed. The interviewees had to rate the status on a range from 1 (not started), over 3 (already started) to 5 (full implemented).

Figure 17: Implementation status

The implementation status was almost at the same level among the firms interviewed. In most companies the value was between 1 and maximum 3. Almost every participant believed that the implementation status from today is not advanced enough, even though the technology is fully developed and ready for application.

➤ *“We already have the technology, we just have no idea what to do with it!”(Xi)*

I4.0/IoT projects in practice

The already released and published I4.0/IoT projects from the interviewed companies are mostly pilot projects. The aim of these projects is to show their customers that the company is actively dealing with I4.0/IoT topics, looking for new

business opportunities that are predicted to attract new customers and ultimately increase their revenues. As they are partially conflicting with the current business model, they can be seen as “test balloons”, which are not part of their existing organization.

- *“All the projects and products, what you can see here on the trade fair, are just pilot projects and not implemented yet - these projects will be evaluated for the next one or two years. Every active company will launch these pilot projects, to do analysis and to make sure that revenue comes out of it, before implementation.”(Sigma)*

6.3 I4.0/IoT business model development process

The development of new business models is, generally speaking, a complex task. This part of the survey included questions about methods for developing new business models, the required resources and manpower as well as challenges in developing business models.

How do companies act to create new I4.0/IoT driven business models?

The study showed that standardized theoretical frameworks for developing new business models, such as Osterwalder’s Business Model Canvas, are barely used in the context of I4.0/IoT or do not find application in today’s practice. Most of the experts doubt that abstract frameworks can create new business models.

- *“In today’s world of digitalization and innovation it makes no sense to standardize the business model development processes, because the technology*

is changing almost every day and new disruptive innovation are emerging from time to time.” (Gamma)

However, the theoretical frameworks are often used as a technique to inspire the staff or to visualize theoretical constructs in meetings and workshops.

- *“The Business Model Canvas is a nice structuring and working tool that can be also used in workshop very well.” (Delta)*
- *“The tool facilitates an easy assignment as well as handling with the different business model elements.” (Rho)*

Resources and duration

According to some interviewees, the amount of manpower and time invested in the development of new business models is considered as sufficient. However, required budget and staff allocation is mostly dependent on the company size and the management attention.

- *“We, as a startup with limited resources, do not have the possibility to establish Industrie 4.0 project teams or huge business development departments.” (Lambda)*

Furthermore, the results from the study showed no consensus regarding the team composition. While some interviewees prefer a strict limitation for the business model development process for the top management, other firms build international teams with experts from different areas and hierarchy levels.

Challenges in I4.0/IoT business model development

This section deals with the challenges for the I4.0/IoT business model development. For better understanding, they were separated into two areas groups, internal and external challenges.

External Challenges

Changes and limitations in technology

Only one third of the interviewees agreed that there is already adequate IT infrastructure in their company to collect the relevant information for the IoT transformation.

- *“The IT infrastructure of most companies is not prepared for IoT or to support the digital transformation.” (Sigma)*

These existing IT systems have to be linked and learn to communicate with each other, therefore new communication networks have to be developed to enable sophisticated analysis and intelligent control of industrial production. Furthermore, the actual status of all the systems should be analyzed. The important point is to evaluate what effectively make sense and where new functionalities must be added. All internal departments, such as purchasing, production and sales must be considered when implementing a new IT architecture.

- *“To provide value-added for the customers and meet their needs, it needs a good network including different databases, production systems and customer information systems. A major challenge is the adaption of existing systems with each other.” (Theta)*

Missing standardization, certification and norms

A challenge which was often mentioned from the interviewees in Germany was the sluggish level of standardization for I4.0 and IoT. Standardized interfaces are one of the prerequisites that is necessary for uniform communication within the company. Examples can be machine-to-machine communication in smart factories or data exchange within the company via smarter infrastructures. Standardization can also help to reduce time-to-market or cycle times due to a better networking in the horizontal and vertical value chains.

- *“Missing standards can be barriers for new technologies. If large companies would cooperate and work together, changes could be made faster.” (Zeta)*
- *“If we do not create uniform standards for information and data exchange, then Industrie 4.0 will fail.” (Pho)*

Unclear situation regarding data handling

Another great challenge of I4.0/IoT will be to agree on international standards for future data handling with clear and transparent rules. According to the experts, the processing of big data requires new legal regulations, company agreements as well as new contracts specifying who will be the data owner, who will be the user and to what extent the data can be used. Only by doing that, the data exchange and administration can be better organized and be more efficient.

- *“To ensure fair use of internal data also beyond the company boundaries, we have to establish new contracts and regulations.” (Xi)*

Unclear situation regarding data security

The Internet of Things captures digital enhancement, but also opens participants up for data theft, industrial espionage and other hacker attacks. The majority of the respondents believe that cyber risks will strongly increase in the next years. Cyber-attacks can have an impact on IoT, for instance by stopping smart production systems. These will force many firms to spend more money for data security.

- *“The increase of digitization in the production may cause serious damage to the manufacturing processes. However, many companies still underestimate this growing danger.” (Kappa)*
- *“Everything that is connected with a network that faces the Internet is endangered to being hacked.” (Nu)*

However, most of the experts are convinced that these risks are manageable by a clear risk management policy and an adapted safety strategy. Modular solutions, decentralized structures and limited access rights have been mentioned several times as successful countermeasures.

- *“We work intensively to invent new security methods for the future – and we will be prepared!” (Eta)*

Internal challenges

Innovation Dilemma

A key challenge, for which disruptive innovations can be difficult to handle, is the lack of an appropriate investment tool. Unfortunately, the successful control of a medium or long-term future investment into a disruptive innovation is not yet

possible. For this reason, it must be discussed and justified with the management as to why they should invest in these concepts

In contrast, companies have to answer the question: ‘does it rather make more sense to invest every Dollar in an incremental innovation to support the core businesses’. This competition between new innovation and the core business is defined as the “*Innovation Dilemma*” (*Alpha*) and needs to be addressed for the future. Moreover, the experts stated the problem that the structures in large enterprises, which generated business for a long time with an established business model, are not as flexible as a young company or startup which was just established.

Gain management attention

The findings showed that substantial investment volumes are necessary to implement I4.0/IoT technology and exploit the entire potential. Thus, this topic should be one of the top points on the agenda of every CEO. In the study, approximately three quarters of the companies interviewed count I4.0/IoT as their main investment task for the future. So, they take the opportunity to increase their efficiency and ensure their competitiveness by investing a major part of their budget in new I4.0/IoT applications.

