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Entrepreneurship & Innovation

Technical, social and economic implications of Machine Learning in IoT

A Master's Thesis submitted for the degree of
"Master of Business Administration"

supervised by
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Affidavit

I, **DI(FH) Aleksandar Bogoevski**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Technical, social and economic implications of Machine Learning in IoT", 69 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 30.06.2017

Signature

Acknowledgement

This thesis is dedicated to my family, especially to my wife Ana and my lovely sons Filip and Luka who are motivating me to develop further and constantly improve myself. Most credit goes to my wife Ana who provided me the time and freedom to focus on my study and write this thesis while taking care of our sons. Furthermore, I would like to thank my parents who always taught me to strive for more and constantly educate myself.

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Abstract

"Data is the new oil, it's valuable, but if unrefined it cannot really be used. It has to be changed into gas, plastic, or chemicals to create a valuable entity that drives profitable activity; so must data be broken down, analyzed for it to have value."

Clive Humby, Mathematician and architect of Tesco's Clubcard, 2006

In today's world data is gathered almost everywhere and for every purpose, especially as more and more devices are connected, which act as a data source in different fields. But what to do with this data? What benefits can result of gaining data? And what new possibilities are coming up driven by digitalization?

How important is analytics in the Internet of Things? This thesis aims to analyze the importance of analytics in the Internet of Things when it comes to creating new business models in the industrial environment and provide a state – of – the – art review on what has been done so far in this domain. Therefore, the value chain of IoT is analyzed where different factors like the amount of data, the processing capabilities and the variety of data play an important role when it comes to creating value out of gained data from all different types of sources deployed in the field. New technologies like predictive analytics, edge computing and different access technologies are unleashing tremendous possibilities for enterprises of all sizes to change industries they are acting in and even disrupt these industries just by gaining new insights in customer behavior, better utilizing their assets or by introducing new business models to the world which are enabled through the Internet of Things and especially through analytics. It is all about gaining value out of collected data in order to remain competitive and to be able to sustain over time.

Businesses of all sizes should analyze their possibilities and benefits in deploying different types of analytics and determine their possibilities in deploying new business models to meet expectations rising out of the new society where possessing goods is not that much of importance anymore, but therefore even more important to provide exactly the desired service at the right time at the right quality level in order to make sure that customer expectations are met and bind customers even closer to a business than it has been possible ever before.

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Abbreviations

IoT	Internet of Things
M2M	Machine-to-Machine communication
CPS	Cyber Physical Systems
LWM2M	Light Weight Machine to Machine
AI	Artificial Intelligence
HW	Hardware
SW	Software

1 Introduction

This chapter is about to provide an outline of the thesis and provide a brief description on IoT and analytics where also a context to understand the interplay between IoT and analytics is provided.

Context of the thesis

IoT is gaining more and more ground due to affordable prices of devices and connectivity costs, which is mainly driven by new technologies that are coming up and by the fact that society and enterprises are recognizing the advantages IoT is bringing with it to improve people's lives in a way nobody would have even could imagined. It is also driven by increasing number of companies and competitors entering the industry. More and more enterprises are digitalizing their business in order to improve internal processes and improve their profitability. But what is even more interesting is that IoT is unleashing possibilities to develop and deploy new business models.

The need for new business models is also very much driven by the change in society as new generations, especially millennials, who playing a more and more important role nowadays. May it be in the field of work where these new generations stake out new claims in regards to work environment and possibilities. But also, consumer habits are changing over time, especially as young generations do not have their focus anymore on possessing things but rather on experience, is the major topic that counts. Therefore, enterprises have to adopt their business models to meet new requirements and demands that are coming up. To be able to fulfill these new requirements and demands products and services have to be adopted accordingly as well.

Enterprises are aware that they have to start their digitalization activities as soon as possible to remain competitive in the market, especially as start-ups are changing the whole economy and are able to attract more and more customers by providing exactly these products and services that society is looking for. And can actually deliver these services and products globally in no time. Furthermore, they have the possibility to disrupt whole industries just by changing the rules of the game and utilizing digitalization in a way that provides competitive advantage even over huge enterprises. Therefore they are developing and deploying analytics to gain as much as possible information out of data which is nowadays generated almost everywhere, and which results in the new insights in customer behavior and preferences and leads to meeting exactly the needs of today's society.

1.1 Aim and objectives

Digitalization is a major topic during the last years and is seen as one of the cornerstones to improve efficiency inside enterprises, but also to generate new revenue streams. But, is this a valid assumption or is it just another new hype, which is mainly driven by vendors of components and other stakeholder (i.e. service providers, system integrators, etc.) along the entire value chain to boost their business?

The overall aim of this thesis is to provide a state of the art review on digitalization driven by IoT focusing on manufacturing companies across several industries. It is to prove and analyze why new business models are necessary and how different types of ventures are gaining benefits out of digitalization efforts for internal improvements but also in developing new business models which fit today's society even better.

Furthermore, this thesis is about to provide best practice examples of successfully deployed IoT projects based on studies conducted by different analysts, whitepapers provided by players in the field of IoT, and surveys executed by different research companies in this field and primarily economics.

What is IoT?

IoT is the concept of connecting any device to the internet including almost everything, starting from smart phones, coffee machines, vending machines, lamps, washing machines, different types of wearables like fitness bracelets and all kinds of sensors. But also, different components of machines like jet engines of airplanes or drilling machines as well as windmills for energy generation. Basically, any device which provides any source of power can be connected to the internet in order to generate data and enable new types of services across all fields one could imagine like reducing downtimes of assets and machines, improvement of equipment utilization and offering products as a service. Different analysts like Gartner or Machina Research predict that the number of connected devices should reach the amount of 20 to 50 billion devices which should be connected to the internet by 2020 where different types of access technology will be used according to the use case the device is meant for. This means that IoT will develop towards a giant network of connected things including also human beings. Therefore, the relationship will be people to people, people to things and things to things which aims to improve our lives in a way nobody would have ever imagined.

What is analytics?

Discovering whether or not x causes y is at the core of many interesting questions for enterprises nowadays. Therefore, analytics often is based on analyzing historical data to identify potential trends, to analyze the effects of certain decisions or events or to evaluate

the performance of a given tool or asset. The clear goal of analytics is to improve business by gaining knowledge which can be used to make improvements or changes.
For this purpose, analytics can be applied across different domains across an enterprise, may it be to predict possible failures of machines on production floor or machines which are used outside in the field or whatever asset that contributes to the success of a business Furthermore, it provides the ability to monitor the entire device lifecycle and so adopt offerings accordingly. But, it is also applied to get a better understanding on people's needs which can help to fulfill these newly identified needs in an efficient and profitable way especially when it comes to lot size one production or differentiating products and services from competition.

Analytics is alongside used to describe statistical and mathematical data analysis, which at the end clusters, segments, scores and predicts what scenarios are most likely to happen in future. Therefore, analytics has garnered a burgeoning interest from business and IT professionals looking to exploit huge mounds of internally generated and externally available data.

What are the main challenges and entry barriers?

As deployments are still lacking backend predictions from all analyst in the market it is important to consider and understand the barriers for IoT deployments in order to be able to address these issues in a proper way and make such deployments easier:

Not understanding the data:

Generating huge amounts of data does not necessarily mean that one can make use of it to gain benefits like having data from different data sources that might need to be translated so that the system would be able to understand and process the data. And because of the range and diversity of IoT use cases, it is unlikely that a single vendor is able to provide a comprehensive solution for an environment of the scale of a production facility for example. And even if it would be possible, it would most likely force a rip – and – replace approach that would be cost prohibitive.

Too much data:

Often the total amount of generated and collected data may be so great that moving it over the network to a central location – often the central cloud or data center of a business - may not be viable. To overcome this obstacle an integrated solution is needed with the ability to aggregate only needed data from any device, normalize it into common data models and making it accessible as needed for any type of analytics. This becomes important when start deploying new data sources. Not all data that can be captured is worth to be captured like temperature sensors in the open field in very close proximity.

Security:

When every device is connected, every device becomes a vulnerability, or potential point of attack. Therefore, the overall security level is only as strong as the weakest device that is part of the ecosystem. If the security on a device from a particular vendor is weak and different applications rely on data from those sensors, the possibility of a critical impact is strong. The importance of security can be seen by considering the MIRAI botnet attach where hackers took over control of millions of devices and managed to cause tremendous problems for network operators.

Privacy:

When it comes to privacy the IoT presents some unique challenges which go far beyond data privacy issues that exist currently. This is mainly driven by integrating devices into the environments without people using them consciously. It is important to consider also laws in different countries. Especially in Austria data privacy is a huge issue and all firms have to follow local rules.

Unpredictable device behavior:

Another challenge for IoT deployments is device behavior especially if devices start sending false data to the system. The reason for it can have several issues like software bugs, low battery or instable power supply, or any external impact caused by ongoing works around the area of deployment. While unpredictable device behavior is not an external security threat, the impact of such devices can be just as destructive. An example would be if a metering device would start all of a sudden send huge amounts of data to the platform although it is expected that data is sent in predefined intervals.

What is available on the market?

Devices:

As IoT and supporting technologies are constantly evolving over time there are new solutions coming up to address all the different needs along the IoT value chain. Starting from devices which are used for data generation. These devices will fulfill different requirements like reduced device complexity which leads to lower device cost and so enables deployments of huge numbers of devices in the field.

Connectivity:

Also, connectivity is constantly evolving and new types of connectivity are arising. These new access technologies will enable deployments of devices without the need of constant power supply and at the same time battery lifetime for more than ten years. This makes data generation possible even in remote areas where infrastructure is lacking. But also, connectivity which enables ultra-low latencies in order to analyze data streams in almost real

time and make decisions and set counter measures in real time as well.

IoT platforms:

IoT platforms providing device management functionalities in regards of software and firmware updates over the air, data aggregation and data brokering to make data generated from different types of sensors for different types of applications available. This in fact enables analytics models put data in correlation to gain new insights and increase the ability to predict what might happen in the future in regards of possible downtimes but also enabling to predict customer needs even before customers are aware of their needs themselves.

Applications and Analytics:

The most important part along the IoT value chain is analytics which accounts for 40%. As analytics can be applied across several fields there are also different applications including different data analytics types for different use cases. The ecosystem of analytics is constantly growing addressing new fields like fleet management to optimize usage and routes of vehicles or predictive maintenance to predict possible downtimes of different types of machines and assets which results in reduced downtime and maintenance only when needed which clearly has an impact on equipment utilization and overall profitability of businesses.