- *“To stay competitive in the future, we have to invest now in the new technology.” (Zeta)*

Establish ‘business model development’ teams

Choosing and establishing an expert team for the innovation and idea generation process is mandatory and at the same time a reason why a lot of firms’ business models cannot be further developed or even fail. The experts concluded that the employees who generate the best ideas also happen to have usually the highest workload and must therefore run the business model development on the side. Furthermore, the experts stated that only a limited amount of people are suitable to develop smart business models.

Qualification of the workforce

According to the experts the digital transformation to I4.0 and IoT will pose many employees with new challenges. For example, in work positions such as strategic planning or the R&D department, the ability is required to identify, initiate and implement new and innovative business opportunities. In mechanical and manual job positions are new technical skills important for the future. The experts mentioned that re-training and further skill training is mandatory and absolutely necessary to exploit the full potential of the new technology.

➤ *“IoT requires completely new types of training and skills” (Beta)*

Training on more efficient data usage

The shop floor offers a huge potential for cost savings and process efficiency improvements. Many production lines collect data, which were currently not analyzed,

structured and applied for process and quality improvements, mostly because the operators do not know how to condense and interpret the existing data.

- *“Our customer could do so much more with the generated data - and there is no knowledge of rocket science necessary.” (Eta)*
- *“We are already sitting on a mountain of data, but we are not capable to use these data for an optimum control of the production.” (Sigma)*

6.4 Lessons Learned from I4.0 and IoT business model development

The following section highlights the lessons learned, which were derived from the interviews with the I4.0/IoT experts.

Reduce time-to-market

One lesson learned is related to the quality of results and the process duration. In a lot of cases many techniques, such as brainstorming or think-tanks have been placed into the identification of the correct business model or use case for I4.0/IoT applications. However to achieve a highly sophisticated business model, the development time was much longer. Interviewee’s experience showed that the 100 percent ‘perfect’ approach is not always the best, especially not in the world of digitalization, so rather there is a focus on a 80 percent/20 percent quality/speed solution to stay competitive and agile.

- *“One of the most challenging disciplines is to figure out the ‘perfect’ timing to bring an innovation on the market.” (Gamma)*

This quote emphasizes that the best innovation cannot succeed, unless the market is ready for it.

Theoretical models versus practical approaches in the practice

Models and methods can help to guide and visualize the meetings and discussions. The experts pointed out that IoT business models cannot be generalized, however, certain tools, such as Osterwalder's Business Model Canvas or Gassmann's Business Model Navigator can help during the business model development process. Furthermore, the experts stated that they use their project experience from the past to draw attention to possible implications rising in new I4.0 or IoT business models.

Customer involvement in business model development

A consistent opinion across all the interview participants and industries was the answer regarding customer involvement during an early phase.

- *“It is the goal to work significantly closer together with the customers as well as discuss with them what their needs are and in which technology they are interested.” (Nu)*

The active participation of the customer in the business model development process should be a main target. This approach bears the great risk that new ideas are shown too early to the market with the risk that competitors are informed too early and may even capitalize from the idea. Permanent customer feedback can speed up the I4.0/IoT business model development process. An often mentioned technique by the interviewees was the ‘rapid prototyping approach’. According to specialists interviewed, the trend goes more in the direction to test immediately whether a new

idea is working and successful. If the idea is not promising enough to revise, modify or completely cancel the idea.

- *“...is the business model set up, it should be validated iteratively and further developed.” (Beta)*

Nowadays this approach is simply implemented by using new technologies, such as 3D-printing. Prototypes can easily be produced and based on the customer response easily be modified.

Active change management required

It was also mentioned that change management is a critical and important success factor for I4.0/IoT business model implementation, which was often underestimated from the project teams in the past. According to the interviewees' experience a piecewise communication from the top management to the organization about the planned changes showed good results. Moreover, the experts stated that positive results could be achieved by using a mix of the top-down and bottom-up approaches, thus giving the staff the opportunity to actively contribute and share their ideas with the management.

- *“Change management is essential for business transformation as well as an important element for successful implementation.” (Pho)*

Clear responsibilities and knowledge transfer

Additional findings refer to clear allocation of responsibilities and the transfer of knowledge in the business model development process.

- *“Clear role allocation is mandatory” (Gamma)*

The interviewees mentioned that a project handover to new associates, especially in the field of business development and in a pilot phase, is seen as critical.

- *“It makes no sense to transfer an Industrie 4.0 solution, which is only in its preliminary phase, to a coworker, who is not involved. This will probably not work because either he does not like this idea or he has problem with the understanding. That’s the reason why ideas or thoughts often grind to a halt.” (Kappa)*

6.5 I4.0/IoT-driven use cases in practice

The main purpose of the conducted interviews was to discover business models initiated by the digital transformations, either already implemented in practice or still in an early pilot phase, but promising to be successful. The selected initiatives were denominated use cases and presented in this section. The experts were asked in the interviews to select a use case from their company or business sector with a high level of maturity, to explain how the business model works and what business improvements are expected. Furthermore, they were asked to indicate the actual implementation status and to explain which competitor activities are expected. Table 4 gives an overview of the use cases detected.

	Industry sector	Use Case
Alpha	Industrial automation	Individualized series production for plastic application
Beta	Industrial automation	Transparency in tool handling
Gamma	Consulting	Digital tool management
Delta	Automotive supplier	Industrie 4.0 assembly in practice
Epsilon	Compressors, electronic motors...	Smart Control systems for refrigerators
Zeta	Compressors, electronic motors...	Advanced assembly line enables batch size 1
Eta	Industrial automation	Remote maintenance and advanced service offer
Theta	Compressors, electronic motors...	Smart use of compressed air
Omicron	Industrial automation	Sensors monitor the water supply
Pho	Industrial automation	-
Iota	Cloud computing services	Platform as a business model
Kappa	Cloud computing services	Cultural change via digital platform implementa
Lambda	Consulting	RFID as lever for Industrie 4.0 and IoT
Nu	Cloud computing services	Improve retail experience by using IoT technology
Xi	Cloud computing services	-
Rho	Automotive supplier	Industrie 4.0 enables just in time delivery
Sigma	Industrial automation	Digital oilfield solutions
Tau	Healthcare	Healthy dosage of information

Table 4: Overview of the use cases

As listed above the use cases received give an indication how companies deal presently with the upcoming digital transformations. The examples identified cover almost every chosen industry sector reaching from Zeta's approach for batch size of 1 production, Rho's software stick enabling just-in-time delivery and Epsilon's smart control system for cooling systems. Remark: only two companies refused due to confidentiality reasons to provide a use cases for the study.

Characterization of the use cases

For the use case characterization a complete new structure has been developed. With the information received from the experts interviewed the specification of the use cases was elaborated. The specification builds a central point of the thesis and is structured in five sections, starting with the headline, followed by the company profile,

the description of initial situation and use case, closing with the desired improvements.

Figure 18 shows exemplarily the use case from company ‘Zeta’.

Figure 18: 'Zeta' use case

This structure was applied to all use cases received. Due to the considerable amount of pages with the extensive description per use case the author has decided not to overload the paper and to present the details by use case in the attachment. However,

the use case characterization builds the basis for the next chapter of the thesis, where the categories for the identified business models were built.

6.6 Identify the category of business model improvement

Each particular use case specified in the appendices is based on a specific business model, which had to be carved out with the study. The target was to identify the business model behind the “use case” and to find out what improvements or new business models are desired/favored by the company/specialists and to build business model clusters. Table 5 indicates the identified business model clusters.

	Industry sector	Use Case
Alpha	Industrial automation	Individualized series production for plastic application
Beta	Industrial automation	Transparency in tool handling
Gamma	Consulting	Digital tool management
Delta	Automotive supplier	Industrie 4.0 assembly in practice
Epsilon	Compressors, electronic motors...	Smart Control systems for refrigerators
Zeta	Compressors, electronic motors...	Advanced assembly line enables batch size 1
Eta	Industrial automation	Remote maintenance and advanced service offer
Theta	Compressors, electronic motors...	Smart use of compressed air
Omicron	Industrial automation	Sensors monitor the water supply
Pho	Industrial automation	-
Iota	Cloud computing services	Platform as a business model
Kappa	Cloud computing services	Cultural change via digital platform implementa
Lambda	Consulting	RFID as lever for Industrie 4.0 and IoT
Nu	Cloud computing services	Improve retail experience by using IoT technology
Xi	Cloud computing services	-
Rho	Automotive supplier	Industrie 4.0 enables just in time delivery
Sigma	Industrial automation	Digital oilfield solutions
Tau	Healthcare	Healthy dosage of information

	Industry sector	Business model
Alpha	Industrial automation	Customized Product
Beta	Industrial automation	Efficiency improvement
Gamma	Consulting	Efficiency improvement
Delta	Automotive supplier	Quality improvement
Epsilon	Compressors, electronic motors...	Efficiency improvement
Zeta	Compressors, electronic motors...	Batch Size 1
Eta	Industrial automation	Predictive Maintenance
Theta	Compressors, electronic motors...	Smart Products and services
Omicron	Industrial automation	Predictive Maintenance
Pho	Industrial automation	-
Iota	Cloud computing services	Platform Business
Kappa	Cloud computing services	Platform Business
Lambda	Consulting	Efficiency improvement
Nu	Cloud computing services	Direct interaction with the customer
Xi	Cloud computing services	-
Rho	Automotive supplier	Just-in-Time delivery
Sigma	Industrial automation	Efficiency improvement
Tau	Healthcare	Just-in-Time delivery

Table 5:14.0/IoT business models

The identified business models were clustered in two categories:

1. Improvement of existing business model or process improvement

2. Identify and implement complete new business model

The next section is referring to the findings recognized by analyzing the use cases given by the experts. The first category refers to the ‘improvement of the existing business models’. This category can include elements like improvement of quality or efficiency in production, just-in-time delivery, or reduction of time-to-market.

The second category presents examples of complete new business models, which were not yet offered in today’s business sector. Some of these new business models use successful business models from other business sectors and ‘innovate’ their industry sector, by creating new business opportunities. Others may be even more revolutionary by changing the business model from ‘selling products’ to ‘offering complete services’.

Figure 19 gives an overview about the two identified categories of improvements and selected examples.

Figure 19: Categories of improvements

1. Improvement of existing business models

Out of the use cases the following improvements could be identified:

Quality improvement

IIoT technology, such as RFID or sensors can help to significantly improve the quality in manufacturing. This can be achieved by improving the production tolerances, producing less defective parts, and creating products with higher quality standards. Company 'Delta' has implemented an operator assistance system with a step by step guidance to reduce failures during the assembly. It combines real montage stations with the virtual world of information technology. It optimizes therefore the reproducible quality and shortens the training period of the operator. Company 'Eta' has equipped the entire production line with sensor technology. On each station the target/actual comparison can be done in real-time. This method helps to identify error patterns in an early stage and to improve product quality and reduce warranty costs.

2. Just-in-time delivery

The key technologies for this business model are RFID technology combined with cloud computing services. Standardized software in the cloud with clear interfaces between the stakeholders helps to improve data exchange between customer and suppliers. Within the plant RFID allows higher flexibility by consistent tracking of the material flow. Company 'Rho' has established a planning tool (on a public cloud server) connecting customers (OEMs) with their 80 productions plants. The goals are to improve the just-in-time delivery and to reduce the stocks in the entire supply chain.

Reduce time-to-market process

Time-to-market is a challenging task in today's business world. I4.0/IoT technology allows the product development process to be shortened, making products available ahead of the competition and increasing the company's revenues. Digitalization and more structured and efficient data analytics can help to eliminate process redundancies, to shorten the design life cycles and the product testing cycles. The company 'Sigma' extended their existing IT system with cloud-based solutions to digitalize and accelerate their entire development process. By implementing this, 'Sigma' improved their time-to-market process as well as the information exchange within their organization.

Efficiency improvement

I4.0/IoT solutions offer many different ways to optimize the existing business models, for example by reducing production costs, by optimizing the product flow or

by improving the company's administration and planning processes. Efficiency improvement can affect many areas of the value creation. It plays a significant role in the manufacturing industry, among others in improving the energy management. Company 'Eta' is taking advantage of the developments in machine connectivity by tracking each machine in their production line. Eta can monitor energy consumption on a machine level and get specific insights about its operational efficiency and possible savings, such as equipment failures or waste. Another example is a project from the company 'Epsilon' and an American refrigerator manufacturer. They invented a smart connection of cooling modules with a central control unit and IoT technology. By creating this connected cooling system, their customers can save up to 30 percent energy costs. The smart integration and interaction of all energy aggregates allows higher effectiveness. This efficiency improvement is a significant product advantage against competition and will definitely help the company to increase their revenue.

2. Identify and implement complete new business models

The following new business models could be identified:

Smart products

The I4.0/IoT technology enables not only the improvement of existing applications or processes but also the collection, analytics and distribution of data. Smart products provide additional benefits to the customer and allow companies to be more attractive than the competition. By applying I4.0/IoT technology to a

conventional product, a completely new variety of product functions can be created. They can be clustered into monitoring, control and optimization. The use of sensors attached to a product allows the monitoring of the product's condition as well as the product's operation and usage. Monitoring can reduce warranty complaints or create new sales opportunities. The embedding of software into a product enables the personalization of product performance, to a point that previously was not cost effective or even possible. Another function simplifies the interaction between customer and product. By combining the possibility of monitoring product data and controlling the product operation firms can optimize the product functions in different ways. For example, algorithms embedded in a product allow predictive diagnostics and continuous improvements. In addition, smart connected products can use these algorithms and analytics to improve their output and utilization. An example from the case studies is the firm 'Theta'. They equipped their products with sensors to monitor and control the principles of operation of their products condition. For example, firm 'Theta' can monitor their devices in real-time and draw predictions about upcoming maintenance work (before a machine/device breakdown).