1.2 Course of investigation

For this study, a state of the art review was chosen. The qualitative approach was used to reveal the key facts of analytics surveys according to the goal of the thesis to analyze the importance of analytics in IoT. With this purpose in mind, literature related to analytics basics, surveys, use cases and solutions was collected and analyzed according to its relevance to answer this question.

The state of the art review provides an insight on what is currently done in the field of IoT and analytics. Therefor it is important to consider that the review is not closed once the thesis is finished as more and more IoT deployments are ongoing across the globe which all provide new findings and insights.
Furthermore, the purpose of this work is to convey to the reader about which knowledge and ideas have been established in analytics in IoT and what the strengths and weaknesses are. It also collects and examines the state of current knowledge in analytics by examining the work of scholars and researchers whose work has been recognized as valuable.
The aim of this work is to provide a detailed insight on how analytics and IoT are changing the way how businesses are operating and the benefits they are generating by applying new technologies in day-to-day business life. It should serve as a reference on newest activities in

this field and allow people who are reading this work to understand the challenges and benefits of such deployments.

Keywords for collecting data were:

- IoT value chain
- Analytics
- Artificial Intelligence
- Digitalization
- New business models
- Business model innovation
- economic implications of analytics in IoT
- Cyber Physical Systems

For the search with these keywords the several databases the libraries of the Vienna University of Technology Libraries (www.ub.tuwien.ac.at), Vienna University of Economics and Business (www.wu.ac.at/en/library), Springer (http://link.springer.com), University of Minnesota Libraries (https://www.lib.umn.edu) , Google Scholar (scholar.google.com) served as a source of academic databases. In addition, websites of organizations that provide material with a high degree of relevance to this thesis and help to frame the research problem like Fraunhofer IAIS, Berg Insight, Analytics Insight, Gartner (www.gartner.com) and Machina Research (https://machinaresearch.com) were very useful.

1.3 Structure of the thesis

This thesis is divided into six chapters. Chapter 1 serves as introduction and the remaining chapters are briefly described below.

Chapter 2 describes why new and disruptive business models are needed. It also provides an overview on how such new business models are developed and what has to be considered in order to develop and deploy successful business models. In addition, it explains challenges businesses are facing when it comes to deploying new business models and how these challenges can be solved across the different domains like knowledge, technology, policies and organizational structures which might be hindering when it comes to deploying new business models. But also, the aspect of lower profitability of new business models in comparison to already deployed business models is discussed in brief.

Chapter 3 is focusing on the Internet of Things. It explains what Cyber Physical Systems are and how they are assembled. In addition, it explains what the benefits of these Cyber Physical Systems are and how these systems can contribute in developing and deploying new business models based on technology which allow to serve constantly changing market

requirements and demands which are driven by technology but also by the change in society. This chapter also describes the technical challenges that come along when enterprises are starting their journey towards digitalization especially how data is captured and transferred, how the vast number of devices can be managed and how value is added to data by applying different types of analytics.
An overview on the different stages of analytics is provided and how the different stages add value to the undertakings in digitalization of an enterprise. It describes how analytics contribute to new business models especially when it comes to offering products as a service where it is absolutely mandatory for the vendor to have a real-time overview on the actual status of the different assets deployed in the field and offered as a service. Also, the importance of understanding what might happen based on usage and changes in environment and how these changes would affect operations of different assets.
Another important aspect that is discussed in this chapter is that Cyber Physical Systems call for flexibility when it comes to adding and removing devices from the entire system and what has to be considered in regards to security, privacy, communication protocols and the vast amount of data that is generated by all the devices deployed in the field. And where the generated data should be processed in order to achieve the best results when it comes to latency, bandwidth, computing capabilities and the right access technology.

Chapter 4 is about to provide an overview on successfully deployed IoT projects. All the described projects are focusing on new business models that are enabled by the Internet of Things. It discusses also what these businesses had to consider in regards to technology and knowledge that are required to deploy these newly developed business models in a successful way while providing benefits for the customers as well as for the vendors.

Chapter 5 is a summary of the key findings and contains conclusions on how important analytics are when it comes to deploying new business models based on the Internet of Things. This chapter also indicates future research fields in the field of education and policy making.

2 Business Modelling based on IoT and CPS

This chapter provides an overview on why new business models are needed and what challenges enterprises are facing when it comes to developing and deploying new business models in regards to knowledge, technology and policies. Furthermore, it describes how businesses can overcome these challenges.

2.1 What is a business model?

Although there is no clear definition in academia on what a business model really is (Zott et al. 2011; DaSilva & Trkman 2014) there is one common understanding. Business models define the way how new technologies and ideas are commercialized (Kindström & Kowalkowski 2014).

As technology by itself has no objective value it is the business model that defines how new technologies and ideas are commercialized. Furthermore, the same technology can be commercialized in two different ways that leads to two different returns. In some cases, already established business models can be used to commercialize new technologies, but in other cases enterprises will have to identify new possibilities and models to commercialize these new developments and gain financial benefits out of these ideas (Chesbrough 2010). In the latter case, technology managers have to widen their perspectives in order to be able to define a new business model which allows capturing value from these technologies (Osterwalder & Pigneur 2010)

Another model developed by Chesbrough and Rosenbloom suggests that a business model fulfills the following functions:

- Definition of the value proposition
- Identification of a market segment and specification of revenue generation
- Definition of the structure of the value chain that is required to create and distribute the offering and complementary assets that are needed to support position in the chain
- Details the revenue mechanisms by which the business will be paid for the offering
- Estimation of the cost structure and profit potential (considering also the value proposition and value chain structure)
- Description of how the business is positioned within the value network linking suppliers and customers
- Formulation of the competitive strategy that allows the venture to gain and keep advantage over other firms

Another model described by Osterwalder and Pigneur suggests that a business model can be described through nine building blocks showing the logic how the company aims to create commercial benefits out of new ideas or technologies and considering the entire eco-system at the same time (Osterwalder & Pigneur 2010):

- Customer segments
  Defines for whom value is created defining also who the most important target customers are
- Customer relationships
  Analyzes what kind of partnership customers expect, how costly these partnerships are and how they are integrated in the rest of the business model
- Value proposition
  Describes what specific value is delivered to the customer and which customer problems a business is solving analyzing also the uniqueness of this value.
- Revenue streams
  Describes what are customers willing to pay for, analyzes if all customers are willing to pay the same and how the value is connected to the revenue stream
- Channels to the customer
  Provides information on how the customer will be reached, which channels are used, how the integration with these channels looks like, which channels work best and which are the most cost-efficient ones
- Key resources
  This block describes which key resources are needed to ensure the value proposition, to fill the channels, to maintain customer relationship and to generate the revenue stream and if these resources are unique, sustainable, protectable, scalable, easy to leverage into other applications and markets.
- Key activities
  Analyzes which activities the value proposition requires and if others are able to perform these activities in the same quality.
- Key partnerships
  Definition of who the key partners are, what resources and key activities from these partners should be acquired, if there is a exclusive partnership and what the possibilities are to prevent partners from acting opportunistic.
- Cost structure
  Considers what the biggest cost factors in a business are, which resources are the most expensive and if and how these resources can be eliminated.

Analyzing both definitions of a business model one can see that both are considering the same building blocks. The main difference is that the model described by Osterwalder is splitting the business model up in more details.

But it is important to note that there is no business model that is able to cover all needs, moreover, every new idea or technology requires a new business model in order to generate revenues through existing or new revenue stream, and so create value for a business and other involved stakeholders.

The same applies also for customer groups, for each and every customer group a separate business model has to be developed as every customer group requires different channels and demands different engagements (Osterwalder & Pigneur 2010).

"There's not a single business model… There are really a lot of opportunities and a lot of options and we just have to discover all of them."
Tim O'Reilly, CEO, O'Reilly

2.2 Why Business Model Innovation is important

There are several reasons why new business models are needed.

1. Servitization
   The service sector is growing globally. This lead to the fact that the service sector accounts for 70% or more of the gross domestic product (GDP) in countries like the USA, Germany, UK and France although the manufacturing sector is steadily declining (Kindström & Kowalkowski 2014).

2. Competitiveness of products
   The example of Apple's iPod shows that a good product that is integrated in an innovative business model is more difficult to be replaced even if competition releases a much better product (Amit & Zott 2012)

3. Industry disruptions through entrance of new players
   Examples in this domain are clearly companies like Uber, Amazon, Skype and Airbnb who have changed the industry they have entered tremendously. Uber is operating the biggest fleet of Taxis without possessing a single car. Amazon has revolutionized the book market without operating one single brick-and-mortar store while Skype is the largest telecommunications provider without owning any infrastructure and Airbnb has revolutionized the hotel industry without maintaining a single hotel room (Gassmann et al. 2016).

4. Profits for sold products are too low

   Many companies that have a strong presence in westerns industrial countries were developing, producing and selling high-quality products. Although these products came along with high pricing the profits generated were not high enough. Furthermore, the profits were mainly generated through “after-sales services” like repair and maintenance services and necessary spare parts. But this business model is more and more in danger due to threats caused by global markets (Plötner 2017):

   - Customers from emerging and developing markets account for the highest growth possibilities even if they are lacking financial resources for acquiring such assets and interest in aftersales services as they intend to maintain their equipment themselves
   - Copied spare parts of established technology firms for products like power plugs from Apple or complex drives from Siemens, GE and alike. This results in lower revenues and profits for well-established technology firms.
   - State interventions in China where previously the cost of all spare parts to assemble a car would have resulted in a ten times higher price. After interventions of the Chinese government the total cost of all spare parts to assemble a car were only three times higher which presents a major loss in profits gained by firms

5. Changes in technology

   The Internet of Things is a catalyst for the development of new business models which are focusing on the needs of users fulfilling exactly their needs. These new business models focus on services and user experience (Bosch Software Innovations n.d.).

   New business models are also driven by CPS where new services are expected which can change many aspects of our life whereas the potential fields of applications seem to be endless like air-and ground- traffic, discrete and continuous production systems, logistics, medical science, energy production, infrastructure surrounding us, entertainment just to name a few of them (Monostori 2014).

6. Innovative business models can serve as an opportunity for growth

   Businesses have undertaken almost everything in order to reduce their internal cost and increase their profitability, but what is important is to act in fields where nobody else does in order to achieve growth and further increase profitability (Amit & Zott 2012).