Smart services

The combination of digitalization, big data analytics and smart devices allows the creation of completely new service offers. Smart services may open new ways to business growth. They can offer for example 'pay-per-use' service operating models. For example, instead of offering production machinery at high costs, the company can decide to switch to payments for using the equipment. In short, the existing principle

of 'selling products' may be completely switched to 'buying a service'. The advantages for the customers are continuous availability of a service, no capital investments and no maintenance costs. The firm 'Theta' offers this 'pay-per-use' business model and sells it already to their customers.

Direct interactions with customer

New ways of connectivity like mobile Internet, smart phones, social media allows direct communication and interfaces to existing and potential customers. With the collected data, firms can better understand and foresee their customer's preferences. Associates can address individual customer segments instead of creating a one-size-fits-all marketing campaign for the customers. Rather than overflowing the customers with the same offers, marketing specialists should create custom-made product/service offers. These gained customer insights help the companies to position their new products (from the product launch) on social media and their selling platforms. Furthermore, the direct customer feedback can help to increase the customer satisfaction and increase customer loyalty.

Customized Products

I4.0/IoT technology allows a complete switch away from mass production to more personalized products. By using the new digital I4.0/IoT applications the companies can create more individualized product offers. They can attract new customers beside existing customers, find out if they are willing to pay more for customized products or can use the direct contact to the customer to help to increase

the company's image. The customer himself has more choice in the future: depending to his personal preferences he can choose a product from the existing product range or he creates and orders his individualized product. However, this approach of individualization is not new for every industry sector. In the retail industry this approach has been successfully implemented years ago. Customers can choose and directly order their personalized shoes. This personalized product concept can be transferred to the manufacturing industry.

The company interviewed 'Alpha' has implemented this concept and produce customized office scissors in a completely connected and automated manufacturing line. Another application from the retail industry is shown by the firm 'Nu'. 'Nu' evaluates customer preferences in America by analyzing the customer behavior in malls or department stores. They help retailers to create customized product offers.

Batch Size of 1

'Batch Size of 1' or 'One Piece Flow' production at affordable costs is an important goal in the manufacturing industry. I4.0/IoT technology can help to achieve this ambitious target. One vision of the I4.0/IoT is to de-couple in the production the assembly modules and to achieve higher production flexibility. One possible way of doing that is to attach a memory to a product (via RFID technology). Materials and semi-finished products can be equipped with RFID tags, thus having the product memory function within the production line.

Another way of creating customized products (small batch sizes) is the additive manufacturing/3D printing technology. It can help to avoid high production costs,

especially for prototypes and after end of series production. Furthermore, it allows higher flexibility in production gives more freedom in design and avoids expensive tools costs. The aftermarket business of an automotive supplier can be a good example to apply the idea of 'batch size of 1' in production. While automotive suppliers generate only a small amount of their profits with products supplied to OEM's during series business, the aftermarket business and services allows high revenues and profits. However, to ensure on time delivery of the complete spare part range of a OEM customer, the supplier has to sign spare parts delivery obligations for at least 10 years, even when he is aware, that he cannot produce all contracted products at the agreed OEM prices. The constant availability of the 'old' parts and components leads to immense costs as here for the required machinery park and production data must be kept up to date. One possible new business model could be that the customer produces the required parts by his own and pays license fees to the supplier. It would save a lot of time and costs for the customer.

Predictive Maintenance

The study showed that continuous availability of machinery plays an important role in production. If a machine is breaking down, the company cannot produce and deliver products in time. The main purpose of predictive maintenance is to enable convenient scheduling of the maintenance work as well as to prevent unexpected machinery failures. Additional advantages are higher equipment lifetime and optimized spare part handling. The firm Theta has the goal of avoiding these breakdowns and guaranteeing a high availability of their products. They improved

their machine park availability by implementing I.40/IoT technology as well as by using new services and maintenance processes.

Platform business

An I4.0/IoT platform can be a business model that simplifies data exchange between several interdependent groups, usually manufacturers, suppliers and customers. Successful platforms allow data exchange with standardized interfaces, reduce the processing time and help to reduce operational costs. As a positive side effect, platforms create digital ecosystems. The IoT ecosystem allows platforms to scale in ways that conventional business models cannot. The firm 'Kappa' created with an external partner a digital in-house platform. Their goal is to change the communication culture within the 'Kappa' organization and to achieve higher transparency of the internal processes. In contrast, the company 'Iota' offers his platform as an entire new business model. Its platform functions is a new digital marketplace (comparable to an app store), where customers and partners can interact with each other.

6.7 Implementing I4.0/IoT projects – differences in USA and Germany

Another research objective was to identify differences in approaching and implementing I4.0/IoT projects in American and German companies. The interview results showed that there are different approaches regarding improvement of existing processes, development of new business models, data handling and data security.

Starting with Germany as a developed industrial nation: the industry can be characterized as a mixture of big, international corporations, mostly listed at the German stock exchange (DAX) and well-established midsize companies, often family owned and partly “hidden champions” in their field. The production of high quality products and machine building/engineering are traditional domains of the German industry. Especially the automotive industry with many automotive suppliers and metal processing industry usually have in-house productions and rely on automation technology from German suppliers. Today’s I4.0/IoT approach in Germany is to equip the existing machinery park with sensors, actuators, RFID or other digital devices and to connect them on the shop floor to a network of microcomputers. The availability of real-time machinery data enables more sophisticated analysis and intelligent control of the entire production process, thus enabling production of highly customized products, even with a batch size of 1. In parallel the real-time data is used for product quality improvements as well as to establish new business fields such as predictive maintenance. In summary, German companies are presently focusing on improving the manufacturing structures, shortening the production times and making the supply chain more flexible. Their innovation process is therefore mostly incremental. According to the experts, the creation of complete new business models is presently

not in business focus. In contrast, American companies have a slightly different approach to the I.40/IoT projects. They are often more customer centered, work very pragmatically and are more open to disruptive innovations. They start first to develop a business model, create a pilot, look in numerous iterations steps for the proof that it's successful and aim to be with the new idea the first in the market. In terms of 'make or buy decisions' they tend to 'buy' according to the motto: 'everything what does not belong to our key competence can be bought separately/externally.