Important to consider is also the fact that Artificial Intelligence (AI) is leading our society to rethink fundamental economic relationships and how value is created and what potential economic growth it can bring to our society which seams extremely important in times when economic growth is more or less stagnating. The potential in Germany for economic growth is estimated to $1.1 trillion in 2035 mainly driven by intelligent automation coupled with initiatives like Industry 4.0. In the UK AI could contribute $814 billion in 2035 with growth rates somewhere between 2.5% and 3.9%. This growth will be driven mainly by augmentation and intelligent automation channels. And even UK's dominating service sector could benefit from AI as it could fuel productivity of knowledge workers (Nanterme & Daugherty 2017).

2.3 How to develop new business models

New business models enabled through the IoT are clearly putting the customer in the center of all undertakings of a business and focusing on providing customer experience instead of selling a product. To be able to do so, a service provider needs to gain very detailed information on their customers and their needs in particular. Furthermore, this gained knowledge and information has to be linked to all processes involved to create value for the end-customer.

Examples of companies in real life are Rolls Royce and Kaeser to name just two of them. Rolls Royce began instead of selling products and services to transform its business to offering the customer a guaranteed outcome in the sense of available flight hours (Smith 2013). Another example of doing so is the German manufacturer of air compressors Kaeser who is offering cubic meters of compressed air (Gibbons Paul 2017). Both cases will be described at a later stage more in detail providing an overview what has been done to be able to change the business model.

To be able to put the customer in the center of all operations and undertakings requires also developing a new business model. When developing this business model, it is important to properly understand the entire process in value generation internally and externally. One tool that supports managers, product developers and also sales people is the Business Model Canvas which was developed by Alexander Osterwalder. The Business Model Canvas provides an overview of all activities that are involved in creating value for the customer (Osterwalder & Pigneur 2010).
Figure 1 shows the business model and all its building blocks.

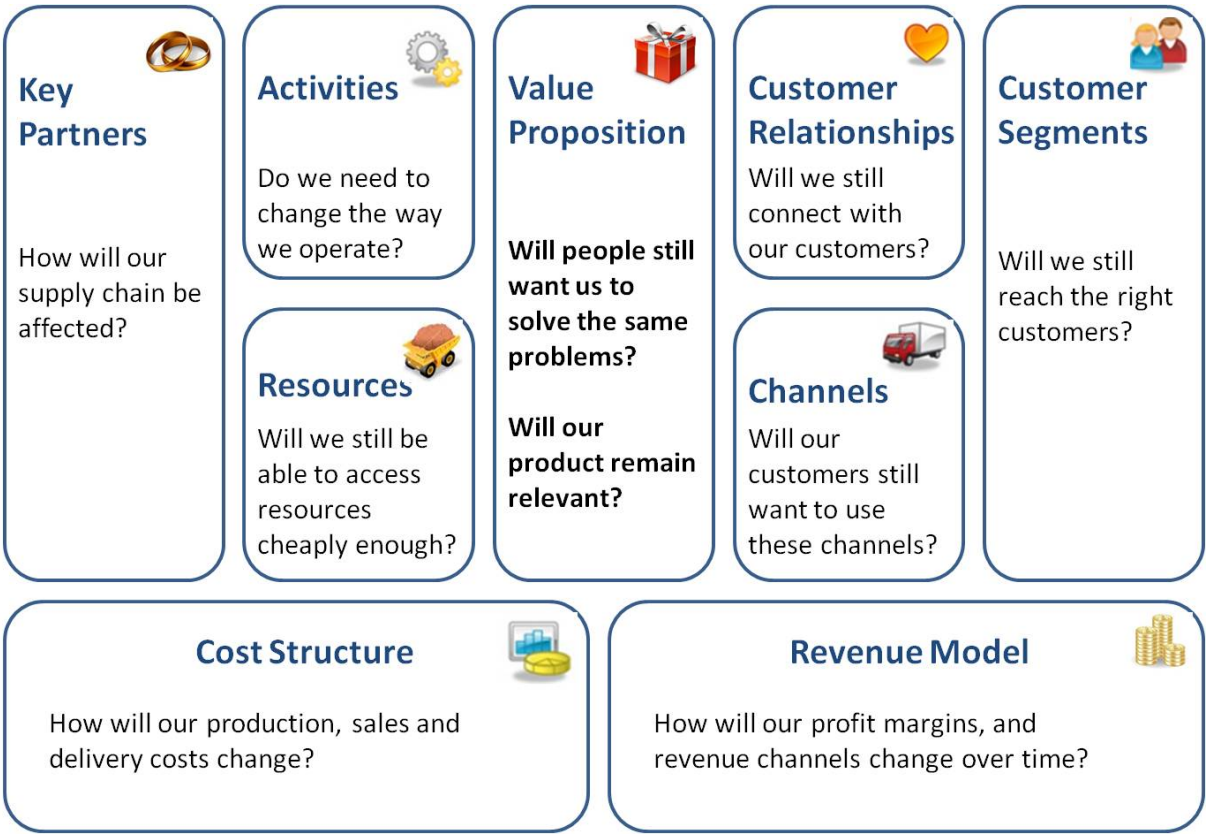

Figure 1 Business Model Canvas (https://fivewhys.wordpress.com/2012/05/18/linking-your-business-model-to-strategy/)

Having a look at the Business Model Canvas one can easily see that the value proposition is put in the center of all activities. The value proposition defines what are customers paying for and why they are paying for it, in other words the value proposition describes the package of products and services that are creating value for a specific customer segment or group of customers.

The right half of the business model canvas describes how the business is interacting with its customers. Firstly, it defines who these customers are that are willing to pay for a particular product or service. Important to note is that every identified customer group or segment has different needs and requirements which means that there is no business model that is able to fulfill all needs from the different groups or segments, moreover the business model and the value proposition has to be adopted accordingly to target customer preference(s) in regards to pricing, how to engage with them, and also important how the relationships with these customers will look like in future.

For example, some customers prefer to source a product that fulfills their needs without any other interactions with the business itself. Other customers prefer being offered a service which allows them to fully enjoy their newest purchase without having to worry about servicing the product or the availability of the product or service they are in need of. These

needs are mirrored in how the customer interaction is taking place if it is through direct channels or indirect channels and how the revenue streams look in regards to their frequency of occurrence, moreover if there is one time payment for the product itself or if they are recurring on a regular basis when instead of offering a product a service is developed and offered to the customer. Therefore, a business has to understand clearly how the relationships with their customers will look like in the future and set all necessary measures which will allow them to interact with customers in a proper way.

When developing a new business model, it is important to gain a detailed understanding if the chosen channels are able and willing to follow the direction how new products or services have to be offered to the end-customer as it might require some adaptations on their side in regards of billing systems and also billing cycles.

The left half of the business model canvas, as indicated in the figure, is focusing more on the internal processes of a business that is creating value for the customer. It considers the key activities of a business in regards to what is activities are required to make the business model work. These activities differ in dependence to the offering itself. If a business is offering products like in the case of the entire manufacturing process has to be included as this is crucial to be able to start offering products as a service. For consulting firms, key activities include solving problems their customers are facing.

Important to consider are also the key partnerships that are required for a successful business model implementation. Key partners can be found across several domains. When it comes to IoT based business models, one of the key partners would definitely be a communication service provider who enables the data communication from and towards the product which is offered as a service. Another important partner would be the analytics vendor, who is providing the capabilities of understanding the actual health status of the assets deployed on customer side by running analytics against the tremendous amounts of data generated. But not only cloud processing capabilities are important, also the storage capabilities that are required to store the data for future analytics processes (T-Systems 2016). Furthermore, the entire supply chain plays an important role as they are the key suppliers of materials, which enable producing assets that are fulfilling customer needs, requirement and/or wants in a perfect way. Therefore, a business should also make sure that enough suppliers are available just in case one is not able to deliver.

Equally important are the key resources that describe what is needed to be able to deploy the business model successfully. These resources include all possible resources that are needed, like human resources – is the firm able to deliver with the people, their skills and knowledge – are all assets available to ensure production. Furthermore, financial resources

are very important as well as some business models require investments that are needed in cases of hiring additional people with the appropriate skills or assets that are required to manufacture new products that can be offered as a service.

In addition, also the cost structure plays an important role as it describes all costs that come along with the new business model. It includes factors like production cost, expenses for customer engagement activities and revenue generation. In some cases this would include manufacturing cost, cost for sales activities, cost for connectivity, cost for the predictive analytics model that is provided by an external partner and delivery cost to mention just a few of them.

For a successful business model, it is important how revenue streams can cover occurring cost. The way how the revenue streams are defined and composed plays an important role because if a business is offering a Product-as-a-Service they have to have the capabilities to bear the needed investment to produce the product which is then offered as a service. Businesses have to understand that revenue streams will occur later on when the product is starting to deliver upon its promise towards the customer. Some ventures are offering models where an upfront payment is needed which can cover at least a part of the cost.

Although the Business Model Canvas is considering internal and external processes and forces it is not replacing the development of a proper strategy where other aspects are considered as well. Therefore, a business model should be aligned with the strategy of a business analyzing also Porter's five forces as not all of these forces are considered in the Business Model Canvas.

Especially the competitive rivalry is important to consider, in order to be aware who else is able to deliver the same or similar service at the same quality and price level to the same group of customers. But not only competitors that are well known have to be considered, moreover it is important to understand also how the competitive landscape would look like when deploying new business models. For businesses that are producing machines and are aiming to market them as a service two groups of competitors can be identified, the ones who are producing these machines or assets which is the primary market, but also these competitors which are offering services to the same groups of customers in regards to spare parts and maintenance services. Both fields bring a different set of competitors to the market which have to be considered properly in order to remain sustainable on the market when offering new services and products.

Furthermore, it is important to carefully analyze and understand the power of buyers. In cases where the number of potential buyers is limited to a market with a limited number of customers that would be addressable with products and services provided by a business, the power on customer side increases tremendously and enables customers more or less to define the price for the jet engines. The situation is a bit different when the products or services offered are applicable for a larger number of customers and play an important role in mission critical systems on customer side. Although more competitors are acting in this segment there is still the possibility to approach other customers due to the much bigger customer group that is in need for such products or services. In general it can be said that the smaller the group of customers is the higher the power of this particular customer group in regards of bargaining is unless there are some features provided that are crucial for customer operations and no other producer is able to deliver (Porter 2008). Additionally, even the geographical area might play an important role as some vendors are located closer to their customers with production and service facilities which enables them to act much faster than vendors located in remote locations. Although in todays world geographical distance does not play such an important role in business life, the situation is different when it comes to delivery of products and services where the location of facilities play an important role.