Significant differences in company expectations regarding data handling and data security could be identified. Data security has become a growing concern worldwide and refers to the ability to control the information which companies and individuals publish about themselves, and to decide who can access that information. The data interchange has dramatically increased through I.40/IoT and creates new challenges for countries, companies and individuals regarding data ownership, protection and data privacy. International agreements are needed to make data interchange safe and transparent, to ensure that intellectual property (IP) of a company can be protected and to avoid that hackers or competitors get access to confidential company data. In Germany, companies expect clear laws and transparent regulations from the government. They are very sensitive and restrictive in sharing company data. American companies follow a more pragmatic approach by developing de facto standards and applying them to new I4.0/IoT projects. They are more open-minded and willing to share data required to run open platforms. However, this topic 'data handling and security' cannot be elaborated further in this study.

CHAPTER 7 - CONCLUSION

Important goals of the thesis were to identify I4.0/IoT driven use cases in operation and to provide a paper that encourages decision makers in the industry to actively verify the companies' business models or start to develop complete new business models. The paper provides insights to the I4.0/IoT driven technologies, business models and business models initiatives in theory and practice.

7.1 Limitations and future research

This thesis could not cover every aspect related to I4.0/IoT business models. The study is based on the method explorative research; therefore it provides a deep analysis across the companies interviewed. The results and conclusions were drawn from the experts' experience and knowledge. To ensure a high level of validity only interviewees with high experience in I4.0/IoT were selected and the interviews were conducted in the USA and Germany. However, the study presents the results of selected industry sectors. Further research could be recommended to investigate if there are in other business sectors (not covered in the thesis) significant differences in creating I4.0/IoT business models.

Furthermore, no deeper consideration of the technical standards and norms which have been implemented in USA and Germany was deliberated. The study does not consider the human behavior by using new technologies. This aspect could be an interesting subject for future.

The selected business framework from Gassmann has, like every theoretical model, some limitations. In the theoretical part of the paper various models have been

presented, however a study which compares these business frameworks would be worth to be evaluated in a future research study.

7.2 Summary

Nowadays, one of the biggest challenges for companies worldwide is to cope with changes resulting from the digitalization of the industry and the creation of new I4.0/IoT enabled business models. The expected companies' shift in value creation from offering predominantly physical products towards creating complete new services with enlarged value propositions in the future will affect the existing revenue models. Market players from all business sectors are forced to carefully analyze their competition to recognize if new players are entering their business sector and endanger their today's market position. To protect today's companies' revenues they should not 'wait and see', but actively decide how to adapt their existing business model and company structures to the new market requirements. More specific, they have to determine if they concentrate their investments on improving the existing business model(s), either by achieving more efficiency in production or by enriching existing product offers with new value-added services or to opt for investments in complete new business models.

The course of the study was to evaluate the meaning and significance of the terms 'Industrie 4.0' and 'Internet of Things', to explore the existing theory regarding business models, to find out which of them are applicable to the new digital world and to present examples of upcoming new business models in the industry.

In the second part of the thesis the objective was to identify business models enabled by I4.0/IoT, ideally already established in practice and to find out which

improvements are expected. An additional target was to identify indicators for new business opportunities which can be later transferred and applied to other companies and business sectors. After conducting 18 interviews with I4.0/IoT experts two categories of business models could be identified. While the first category is referring to improving the existing business model, the second category relates to the exploration of complete new business models.

Furthermore, this study explored the differences between the American ‘Industrial Internet’ and the German ‘Industrie 4.0’ approach, not only from a theoretical, but as well from the practical side. Germany, as a strong engineering-driven nation, presently equips existing machinery park with digital devices, sensor technology and IT networks. One outcome out of the interviews with German companies is that their present focus is on digitalization and process improvements, mainly in the manufacturing. The creation of new business models is currently not in their focus and often targeted as a second step in Germany. In contrast, the learning’s from the interviews with American companies were that they act more pragmatically. They are more customer focused and eager to develop new business ideas. Therefore, they act quickly and build small project teams, formulate the target(s) of the new business model(s) and purchase the necessary hardware or software from outside. The American firms are more open to disruptive business model approaches. Their approach is mostly to establish a pilot project to prove that the new business model can operate successfully and look in iterative cycles for improvement potential. In addition, they are quick in introducing the business model to the market. The worldwide trend to more and more data-driven societies will strongly influence the

existing business models in the American and German industry. The findings from the study leads also to the conclusions: IoT/I4.0 will accelerate and boost the creation of new services. Different industries and business sector will merge together and new distribution structures will appear, mostly with a focus on direct to the customer (business-to-business-to-consumer) modes. Regarding the implementation of new business models, the study showed that the ‘correct timing’ is a key factor in the today’s industry world. Companies which only look at today’s revenues and profits and who are not willing to invest in time in new IoT/I4.0 structures risk of being over rolled by new market players.

APPENDICES

I. USE CASES

Appendix 1: Case Alpha

Individualized series production for plastic application (In-house)

Company profile

Alpha is a German machine construction company, which produces injection molding machines with small and medium clamping force. Their machines are used to manufacture plastic parts for medical technology, automotive technology, communication electronics as well as domestic appliances. Alpha employs around 2.400 employees worldwide. The turnover for 2015 was over 500 million euros, including all subsidiaries.

Initial Situation

The need for individualized plastic increased in the last years. The challenge is to implement small batch size production with high availability and economy. The combination of injection molding, additive manufacturing and Industrie 4.0 techniques, such as Cyber-Physical-System can enable an economic batch size 1 manufacturing approach for plastic parts.

Use case

A completely digital connected, constant automated manufacturing cell produces individualized office scissors. The specific injection molding machine and the ‘Y’ machine (for the additive manufacturing) are connected to a 7-axis robot. During the order entry, the operator/user writes down his individual lettering by using a tablet computer and select one out of four scissor types. The data gets digitally gathered and starts automatically the mass production. Every single product is turned into a data medium by using a data-matrix code. The next step is the installation of the individual plastic lettering. One of the most important components is the host computer system, which detects the parameter and forwards them to the web server. The product, process as well as quality data can be reviewed all the time by scanning the code with a mobile remote.

Benefits

- Flexible and efficient mass production for single components
- Increase of value chain and production efficiency
- Traceability of parts
- Improved quality control documentation

Appendix 2: Case Beta

Transparency in tool handling (In-house project)

Company profile

Beta is a global sensor manufacturer, located in the south of Germany. This family-run business is one of the biggest producers for industrial sensors and sensor technology. Beta employs worldwide over 3000 employees and had an annual revenue of over 300 Million Euro in 2014.

Initial situation

Tools for injection molding machines perish very quickly. Hence, they must be maintained frequently. In most cases an inspection was only conducted, if the quality of the produced component did not match the defined requirements or the machine tool was already broken. The new invention 'X' from Beta is taking care of this problem. 'X' allows the retracing of injection molding tool operation by using industrial RFID. By doing this, it collects data which enable a condition-based maintenance.

Use Case

Using industrial RFID makes it possible to retrace the use of injection molding tools and provides therefore the data for condition-based maintenance. 'X' is a self-sufficient system, which can be expanded worldwide. The additional benefit lies in the automated data collection, which is attached on the tool and the data transfer. By using LAN or Wi-Fi technology, every 'X' system can be connected with the control level

such as ERP or MES, thus the access to the data and processes is available from everywhere.

Benefits:

- Unmistakably assignment of the tools
- Consistent recording of the production cycles
- Worldwide access to the data
- Integration to superordinate systems

Appendix 3: Case Gamma

Digital tool management (In-house project)

Company profile

Gamma is a German consulting firm with focus on process advisory and information technology. The company is divided into different divisions such as enterprise resource planning, supply chain management, manufacturing execution systems, customer relationship management etc. Gamma employs almost 400 employees and had 40 Mio Euro revenues in 2014.

Initial situation

Gamma launched the project ‘digital tool management’, which consists of the following features: fully automated logistic processes, self-triggered SAP orders, visualize tasks and predictive maintenance for injection molding tools. The benefits are an increase in process stability for the logistics and an increase in availability for machines and tools.

Use Case

By the use of Gamma’s own developed software and RFID technology, the customer ‘X’ implemented a SAP ERP system to connect injection molding tools, machinery, forklifts and storage bins. Each tool and each storage bin gets an individual RFID tag for explicit identification. Gamma’s software allows the transmission of the data in real-time to the SAP ERP system which can be visualize the information simultaneously and user-specific on the forklift dashboard. The tools can be therefore

tracked permanently in the factory. This transparency makes it possible to optimize the use of tools, in terms of production planning and maintenance – and ultimately reduce the costs.

Benefits:

- Automated processes increase process stability
- Automatization of the entire tool management
- Optimized production control and maintenance
- Predictive maintenance for injection molding tools

Appendix 4: Case Delta

Industrie 4.0 assembly in practice (In-house project)

Company profile

Delta is a subsidiary of a large German industry corporation and focused on engineering products such as hydraulics, electric drives & controls, tightening systems, linear motion and assembly technologies. Delta employs almost 40,000 people worldwide and achieved total revenue of over 5 billion Euros in 2014.

Initial situation

Industrie 4.0 allows flexible assembly with high variants from small batch sizes to batch size 1. This increases the need for manual assembly. Nowadays, the operators have to identify several thousand variants with different materials, know the different work instruction and assemble the parts with a constant quality.

Use Case

To satisfy the above mentioned requirements, Delta invented fully adjustable operator assistance systems. It combines real assembly stations with the virtual world. The web-based software identifies the RFID tag, which is attached on the workpiece and downloads the appropriate assembly plan from the ERP or MES. Digital assistance systems, such as projectors, project the operating procedure. Another option is the use of pick-u-light modules to support the operator. In combination with the smart wireless screwdriver 'X', the operator can automatically locate where screws are required and double-check if the screw is assembled correctly. Modular integrated

systems, such as 3D cameras or ultrasonic sensors can afterwards check the quality and workflow.

Benefits:

- Higher quality
- Improved training time
- Web-based software with interface to MES or ERP systems
- Modular design and expandable

Appendix 5: Case Epsilon

Smart control systems for refrigerators (Customer project)

Company profile

Epsilon is one of the world's leading manufacturer of electric motors and fans. The firm employs around 11,000 employees in over 15 production plants. The motors and fans are used in various applications such as computers, refrigerator or supermarkets. The revenue was over 1.57 billion Euros in 2014.

Initial situation

Globally, there are over 50 million refrigerators in the food retail industry, which expend at least a total of 90 TWh per year. Refrigerators can be also used for precise cooling of production machinery, tools, industrial electronics and medicine. The new social and environment changes require smarter products which work more efficient.

Use case

Epsilon developed together with an American refrigerator manufacturer an I4.0/IoT solution. It is a smart, connected control system for refrigerator for the industrial and private sector, which increases the efficiency of the entire system. By up to 30 percent energy savings, the new invented cooling cycle system also supports the climate protection. The innovation of this project is the smart integration of all energy served units with the goal to optimize the energy consumption and the performance. The centralized-control system solution with integrated data link enables proactively

adaption of the cooling performance. This increases the energy efficiency of the system and facilitates an economical use.

Benefits:

- Improvement in efficiency and economy
- Energy saving of at least 30 percent
- Autonomous data shipment
- Monitoring and controlling of the devices

Appendix 6: Case Zeta

Advanced assembly line enables batch size 1 (In-house project)

Company profile

Zeta is a German family owned company, which produces high-pressure cleaning devices and systems. The range covers wash water treatment, part cleaning systems, floor cleaning equipment, etc. Zeta is one of the world market leaders in cleaning technology, employs around 11,000 people worldwide and had revenue of over two billion Euro in 2014.

Initial situation

The demand for individual cleaning devices increased over the last 10 years. It is possible to configure the cleaning device in 40,000 different variants, depending on the customer wish/request. However, the previous assembly system was not able to fulfill the requirements of high variety, suitable costs and large-scale production.

Use case

When a new order for a cleaning device comes in, the system creates a new QR-Code, including all relevant production data. While this RFID tag is attached to the individual work piece, it collects every data from the corresponding production step. The information is readout on every production station to adjust the machine to the particular customer requirements. The 'Pick-by-light' assembly systems help the operator to pick and assemble the correct part. The last step of the production contains

the quality control. If the assembled part passed this test, the QR-Code is scanned and sends an update to the system.

Benefits:

- Cost-effective implementation of batch size 1
- Enhanced assembly for multi-variant product
- High data transparency
- Increased functionality and flexibility of the assembly line

Appendix 7: Case Eta

Remote maintenance and advanced service offer (In-house project)

Company profile

Eta is an international corporation, which is operating in the robotics and automation technology area. Eta is a large engineering companies with over 140,000 employees in over 100 countries.

Initial situation

Industrie 4.0 offers big chances for the current industry for example increase in production efficiency by more than 30 percent. But not only new engineering technology supports the increase of revenues. Eta invests also a great amount of money into the service and software.

Use case

Eta started already with the Industrie 4.0 implementation. One of their Industrie 4.0 key enabler is the software 'X'. The software allows the simulation of robot programs in advance. By connecting the software with the tool Automation Builder, engineers and operators are able to plan, to do maintenance or even to improve the energy efficiency in a factory. Eta plan to sell new service offers to his customer. These packages include all-round carefree service, which can result in lower downtime or higher energy efficiency for the customer.

Benefits

- Improved availability to every time
- High efficient operation
- Energy reduction
- Cost savings by more than 30 percent.

Appendix 8: Case Theta

Smart use of compressed air (In-house project)

Company profile

Theta produces compressed air and vacuum products, including different types of compressors and blowers and other related products. The firm also offers rentals and consulting services beside their traditional business. The firm employs 5000 employees and has locations worldwide.