Also important is the power of suppliers. As this can have a huge impact on the entire business model. The same rules as for the power of customers applies also for the supplier side but with different implications for the business. The less vendors are available on the market that are able to deliver a component that is needed to provide the desired service to the customer, the higher is their power in regards of setting the price and all other business related conditions like frequency of delivery, after sales services and so on. So one possibility to escape from this vendor lock in is to standardize product specifications as much as possible to widen the supplier landscape and so eliminate dependencies on one particular supplier as much as possible (Porter 2008).

To remain competitive in a market and keep profits at a high level it is important to protect the market as much as possible and set entry barriers that create difficulties for new market entrants. This can be realized through elevating the fixed costs like increasing R&D expenses like it is in the case for jet engines (Porter 2008). In this case it is very cost intensive to develop and manufacture products that are able to fulfill capabilities which are crucial for safe and reliable operations for the end-customer as high end technological components are required (BusinessCaseStudies n.d.).

Furthermore, the threat of being substituted has to be understood as well which is also determined by the customer group that is meant to be approached. Taking the jet engine market as an example there is no other possibility available to make aircrafts fly which means that the threat of substitutes is minor. But considering for example the travel industry where new ICT solutions like unified communication solution enable collaboration between peers in remote locations without the need for travelling. In this case telecom operators and vendors of such communication technologies represent a major threat for being substituted as they are enabling collaboration almost in the same way as it is the case for face-to-face meetings while also reducing travelling costs to a minimum, reducing inefficient use of time as it is the case during travels as still the possibilities to be connected to the outer world is still pretty limited today (TheEconomist n.d.).

2.4 Challenges in deploying new business models

Although there is a common understanding that new business models are needed due to several reasons as described above, still organizations are facing enormous challenges in deploying these new business models that might help them to remain competitive on the market or even enter new markets.

Challenges for deploying new business models can be found across several domains. One of the reasons is for example that new technologies and new markets might require different knowledge than already available inside the company as underlying technologies and products are changing as well. Furthermore, new technologies and business models are addressing different customer groups where the organization itself has limited knowledge about these new customer segments and markets and are also not aware how to position themselves in such a new environment in regards to channels that have to be activated to be able in order to serve the market with these newly developed business models. Another reason that is hindering the deployment of new business models can be found in the fact that usually the gross margins for emerging technologies and business models are initially far below these of already well established ones which leads to the fact that organizations are allocating resources to more profitable business models instead of fostering new business models. Therefore, one can see that the root of tension is the conflict between existing and well establishes business models and that needed to exploit the emerging, disruptive technology. An additional barrier for developing and testing new business models can be found in the fact that successful established business models are heavily influencing the information flow which means that some information are simply filtered out or routed into decision making process of a corporation. This fact can lead businesses to miss potentially valuable use of technology that does not fit current business models (Chesbrough 2010).

Additional reason to lacking willingness of implementing new business model can be found that it goes along also with additional new efforts or new processes for some departments and the shift of power within an organization (Bucherer et al. 2012). Especially when it comes to developing and deploying of new business models several departments within the organization have to be involved. There is clearly the need to involve the sales and business development part of an organization as they have to sell new products and services on the market which are using all new technologies required to make this happen. Furthermore, the marketing department is needed to develop an entirely new marketing strategy, which enables the sales force or sales channels to successfully sell new products and services. But, also the IT department plays a crucial role in this entire process as they have to make sure that information gathered from new sensors and devices in the field can be transferred into valuable information for business related decisions. Additionally, the IT department has to make sure that these new business models that are developed can be served with the existing infrastructure or they have to adopt the infrastructure in order to make these new business models successful. But also important is to integrate all different sales channels the business will utilize in order to market the solution. Some sales can be generated through the web, some through sales channels like resellers and not to forget also direct sales which is mainly driven by the own sales force.

All this means that distraction from ongoing activities are needed and the main constraint to follow these activities is the unclear outcome of deploying these new business models. This is mainly caused by lacking experience of a business when it comes to entering new markets and offering new services to customers the organization has not served yet.

To overcome these challenges organizations can learn a lot from the activities in Social Movements like fighting for equal rights for men and woman or black and white people, which were facing exactly the same challenges. Especially the activities during the Civil Rights Movement can be compared to the resistance of deploying new and innovative business models within an organization as in this case also different groups were involved and needed to make these changes come true. Therefore, it seems important to understand what makes institutional change difficult. First, institutions are schemas, norms and regulations designed by humans that enable and constrain the behavior of social actors and make social life predictable and meaningful. Furthermore, it has to be differentiated between institutional actors which are entities and institutional arrangements so called institutions. Institutional arrangements can be very simple like a stoplight or a school bell or very complex on the other hand which are highly contested like environmental laws and often described as governing actions in organizational fields (Hargrave & Van de Ven 2006).

Considering the fact that an organization can be seen as ecosystem, consisting of several groups and individuals which all have different views and opinions it is important to search for the dialogue which helps understanding the motives of all parties involved in business model innovation. As discussed before, in business model innovation based on IoT there are many parties involved that have a different view and perception of challenges that the organization is facing in the market. Therefore, it is important to discuss all the different views, consider all arguments – which is very important as all different groups bring different views and arguments to the table – and find a common way which all involved parties are willing to support in order to innovate from product and service side but also from organizational side as the development and commercialization of technological innovations can be seen only as collective achievements in regards to developing an industrial infrastructure that allows economic development between actors who are distributed across the entire organization, act like partisan and embedded in path-dependent processes (Hargrave & Van de Ven 2006).

Having analyzed the challenges of deploying new business models and the underlying theories connected to social movement activities which can be connected pretty well to organizational innovation, there are some capabilities an organization needs to become an adaptive enterprise that is able to adjust to changing market requirements and technical progress which will allow all the different groups to understand what and why something has to be done (Lankhorst et al. n.d.).

- Simplification
  As complexity can be the enemy of any change process as it usually causes uncertainty and undesirable side-effects, it is important to simplify the organization as much as possible, to simplify the rules and policies as well as processes especially when it comes to innovation as this often requires breaking the rules, and simplification of the IT landscape in order to ease the implementation of new services and products. It is crucial that it is foreseen in the beginning, as later on, changes that need to be established and executed will be harder to implement.
- Innovation
  Many organizations are focusing on existing business and it business models and dedicating all resources to maintain this business instead of developing future business. Therefore, it is important to allocate resources also to finding business opportunities for the future

- Collaboration

  As change is involving many disciplines in an organization it is important to empower people to use their profound knowledge and cooperated within and outside the organization to better understand the ecosystem and gain ability to design customer journeys. Internal collaboration should also take place across different layers inside the organization, it is not sufficient to follow the top-down approach as it is often too slow, ineffective and often lacking timely and accurate information. So, a horizontal approach should be applied which integrates the top-down and bottom-up approach.
- Acceleration

  As the environment is changing at a high pace organizations have to change the way they change which would allow them to follow the same speed as the environment is providing. Furthermore, organizations have to learn to fail fast and understand that if something is not working well it has either to be discarded or changed again, but fast.
- Decision making

  When it comes to changes the should be done on all levels inside the organization in alignment of long-term, strategic decisions and local day-to day decision. Therefor it is mandatory to delegate authority across all levels and create a single source of truth that provides the same information for all parties involved in decision making.
- Control

  An organization has to be aware of the risk it is running, therefore it is crucial to create transparency, check for compliance and analyze the risk across the entire enterprise.

2.5 Overcoming challenges of deploying new business models

The internet of things can be seen as the catalyst for digital transformation. It creates new business models with a clear focus on the end-customer itself. But this has to be supported through different measures in order to be able to implement such a new business model in an organization.

Policies:

From an organizational point of view, as described above organizations are facing the challenge that not enough resources are allocated to these activities and the main focus still remains at previous business models as they are still generating cash and profits.
To overcome this challenge there is the possibility to outsource this part of the organization and allow the start-up within the organization to take care about the resources needed on their own. This provides the benefit that the newly founded company has the possibility to

fully focus on innovation including product- and service innovation as well as business model innovation without having to stick to the processes a huge corporation bears in itself. This also provides more flexibility and the start-up is able to act much faster and more agile and is so able to fully focus on customer needs and developing a solution that is fully covering these needs (Bucherer et al. 2012). Furthermore, such start-ups can be developed from scratch, including also hiring policies which allows to hire people that are willing to participate in such innovation projects by having the possibility to fully focus on innovating products and services and the needed business models that allow to commercialize all these undertakings.

Another important point is that such start-ups are able to develop their own partner eco-system and can benefit also from the partner eco-system the parent company has established that would also provide a shorter time-to-market.

Examples for such sub organizations can already be seen on the market. Telekom Austria Group has founded a start-up which was focusing only on IoT and machine-2-machine communication where to freshly founded company had the possibility to use resources like network infrastructure and other "side" resources that are not differing so much from the core business from Telekom Austria Group's core business which is enabling communication, i.e. HR, finance, logistics, etc. This provided mentioned start-up the possibility to use also resources like billing capabilities to be able to charge the services they were providing.

Putting together small teams of engineers, of varying experience, who are engaged with digitalization is not enough. It needs a change of mindset throughout the organization. (Bosch Software Innovations n.d.)

Knowledge:

Bridging the gap regarding knowledge there are several possibilities. For example, IBM and SAP were lacking detailed knowledge about analytics as well at the beginning of their IoT journey which they were very much aware of. These companies followed the approach of acquiring knowledge that helps them to act in the field of analytics in the form of acquiring companies that were focusing on data science and developing analytics models.

This approach helped IBM in designing the broadest product portfolio when it comes to analytics (Russom 2011) and contributed to further develop the IBM Watson analytics machine which is recognized as one of the most advanced analytics tools available on the market. SAP was following the same trend and acquired companies who were acting in the analytics domain in order to develop their analytics portfolio which provided the needed knowledge and expertise to develop predictive analytics tools for companies like Kaeser

Kompressoren and GEA, but also TrenItalia is one of their customers who are using predictive analytics tools developed and provided by SAP (SAP 2016).

Another possible approach would be hiring the right people who bring the right knowledge with them and so are able to develop such analytics models which can be used to develop new business models in order to differentiate from competitors. But not only new business models can contribute to success, also improving internal process optimization plays an important role. Steve jobs quoted once that he was lucky as he: “Attracted great people to make the vision come true!”.