Initial situation

The new digital interaction between a workpiece and a machine offers the possibility to manufacture individualized products in high lots. This innovative production process presents completely new chances and opportunities for the firm Theta.

Use Case

Theta offers smart, cross-linked compressed air systems for its customers. Since 2013, the company is not only selling the hardware such as compressors, they are also selling the compressed air, as a service. For example, the compressor is placed at the customer's plant but the compressors remain property of Theta. By guarantee a high service-level agreement, Theta ensures the consistent availability, performance and quality. Beside these two business model, Theta is also selling a combination between the hardware (compressor) and the service. This service could be for example Predictive Maintenance to predict the next outage.

Benefits

- Variable adjustment of the compressed air control
- Best possible efficiency
- Maximum availability

Appendix 9: Case Omicron

Sensors monitor the water supply (Customer project)

Company profile

Omicron is a provider of automation technology. The company produces sensors, industrial interfaces, bus systems and components for the control technology of machines. The firm employs over 5000 employees and is located in over 70 countries.

Initial situation

If the water supply is interrupted, entire parts of a city are cut off from water distribution system. The target was therefore to constantly monitor and visualize the status of the water pump system. If certain data boundaries are exceeded or not reached, an alarm is triggered to schedule maintenance work and prevent idle time. The data can be monitored in real-time by the SAP system.

Use Case

Smart sensors and assessment systems were installed on every engines and pumps, as well as smart software was integrated in the system to analyze the data. The control center is equipped with displays at each station to obtain an overview about the system condition in real-time. Since the installation of the entire new system, there were less incidents and downtimes. Moreover, maintenance work and spare part ordering can be scheduled by a digital dashboard system.

Benefits:

- Reduce service costs
- Increase service quality and speed
- Sustainable customer loyalty

Appendix 10: Case Iota

Platform as a business model (In-house project)

Company profile

Iota is a subsidiary of a large American firm, which offers cloud computing solutions and platform services. It can provide large computing capacity quicker and cheaper than a most of his competitors. The firm employs over 230,000 employees and had over 107 billion dollar revenue in 2015.

Initial situation

Cloud computing offers various ways of value creation. One possibility for offering a new business model is to bring different groups of supplier, developer and producer together on a digital platform.

Use Case

‘Iota IoT’ is a managed cloud platform, which allows smart products to communicate and collaborate with cloud applications and devices. It can cross-link /support billions of devices, trillions of messages by forwarding these messages reliably and securely to other end machines. With the ‘Iota IoT’ platform, every application can keep track of the devices and communicate with them, to any time, even though they are not connected.

Benefits

- Increase up to 20% for the overall equipment effectiveness
- Enables data analytics in the cloud
- Applications and data are managed from the cloud

Appendix 11: Case Kappa

Cultural change via digital platform implementation (Customer project)

Company profile

Kappa is an American cloud computing company, located in California. The product range lasts from customer-relationship-management software to software application for the business world. These services should bring staff, customer and products together. Kappa acts in general as a “software as a service” and “platform as a service” provider.

Initial situation

For the customers and partners, it is not only important what rolls off at the end of assembly line. The customers focus on services and customer support. Only by doing that long-term customer relationships can be keep alive. For example the firm Kappa helps manufacturing companies to open up new market segments through digital customer services and transform their services into profit center.

Use Case

Kappa supports a German industrial automation company to improve and digitalize its entire value chain and all its touch points with employees, partners and customers. The main goal is the change of the communication culture within the firm and with the external partners. By implementing the ‘new’ platform the industrial

automation company can create and offer completely new applications and services for their internal and external customer.

Benefits:

- Order management captures and manages new orders more efficient
- The resource management orders automatically material if necessary
- Higher transparency over all areas

Appendix 12: Case Lambda

RFID as lever for Industrie 4.0 and IoT (Customer project)

Company profile

Lambda is a startup company, located in Connecticut, which is focused on RFID technology and software. It offers IoT solutions/consulting to facilitate retail, manufacturing, and health care application. It provides an open-source RFID software platform, consulting services and support.

Initial situation

RFID technology is capable to improve the world in different ways. One of the keys for this ‘transformation’ is that the solutions have to be simple and integrated. Lambda invented/established one of the most popular RFID middleware platforms by using an open source community approach.

Use Case

One of the big trailer manufacturer in the U.S. already implemented Lambda’s technology into his factory. He equipped every delivery area (in front of machines) with RFID sensors as well as every charge carrier. This enables the measurement of the time between the working operations as well as the monitoring of the production process. The production system is connected to the ERP system, which allows an efficient flow within the entire supply chain. The RFID tags can be backtracked to the individual machine or component, to identify failures or errors in the supply chain. The company ‘Iota’ offers his platform as an entire new business model. The platform

functions as a digital marketplace (app store), on which different customer and partners can interact with each other.

Benefits

- Increased production efficiency
- Higher information transparency
- Enables system networking for factories

Appendix 13: Case Nu

Improve retail experience by using IoT technology (Customer project)

Company profile

Nu is a multinational player and one of the world's strongest brands. It employs currently over 375,000 employees in over 170 countries. Nu focuses on numerous IT solutions such as cloud computing, business analytics, mobile enterprise, social computing and smarter planet solutions and consults/supports companies of all sizes in facing the chances offered by increasing digitalization and globalization.

Initial situation

Nu developed an IoT concept together with one of their customer from the rail industry. When private shoppers enters a store seeking advices and they are not able to find a sales representative quickly, they leave immediately the store empty-handed. The result for the store is a loss in sales.

Use case

The new approach/technology from Nu analyze video, Wi-Fi and sensor data to recognize the shoppers' faces and body postures as well as track their in-store movements. The collection of the data allows retailers to send staff to the people who need support or advices and to make them personalized offers. The data can be used to offer the same customer individualized offers when he or she enters the store again.

Benefits:

- Individualized product offers
- Increase sales volume
- Gain better knowledge about customer behavior

Appendix 14: Case Rho

Industrie 4.0 enables just in time delivery (Customer project)

Company profile

Rho is an American, international corporation with the focus on automotive parts, battery technology, building technology and industry services. It employs over 170,000 employees in over 1,300 locations worldwide.

Initial situation

While the focus was on just-in-time material supply for last years, the trends is going over to just-in-time product delivery. One of the main goals for the manufacturing industry was to have the correct material at the right time on the right place. However, customer demands and market changes inquire for new efficient methods of delivery, such as just-in-time delivery. The delivery of the material could take place in the same order as the OEMs produce their vehicles. By doing that, both systems would result in significant economies of scale, while storage capacity and procurement costs can be decreased.