Hiring and acquiring does not only help to gather needed knowledge but also shortens time to market as knowledge is available right from the beginning and has not to be developed from scratch in order to take the first steps in this challenging domain. Another approach would be educating people in order to gain the needed knowledge. This provides the benefit

In fact, the best teams need both youth and experience, believes Thomas Alber of Bosch Software Innovations: "While the younger ones do quickly embrace a new way of doing things, they sometimes struggle to see the implications. Senior associates have the experience to see the implications of change but not always the willingness to do it, which is why the best teams need a mix of the two." (Bosch Software Innovations n.d.)

What skills will your people need in the digital era? They will have their existing specialties and strengths. They do not need to change these or unlearn the old ways of doing things. After all, these were the skills and methods that made the organization successful. But what they should abandon is the old thinking that they are responsible for one particular thing, which they will continue doing for the next 20 years. To succeed in the future everyone needs to keep learning and be open to new things (Bosch Software Innovations n.d.).

Important to understand is also that learning will change tremendously. Nowadays, technical education is focusing on transferring the knowledge how to use machines. This will have to change as it is important to integrate human intelligence with machine intelligence to unleash full potential of analytics which is driven by artificial intelligence. Furthermore, enterprises will also have to take care about the proper mix of skills in an enterprise. It is important to understand that old skills and knowledge will still remain important as this is what has lead the business to success. Nevertheless, new generations will bring new insights into the world of technology and new skills based on using technology to their benefit (Purdy & Daugherty 2017).

But these new generations who are digital natives as they are using technology since they are children will not only apply technology to get their jobs done faster and better, they will use technology also to change the way they are working. This means that the working models known for more than a hundred years with strict hierarchies and designed for times of stable markets and long-term project planning. Therefore, even the labor market will transform and adopt to the needs of enterprises and vice versa. There are already examples where enterprises are using artificial intelligence to hire the right people for projects who bring exactly the skill needed to successfully realize these projects. Hence, as these projects are not lasting for a long time, the entire labor market will shift towards a more free-lance based work model which allows enterprises to hire people whenever needed without geographical limitations as new ICT technologies have brought people together independently of the place they live, and this will be used also for the workforce of tomorrow. A perfect example for this development are the United States where 35% of the US workforce are already freelancers with estimated earnings of $1 trillion. This indicates that it is important for enterprises to start their journey towards using more freelancers which will contribute to the existing knowledge. Furthermore, this will provide enterprises the possibility to learn how to integrate such freelancers into their hierarchies and the lessons learned will drive larger transformations towards a task based working model by choosing the right people using a market place approach which allows staffing according to skills, knowledge, experience and based on demand(Nanterme & Daugherty 2017).

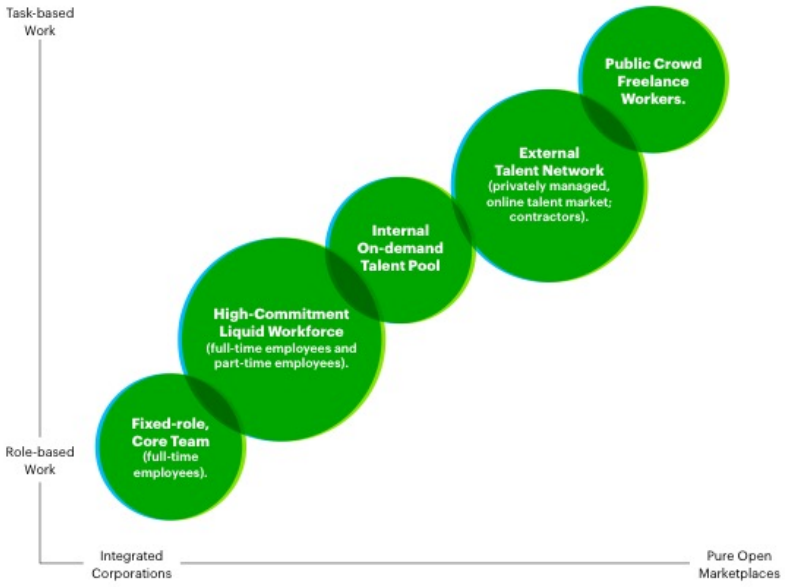

Figure 2 Market-Place development (Accenture Amplifyou report)

Figure 2 shows how the market place will develop over time.

Technology:

To transform the business model from a product based business towards a service based mode,l technological adjustments are needed to be able to fulfill customer expectations. When offering services, it becomes very important that the service can be delivered whenever, wherever needed as this is the centerpiece of servitization. In some cases, it might be sufficient to deliver best effort services, especially in the consumer segment. But when entering industrial domains, it is crucial for customers to be rely on the purchased services. Therefore, suppliers have to have a real-time overview on the status of assets which are offered as a service which provides all needed information that are required to predict how the asset might behave in the near future and which services or maintenance will be needed to keep the offered service up and running and so also the revenue streams active. This is another crucial part when it comes to service offerings, as no service provided means that no revenues will be generated.

To be able to create an overview on all different aspects, which are used to provide services for customers, several technical aspects have to be considered. Aspects like devices for data generation, which are collecting data to provide an overview of the actual status. Actuators are required to execute commands sent from remote locations in order to ease life of end customers, like turning on the heating or cooling system in the weekend cottage. One can easily see that it is important to provide a very stable data communication channel to create an understanding on the actual status of any device and send commands for any actions that are required. To transfer data and commands it is important to choose the right access technology in regards to coverage, bandwidth and robustness of the communication channel. Furthermore, in some cases it is required to enable the device to take autonomous decisions based on actual and historical data which helps keeping the system up and running. In the following chapter it is described how these challenges look like more in details and an overview on the state of the art technologies is provided which help overcoming most of the challenges enterprises are facing when they start their digitalization activities.

3 Cyber Physical Systems and State of the Art technologies enabling new business models

Considering the value chain of IoT, this chapter provides an overview on Cyber Physical Systems, which represent a digital picture of a physical asset, and State of the Art technologies that are addressing the challenges and needs for successful deployments of IoT projects and new business models in order to gain the most possible value out of it.

The Internet of Things is on its rise and so shaping the development of technologies in the ICT segment tremendously. The shift from connecting end-user devices to connecting physical systems that communicate with each other and/or with humans requires again to reassess the conventional approaches conventionally used in networking, processing and service provisioning and management (Miorandi et al. 2012). As described in chapter one this is also driven by different types of analytics which are applied by businesses across different fields with different requirements to data transfer, data storage, processing capabilities in order to make the different types of analytics possible and even more important valuable for enterprises and end-users.

Important to note is that the Internet of Things is still at the beginning stage, which means that there are still no standards that can be applied to make such activities and deployments easier for enterprises. Therefore, businesses have to think carefully about their first steps in the field of IoT and consider also future plans where it is important to be able to integrate all new deployments into the same infrastructure which brings the benefit of less proprietary systems and so less maintenance and higher scaling factors, keeping in mind that rends, as well as market and customer requirements and wants might change alongside.

3.1 Definition of Cyber Physical Systems

Cyber Physical systems can be seen as the key enabler for transforming business models from offering products to offering services. Furthermore, Cyber Physical Systems (CPS) represent one of the most significant directions in the development of computer science and information and communication technologies (ICT). These CPS are systems which are composed of collaborating computational parts that are extensively communicating with the physical world that is surrounding them. Furthermore, at these places data is generated and used at the same time and data-access and data processing capabilities are provided through the internet. Further evolution of such CPS can be seen in Cyber Physical Production Systems (CPPS) which are also relying very much on further developments in the field of computer science, information and communication technologies on the one hand and manufacturing science on the other hand. This might also lead towards the fourth industrial revolution, known also as Industry 4.0 (Monostori 2014).

CPS as such provide the potential to change every aspect of life through concepts such as autonomous cars, robotic surgery, intelligent buildings, smart manufacturing, smart electric grids and even implanted medical devices. This are just examples of practical use cases that are already in place and use (Sztipanovits et al. 2012). In order to be able to act fully autonomously CPS rely on all different types of analytics beginning with connecting different assets which in turn enables data collection of all connected devices. These data

are then visualized to provide an overview on the status of a physical system, and can be seen already as the first step of applied analytics, namely descriptive analytics. Furthermore, CPS also rely on diagnostic analytics where it is possible to analyze why something is happening. Predictive analytics is applied in order to get an understanding of what might happen, which is a crucial part in order to increase availability of connected machines and assets. And the last step is to apply prescriptive analytics which then enables CPS to take decisions based on data from own operations and assets and machines CPS are connected with.

To apply all the different types of analytics is crucial for CPS as the expectations towards them are (Monostori 2014):

- To be robust at every level
- to self-organize
- self-maintain
- self-repair
- act fully autonomous
- provide remote diagnosis
- enable real-time control
- provide transparency
- be predictable
- act efficient
- and provide model correctness

Applying these cyber physical models could potentially result in smart cities, smart production, smart logistics, smart communication and smart energy systems. But, CPS are also influencing quality of live in a positive way where we are talking about the cyber-physical society which includes social, human and cultural spheres including also physical and cyber spaces (Monostori 2014).

Important to note is that the ability to interact with, and expand the capabilities of the physical world through processing capacity, communication capabilities and control is a key enabler for the developments of future technologies. Although CPS provide a lot of possibilities they come also with some challenges, especially when it comes to sensors, communications and networking, mathematics, software engineering and computer science (Baheti & Gill 2011). Figure 3 shows the structure how CPS are built.

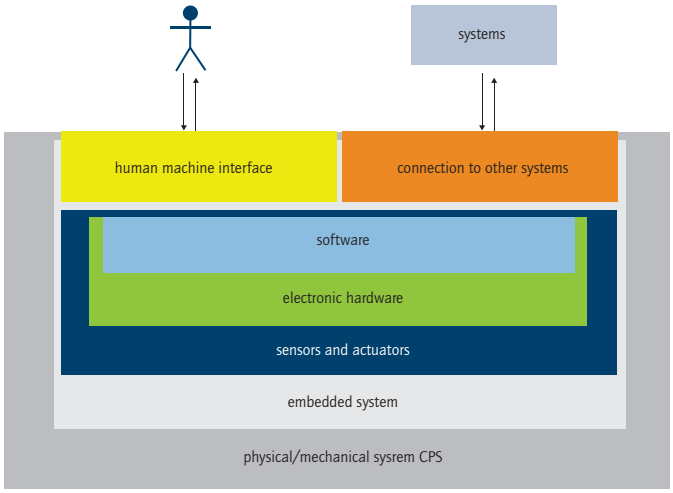

Figure 3 Structure of CPS (Software- & Systeme 2010)

Another important aspect is the increasing complexity of devices and the use of more and more advanced technologies for sensors and actuators, wireless communication, and multicore processors represent a huge challenge in building next-generation control systems where both, vendors and integrators are in need of new systems that enable reliable and cost-effective integration of independently developed system components. Therefore, theory and tools are needed to develop cost-effective methods enabling

1. design, analysis and verification of components at various levels of abstraction covering system and software architecture levels
2. analyze and understand interactions between control systems and other subsystems, and
3. ensure safety, stability, and performance while keeping control over cost of control systems are major factors for business viability (Baheti & Gill 2011).

Hence, CPS can be seen as digital twins of physical systems where the actual status of machines, assets and devices can be monitored remotely, which helps enterprises to schedule activities to keep these goods up and running and so maximizing customer satisfaction and customer experience by making sure that the offering is available at any time at any place whenever the customer is in need. This furthermore enables output based business models where revenues are generated only when the service is available to the customer.

3.2 Technical challenges

Cyber Physical Systems represent a composition of huge numbers of sensors and actuators, which interact with each other but also with the environment at the same time. This huge complexity comes with some challenges regarding technology and science which have to be addressed in order to realize the vision of pervasive and ubiquitous Cyber Physical Systems which are discussed in the following sections (Esterle & Grosu 2016).

Mathematics:

Interacting of computers with the real world means that they have to deal with continuous changes within the discrete process of a computer. This increases the need for harmonized models that are reflecting the continuous environment, ideally providing an infinite number of states with models for the discrete computing system providing a finite number of states which requires updated mathematical approaches that are able to handle the discrete-continuous duality of such situations. Although this phenomenon is not new, it is already known from physics with the particle-wave duality as it shows that light and elementary components of atoms are neither waves, nor particles, but both. The harmonization in this case happened within quantum mechanics by applying a probabilistic approach where discrete probability distributions model the discrete aspects and the continuous probability distributions model the continuous aspects. Fascinating in this approach is the use of complex numbers to model the wave function (Esterle & Grosu 2016).

Such developments can be seen also in the arena of computer science as quantum computing is emerging. The first commercial quantum computers are already available on the market which will tremendously increase the processing capabilities of computers and so unleash use cases in the future for processing needs in real time as quantum computing is addressing the needs of ultrafast computing capabilities. Quantum computing is benefiting from the strange ability of subatomic particles which can exist in more than one state at the same time. This provides the possibility to execute operations much faster by using also less energy (Beall 2017).

In contrast to this ability in traditional computing where a bit represents a single piece of information can exist only in two states which are 0 and 1. Instead of bits, quantum computing is using quantum bits or ‘qubits’ and they provide the possibility to store more information as they are able to exist in both states of these values. This means that a qubit can be envisioned like a tennis court where classical bits can be either on one side or the other, but qubits can be on both sides at the same time. Given this fact a computer that is using qubits can store much more information by using less energy than a classical computer

which will allow quantum computers to perform tasks like searching large databases or processing large numbers which would be unfeasible for classical computers. Furthermore this will provide the possibility to process analytics not in near real-time anymore, but it would be almost real-time (Beall 2017).

Architecture:

As the number of devices communicating with each other new architectures are required in order to deal with the increasing complexity. Furthermore, devices are equipped with higher functionality at the same time. This in return calls for development of applications that are able to deal with an incomprehensive number of devices with currently known capabilities. In addition there is a need for operating systems for CPS as it has to deal with several problems which have to be solved by the CPS operating system, like (Esterle & Grosu 2016):

- Openness: Interaction with possibly new devices has to be enabled in order to achieve common goals by empowering devices to share resources so that one device is able to accept tasks from other devices if resources are available.
- Isolation: Every device needs the possibility to isolate itself to make sure that goals are achieved within a given time. Therefore, it is important to make sure that the device cannot be abused by other devices through offloading their tasks in the same network.
- Safety: As CPS and IoT will be omnipresent and will have a tremendous impact on our lives it has to be made sure that they will behave as intended. This becomes even more important in safety-critical applications and its implications like autonomous driving.
- Security: The operating system of the CPS has to make sure that the data shared with other devices is protected, especially when handing over tasks to other devices with sensible data. In addition, the operating system has to ensure that sensible data is not shared unauthorized.
- Privacy: It has to be ensured that there is no possibility to identify the owner of a device without a proper authorization including information that might be used to identify the owner of a particular device.
- Extensibility and Discovery: In order to achieve common goals faster there has to be the possibility for new devices to join the network providing also the possibility that these new devices can be discovered autonomously by the devices which are already existing in the network whereas. Therefore, the network has to be able to learn about the capabilities of these new devices as this makes sure that devices are utilized as

new resources. At the same time new devices also need the capability to learn about the capabilities of the existing devices in the same network.

- Robustness: Removing devices from an application should not affect the performance of the system itself. If an application relies on specific devices, the network is required to have the capability to deal with failing of devices or even with the removal of devices by using respective mechanisms.
- Self-protection: Attacks from the outside have to be detected and defended as well as fault devices that are trying to join the network. This is obviously very challenging as it is also contradicting to the aspect of openness of the CPS operating system. Therefore, the network is in need of clear protocols, reasons and classifications to block specific devices. These classifications and reasons can be defined and negotiated by the devices of the network at runtime.
- Self-maintenance: The functionality of such CPS has to be ensured in standard as well as in uncertain situations including also proper handling of resources such like memory or battery levels, but also that performed actions deliver the expected outcome. If the outcome is not delivered also the process might be adapted accordingly by autonomous adaptations as well as through coordinated software updates.
- Self-awareness: All devices have to be aware of their own capabilities and the impact of own activities on the environment as well as on other devices. In addition, they have to be able to handle actions by other devices in the network regardless if these actions are beneficial or disadvantageous for their own goals.
- Connectivity: As the devices in the networks are not operating isolated from each other they need the capability to connect to the web and cloud services in order to exchange information with other devices in the same network.
- Location: In some cases there might be the need for devices to localize other devices, which can be done only relatively to their own location or in absolute space.
- Data storage: data has to be stored and made available in a distributed fashion among the devices where at the same time neither the application, nor the user should be concerned about the actual location of the data.
- Communication: devices need the ability to communicate with each other. Furthermore, it has to be made sure that this does not affect the performance of the application running on the device or the user who is using them.
- Time: For some applications timing is crucial in regards to communication but also sensing. For sensing it is important that now events are missed and in communications it might be needed that devices synchronize and operate with time constraints.

Space-time:

One of the biggest challenges of CPS is how events at certain times are conceived by the number of various systems. Considering CPS with heterogeneous systems there can be identified three different problems which are synchronicity, frequency and granularity (Esterle & Grosu 2016).

- Synchronicity: if two sensors measure the system with a frequency but differ in timing would result in contrary measures.
- Frequency: causes problems if results have to be compared or combined and therefore need to be considered explicitly.
- Granularity: in regards to how detailed the environment can be sensed. If sensors provide different granularity a mechanism is needed to achieve representative results. Although this can be solved for small numbers of sensors, for huge numbers of sensors in a CPS this has to be automated whereas each device has to be aware of its sensing capabilities.

Uncertainty:

A CPS is a combination of multiple systems to build a larger system which is operating in real environment. Therefore, the CPS is required to deal with the inherent uncertainty of this environment for two reasons. First, the CPS has only a partial knowledge about the environment caused either by insufficient distribution of sensors, the frequency of sensing is not high enough or that the granularity is not sufficient to sense an event. Second, the CPS is limited in resources to observe the environment. As so, events might be disregarded in order to safe resources ranging from conceptual models on how to deal with uncertainty to methods how available information should be used to overcome these challenges in uncertainty (Esterle & Grosu 2016; Baheti & Gill 2011).

Safety:

Although safety of a CPS can be realized through the huge number of sub-systems incorporated, techniques have to be considered to ensure safety of the entire system in case a sub-system fails during operations. This can be ensured by self-healing processes and the autonomous integration of new components in the CPS. These capabilities will lead to a emergent behavior which the designer of the system has not intended originally but results out of capabilities and interactions. Detecting such a behavior is very challenging and has to be solved, especially if it is not contributing in a beneficial way. Therefore, the interaction between ensuring safety and guaranteeing security of the system has to be considered very carefully (Lee 2008).

Security:

In large CPS the information aggregated has to be secured on all possible levels. This can be done on the sensor level which is monitoring the general environment or personalized sensors, but also on the network level where sensors are exchanging data among each other's and sensor gateways up to the cloud storage. It has to be made sure by the system that no access to devices and aggregated data is provided to unauthorized users. This becomes even more important when it comes to interaction between devices or machines and human beings as insufficient security might grant access to unauthorized persons causing financial and even more dangerous, human damage (Ashibani & Mahmoud 2017).

Privacy:

As security, also privacy presents a big issue in creating CPS. Especially if personalized data is exchanged between different sensor nodes or aggregated for further analysis, it has to be ensured that data cannot be mapped to a specific person. Although in some situations it is important to be able to map information to a specific person, in CPS this should only happen in an anonymous way (Gurke 2009).

To overcome these challenges several technologies are available on the market which allow the development and deployment of CPS and so also deploy new business models based on service offerings instead of product offerings and so generate new revenues streams that occur on a regular basis based on outcome or service delivered.

IoT platforms:

IoT platforms are addressing some of the crucial challenges when it comes to creating CPS. They come in different flavors, depending on the vendor they have a different focus with their capabilities as described below.

In general, there are 3 types of IoT platforms available on the market:

- Generalists: provide a wide set of functionalities
- Wireless management platforms: focusing mainly on connectivity and networking
- Industry or use case focused: specialized on covering the needs of special industries or use cases; the platform General Electric is offering on the market is an example for such an industry focused platform (Kurzlechner 2015)

Integrated IoT platforms are required due to the increasing scale, sophistication, and business value where IoT platforms serve as a link between operational technology and IT and enable both sides based on their interaction. Some self-developed platforms of enterprises and proprietary solutions by vendors provided limited capabilities to scale and integration (Velosa et al. 2016). Therefore, as it is becoming more and more important to

integrate with other solutions it can be seen that there is also a move from classical Machine-to-Machine projects towards real horizontal IoT deployments providing the users the possibility to integrate countless vertical use-cases in one single platform following also the needs in scalability (Green 2016).