Use Case

Rho invented together with an American platform provider a software stick, which enables the above mentioned just-in-time delivery. This software allows him to deliver just-in-time requested products to his customers, never mind how many or with which characteristics. The unique selling proposition of Rho is therefore his supply

chain and his products. It is one of the first times that an automotive supplier is using a public cloud server to communicate with his customer.

Benefits:

- Enables just-in-time delivery
- Higher flexibility
- Higher process transparency

Appendix 15: Case Sigma

Digital oilfield solutions (Customer project)

Company profile

Sigma is an American manufacturer of industrial automation and information provider. The company employs over 22,000 people in more than 80 countries worldwide. Most of his products find applications the industrial automation sector.

Initial situation

The increasing global hydrocarbon regulations and requirements force the oil and gas industry to invent new efficient methods for the production of petroleum and other fuels. IoT solutions can help to fulfill these requirements and stay competitive in the future.

Use Case

To stay competitive in the oil and gas industry, Sigma wants to establish new automated process of data gathering and analysis. The tools used in mining, refining and selling petroleum are expensive and require high quality standards. Enhanced by the new technology, Sigma is extending his own systems with cloud-based solutions to monitors these precious equipment and uses the data for real-time insights and predictive maintenance. It enables the transformation of his entire petroleum supply chain to accelerate the time-to-market processes and creates essential results in total productivity.

Benefits:

- Reducing costly downtime and maintenance
- Accelerates business growth
- Faster time-to-market process
- Stimulate innovation thinking (within the organization)

Appendix 16: Case Tau

Healthy dosage of information (In-house project)

Company profile

Tau is one regional leading healthcare provider in the middle west of the U.S. It employs around 2,200 employees and is taking care over 6,000 patients per year.

Initial situation

The use of smart products and systems is changing the existing business in several industries. Not only patients but also health care provider will benefit from the IoT expansion in the health care area. Possible applications for the healthcare industry can be wearable devices or mobile medical applications.

Use Case

Tau's goal was to develop a better solution for medication management and to improve patient care and efficiency. Therefore, Tau implemented a solution that connects medical devices such as pharmacy carousel, anesthesia workstations, and medication-dispensing cabinets with a central server and a Microsoft SQL server database to manage the inventory, the billing and the medical records electronically.

Benefits:

- Reduces medication delivery time
- Decrease in pharmacy inventory costs
- ROI is reached in two years

II. Questionnaire

Appendix 17: Questionnaire

THE
UNIVERSITY
OF RHODE ISLAND
COLLEGE OF
ENGINEERING

THINK BIG WE DO™

DEPARTMENT OF MECHANICAL, INDUSTRIAL AND SYSTEMS ENGINEERING

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I. Interview guidelines

Interviewer will provide interviewee with signature form for informed consent and with agreement, begin the audio recording. Alternatively, if the interview is via telephone, interviewer will ask if the interviewee has received the consent form and agrees to participate and be recorded. Once the recorder is turned on, the interviewer will repeat the name of the study, date, names of those present, and ask for verbal confirmation to continue recording.

II. Interview questions

1. Questions about the interviewee and his background

1.1 Position and responsibilities:

Please describe your position and your responsibilities in your company.

1.2 Experience with business models

How much experience do you have in the field of Internet of Things (IoT) or Industrie 4.0 business models?

[Content and time – number of meetings, etc.]

1.3 Difference between Industrie 4.0 and Internet of Things

What are the differences between I4.0 and IoT? Please describe in detail.

[If the interviewee is not familiar with the term Industrie 4.0 -> use the term Industrial Internet]

1.4 Conceptual understanding business model

Gassmann (2014): A business model defines: who are the customers, what is being sold, how to produce it and how to realize a profit. Briefly: the Who-What-How-Value.

This definition forms the basis of my thesis. From your perspective does this definition cover all key elements of a business model?

A large, empty rectangular box with a black border, intended for a response to the preceding question.

2. Questions about the I.40/IoT business models in your company

2.1 Dynamics of the industry

How do you classify the dynamic nature of the industry in which your company operates, – on a scale where 1 means static and 5 means very dynamic? Please explain your answer.

[Product life cycle management, regulatory changes, innovative competitors]

2.2 Relevance of I4.0/IoT business models

How important is the topic I.40/IoT in your company, including the related business models on a scale of 1 (not important) to 5 (very important)? Please explain your answer.

2.3 Current state of I4.0/IoT implementation

How do you assess the current implementation status of I4.0/IoT projects on a scale from 1 (not started yet) to 5 (already on the market) in your market? Please explain your answer.

2.4 Amount of I4.0/IoT projects

Can you please mention the current amount (estimated value) of I4.0/IoT projects in your company?

A large, empty rectangular box with a black border, intended for the interviewee to provide their answer to the question about the current amount of I4.0/IoT projects.

[If interviewee is from a research institute, consultancy, etc => please mention practical examples you know well]

2.5 Specific I4.0/IoT business model

Can you please state a specific, advanced example of an I4.0/IoT business model for your company, including the status of implementation?

A large, empty rectangular box with a black border, intended for the interviewee to provide their answer to the question about a specific I4.0/IoT business model.

[If interviewee is from a research institute, consultancy, etc => please mention practical examples you know well]

3. Questions about the specific I4.0/IoT business model

3.1 Driver of the I4.0/IoT business model.

What was the external and internal driver for the development of this specific I4.0/IoT business model?

3.2 Aim of the I4.0/IoT business model

What is the aim of this I4.0/IoT business model?

3.3 Dimensions of the I4.0/IoT business model

Gassmann (2014) describes a business model based on a magic triangle [Figure from the appendix] including four dimensions (customer, value proposition, value chain, revenue model). Can you please describe how your specific I4.0/IoT business model fits with this model?

3.4 Method

What method did you use for the development of this I.40/IoT model? Please describe in detail.

3.5 Involved staff and roles

Who was involved in the development process of the business model? Please state the internal departments/people and also any external partners.

3.6 Challenges and resistances

What challenges or resistance did you have to overcome during the development process?

3.7 Business model from a competitor

Can you please provide me with specific examples of I4.0/IoT business models from your competitors (which operate in the same industry), including the advantages and disadvantages (compared to your own business model)?

4. Questions about “Lessons Learned” and further I4.0/IoT implementation

4.1 Lessons Learned for further business models

Do you have any specific recommendations for developing further I4.0/IoT business models because of your experience with the development process of your own business model? Please explain.

4.2 Hints for Implementation

Your team and you have developed a new I4.0/IoT business model. What is a successful implementation process within your organization?

[How important is the change management in terms of disruptive business model development?]

THE RECORDING DEVICE IS TURNED OFF!

End of the interview

- May I contact you again, if I have some further questions?
- Do you know any other colleagues, who might be approached to participate in the study?
- **Thank you very much for your support!**

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