An IoT platform is a software suit deployed on premise or in the cloud that is monitoring, managing and controlling different types of endpoints through applications that are deployed by businesses. The majority of IoT platforms are key components enabling building applications which can be deployed by different business units to address their particular needs and business processes leveraging a gateway-based architecture (Velosa et al. 2016; It-daily.net 2017) as it is shown in Figure 4.

Usually an IoT platform integrates operations involving IoT endpoints (like sensors or fleets of devices and sensors), IoT gateways (enabling data communication of sensors and devices that are lacking capabilities transferring data via the internet (RedLion n.d.) and back-end enterprise applications. It also enables monitoring IoT event streams, data aggregation, analysis and also application development, and it engages back-end It systems to share gathered data with business applications. Furthermore, IoT platforms play a major role when it comes to provisioning, controlling and also changing the replacing or changing the devices to support IoT solutions (Velosa et al. 2016; Kurzlechner 2015).

These functionalities clearly address the needs of Cyber Physical Systems where it is important to provide a flexible environment having the possibility to add and remove devices according to the needs of a use-case including also the different IoT applications that are relying on the different data sources. At least equally important is the fact that these horizontal IoT platforms allow for scaling activities which provides enterprises and businesses the possibility to add new assets or machines to the system without impacting operations of already existing systems. But, it also provides the possibility of removing systems from the overall system which becomes important when a service or a product reaches end of live and some particular components have to be removed from the system which also supports eliminating non-active members and so supports a more clearly represented overview on the entire ecosystem.

IoT platform capabilities usually include (Velosa et al. 2016; Kurzlechner 2015; It-daily.net 2017):

- Provisioning and management of IoT devices and gateways
- Functionality to build and customize applications
- Processing events based on event streams and aggregated data, analysis of streams, storing and managing data and managing information

- Processing decisions enabled through rule engines, workflow orchestration and business process management
- Analyzing and visualizing IoT data including also different types of dashboards according to the use-case
- Covering cybersecurity issues like authentication, encryption and certificate management
- Enabling device communication on the physical layer like WiFi or cellular connectivity and on the data layer including MQTT, LwM2M or HTTP
- Integrating with other applications through APIs allowing to publish, subscribe, protocol hopping to connect to business applications and data sources, cloud services but also mobile applications running on smart phones or tablets (Velosa et al. 2016)
- Providing adapters to connect different types of devices using different communication protocols
- User interfaces for users and developers

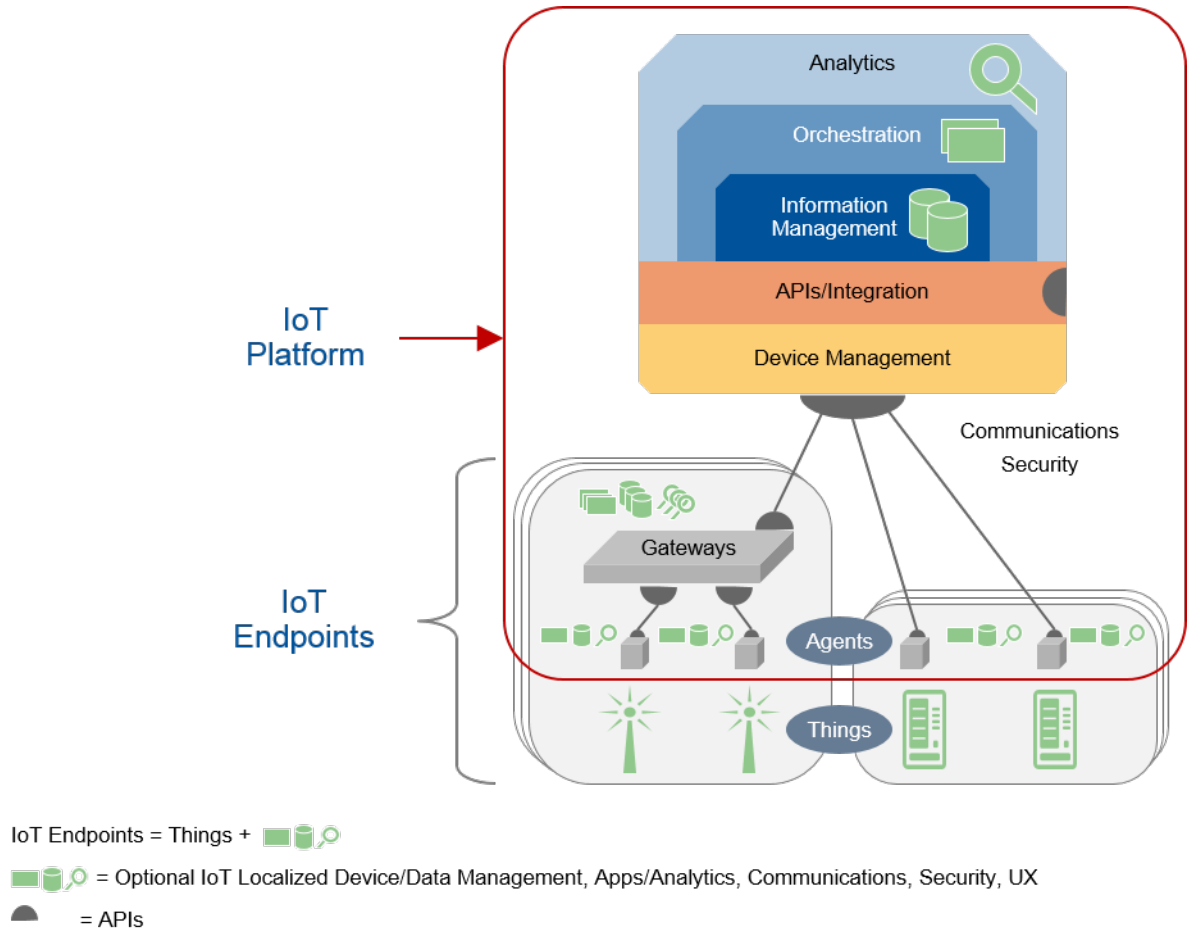

Figure 4: Architecture of an IoT platform (Kurzlechner 2015; Velosa et al. 2016)

Figure 4 shows how the architecture of an IoT platform looks like.

Usually IoT platforms support the deployment of basic and advanced IoT solutions and enable digital business operations by providing web-scale infrastructure capabilities. The platform may be deployed on enterprise premises, or offered as a Platform as a Service (PaaS) solution from the cloud or even a hybrid solution composed of on premise deployment and PaaS usage (Velosa et al. 2016; It-daily.net 2017).

The IoT platform landscape is still very complex with hundreds of vendors claiming that they offer the best IoT platform solution covering all different needs and requirements. This is expected to remain like this for the next 3-5 years considering three main drivers for a continued diversification of solutions (Velosa et al. 2016; Kurzlechner 2015):

1. Users from different industries and regions have different requirements, like for example requirements from manufacturing companies differ in regards of needs from companies in the health care segment or even automotive segment when it comes to connecting devices, frequency of sharing data with the application, different protocols for device communication are used.
   On the other hand also region plays an important role due to regulations, culture, language and also different privacy regulations.
2. Different vendors are entering the market ranging from small and midsize vendors and IT mega-vendors who are incorporating IoT capabilities in their offerings. But also start-up companies focusing only on IoT solutions and use-cases play an important role in the entire eco-system.
   Especially mega-vendors like AT&T, Bosch Software Innovations, General Electric, IBM, Amazon, SAP, Oracle and Microsoft are pursuing the market very actively and trying to educate the market in order to influence enterprises in choosing the right solution for their IoT undertakings. These mega-vendors, as one already could imagine by having a look at the companies mentioned are composed of traditional IT companies like IBM, SAP, Microsoft but including also vendors coming from the Operational Technology (OT) domain like it is GE or Bosch, to name just a few of them.
   Both, traditional IT and OT players are leveraging their knowledge of key vertical markets and capabilities to build either niche solutions or general IoT platforms able to serve use cases in different industries and verticals.
3. The needs of an enterprise differing between developing and manufacturing new connected products with an external focus towards the end-customer and retrofitting existing assets for internal process improvements. In many cases these cases will be mixed up but still they have to be considered as they provide guidance on project design and suppliers of appropriate solutions to fulfill their needs.

i. External focus: focusing on products that are designed and produced to be connected are simpler to handle as the OEM controls the majority of the inputs like the number and types of products to be connected, the protocols used to enable communication with IoT platforms but also the procedures and standards that are applied. It becomes difficult when it comes to how the end-use, both – enterprises and consumers – are using the assets including also the need to protect personal data.
ii. Internal focus: for equipment operators which aim to retrofit their assets the requirements towards an IoT platform are different as there is the need to connect machines and equipment from different vendors who are using different types of protocols as all this has to be considered as well as the needs of security levels to protect data as well as the internal processes that are impacted by such deployments. Furthermore, the need of different types of information for different user is important to be considered as so also the different dashboards have to be created in order to provide the right information to the right group of users.

Considering the functionalities that IoT platforms provide, one can see that they represent a major cornerstone of IoT deployments and the benefits coming with it. They are responsible to manage all different types of devices independently of communication protocols used by the different types of devices, they ensure that the right information is delivered to the right application and so addressing the needs of the different user groups that will have access to the system, they allow adding and removing devices, make sure that nobody with proper rights has access to the system and the data it includes, take care about security issues in order to make sure that no information is disclosed to any unauthorized users but also make sure that device high jacking becomes almost impossible. Furthermore, in many cases IoT platforms are also managing all types of connectivity based on the needs of applications and use-cases.

In general, two types of IoT platforms can be found on the market, horizontal and vertical ones. Vertical platforms are focusing on one particular vertical like for example asset tracking where the application provider is providing also the required hardware and the IoT platform to manage and provision all these devices. In this case the vendor has the power to decide which devices can be attached to the system which might lead also to vendor lock-in. Such vendor lock-ins might be dangerous in today's world as there is no guarantee that the vendor

will exist in the future. The alternative to vertical IoT platforms would be the horizontal IoT platform that provides the flexibility to integrate devices from different vendors for all different verticals while having the possibility to connect different applications according to the vertical a business is aiming to act in choosing a horizontal IoT platform a business gets the possibility to avoid the vendor lock-in and so develop according to the strategy it defines especially when the strategy is changing over time.

Different types of connectivity:

Considering that data visualization and analysis is only possible if data is available, may it be stored data or live data from different devices and sensors, it is absolutely crucial to ensure that required data is made available. This becomes even more important when businesses are evolving across different stages of analytics. According to the use case businesses have different options to connect devices to the internet and enable them to provide data for different applications, but it is clear that the use case determines the appropriate access technology (i-Scoop 2017). Also important to consider is the fact that IoT devices communicate differently than smartphones and computers. In some use-cases IoT devices are sending relatively small amounts of data and connect and disconnect to the network very frequently like is it in smart metering where smart meters provide their latest value to a centralized data base. On the other hand a connected car might send diagnostic information to a central hub while also providing mobile broadband services for in-car entertainment exchanging high amounts of data over mobile networks for a longer period of time (Salaets 2016).

In general it can be seen that wireless connectivity is instrumental in the Internet of Things domain even in the industrial environment where several wireless connectivity technologies are used, such as WiFi, Bluetooth and 802.15.4 based technologies like WirelessHART, ISA100.11a and ZigBee (Svanberg 2016).

To fulfill all these different requirements for all the different use-cases new access technologies are evolving which fit exactly the needs in regards of bandwidth, latency and robustness.
Figure 3 shows that different connectivity technologies will coexist in the IoT domain.

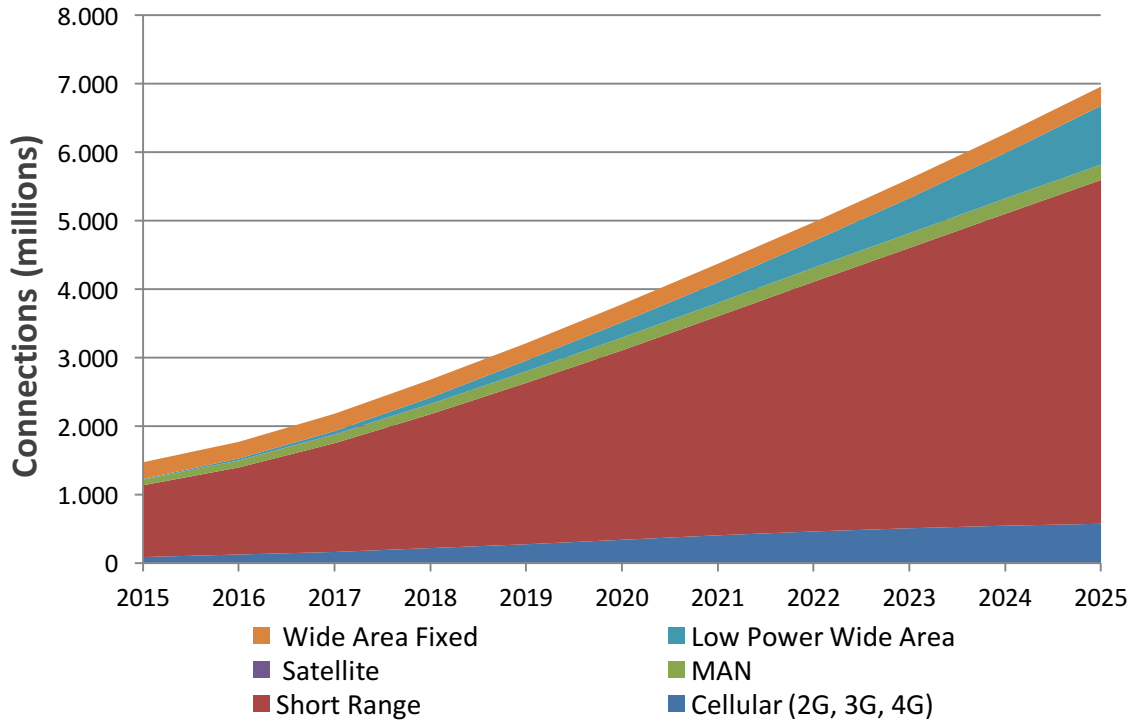

Figure 5 Different connectivity technologies in the IoT domain (Machina Research 2016)

One can see that new connectivity technologies are developed with the focus on connecting things instead of people like it is the case for developing 5G networks (Majithia 2016), which is happening for the first time in history and is mainly driven by the fact that IoT devices will surpass smartphones in mobile networks by 2018 (Ericsson 2016). But also, other connectivity technologies are developed to fulfill the need of different IoT use cases. Especially NB-IoT is an access technology for IoT use cases where latency and bandwidth are not that much of importance but battery life time, deep indoor penetration of networks is crucial to enable data communication for devices deployed in cellars or even in rural areas (GSMA n.d.).

Furthermore, networks in an unlicensed spectrum are evolving especially Low Power Wide Area (LPWA) networks like LoRa and Sigfox. Both technologies are focusing on IoT to enable different use cases where long battery lifetime is crucial. Both, Sigfox and LoRa are providing network coverage with low bandwidth and are therefore mainly applicable for applications where only small amounts of data have to be transmitted to a central data base. Both access technologies provide deep indoor and wide area coverage which supports use cases with more stationary device deployments like smart metering as often, and especially in new buildings are located in basements where network coverage is poor and data transmission can be difficult to achieve (Hewlett Packard 2016). But this means that

connectivity will not be provided only by communication service providers in the future, everybody will have the possibility to deploy its own radio network which enables data transfer without the need of a communication service provider anymore.

These wireless connectivity technologies or means provided by communication service providers enable businesses to generate and process data from different types of assets and machines spread all over the world. But not only data generation is enabled by these connectivity technologies, also new output based business models rely on data transfer as a business has to know exactly what it can charge towards their customers. And this has to be realized in a way where the vendor is fully independent from the customer when it comes to data transfer. This is not only important for billing issues but also to be able to understand the current status of different types of machines and assets. In addition it provides the possibility to switch off services in case of unauthorized use like irregular payment activities on customer side.

But, also other technologies are coming up which enable enterprises to deploy their own networks for use cases where bandwidth and latency are crucial. Especially MuLTEfire, a LTE technology which is operating also on the unlicensed spectrum will enable businesses in deploying their own LTE networks on campus without the need for telecom operators. This technology provides even the possibility to seamlessly handover devices from private networks to public networks operated by communication service providers (Chambers 2016).

All these new network technologies are mainly evolving to fulfill the different requirements of analytics applications used across all different industries in order to enable the development of cyber physical systems and deployment of new business models focusing on providing excellent service to customers and so recurring revenue streams instead of one time revenues. These recurring revenue streams allow also for better planning as a business is able to predict revenues generated by sales of services instead of products and after-sales-services where the business cannot be sure that these services will be sourced from the same vendor or any other vendor that is operating in the same field.

Beside connectivity, that ensures that generated data is provided to the right application there is also the need for computing capabilities which can be spread across several layers in the system architecture.

Computing:

As it seems to be clear that in the future more and more devices will be connected to the internet which will require totally new capabilities of computing to process the generated data from all different types of assets spread all over the world. Gartner predicts that the number of connected devices will reach the amount of 20 billion devices starting from almost 5 billion in 2016. In comparison to the number of connected devices, in 2020 it is expected that 6 billion smartphones will be in use all over the globe. This means that there will be a huge number of devices that are all in a way interacting with the environment and all of them will execute some processing tasks which leads to the question where all this computing will be performed at the end (Golden 2017).

Therefore, new models for analyzing and acting on data generated through IoT are evolving, called edge computing or fog computing (Cisco 2015):

- Most sensitive data will be analyzed at the edge of the network which means close to the place of capture instead of sending huge amounts of data through the net to the cloud
- Latencies will be shortened so that acts on data can be performed in milliseconds which is based on the policy of the application that requires this data processing and
- Only selected data is sent to the cloud to enable historical analysis and also long-term storage for future usage

This becomes very important if the different types of services are considered that are enabled by the Internet of Things. In some cases it will be crucial to have processing capabilities right at the edge of the network as this increases the independency of connectivity and especially bandwidth when it comes to processing high amounts of data. For example, TrenItalia is using distributing computing capabilities to understand process the huge amounts of data generated in trains in real time and so enable different types of services in case of need at the right place at the right time. This not only accounts for less downtimes of assets, but also increases reliability of transportation services towards end customers which often also allows for charging premium fees and so improves the financial results of a business tremendously through higher prices and less losses because of unplanned downtimes and providing customer service exactly when it is needed.

Having this in mind means that to be able to commercialize on the IoT a new type of infrastructure is needed. Cloud models available today are not designed for the value, different types of data generated and the velocity data comes into the cloud generated by the devices and sensors connected to the internet. Especially as billions of devices that are not connected to web yet are generating more than two Exabytes of data on a daily basis. The estimated 50 billion things that will be connected to the internet by 2020 will require

transferring data to the cloud to be processed which in turn will call for very high bandwidth (Cisco 2015).

Hence, IoT and cloud computing can be seen as natural compliments and from today's perspective cloud service providers are able to support this ongoing development (Golden 2017). Contrary to that some believe that computing will be executed directly at the edge and the place of capture like it is the case for autonomous driving where a car is gathering 10GB of data per driven kilometer. This huge amount of generated data has to be processed right at the point of capture in order to enable information exchange for car-to-car and car-to-infrastructure communication in order that the autonomous car can make decisions in real-time without having to send these amounts of data through the entire network to the cloud where it is processed and sent back to the car itself (Levine 2016a). The same rationale is used also by edge or fog computing vendors like Nokia (Sprecher et al. 2014) and Cisco (Cisco 2015; Golden 2017).

The reasons why computing at the edge is required are described in more detail below:

- **Minimize latency:** every millisecond is important when trying to prevent shut downs of manufacturing lines or electrical service has to be restored. Therefore, analyzing data at the point of capture can make a huge difference between preventing a disaster and a cascade system failure (Cisco 2015; Sprecher et al. 2014).
- **Conserve network bandwidth:** considering the amount of data generated for all different use cases like a commercial jet which is generating 10 TB for 30 minutes flight time or an offshore oilrig with 500 GB of data on a weekly basis one might understand that it is not beneficial to transfer data from all devices deployed at the edge to the central cloud. Furthermore, it is not necessary as many critical processes do not require cloud-scale processing and storage (Cisco 2015).
- **Address security concerns:** it is important to make sure that IoT data is protected during transfer and at rest as well, which calls for monitoring and automated response across the entire process chain (Golden 2017).
- **Reliable operation:** more and more IoT data is used for decision making in public safety and for critical infrastructure where the integrity and availability of the entire infrastructure and data must not be in question (Sprecher et al. 2014).
- **Move data to the best place for processing:** the most appropriate location for data processing depends on how fast a decision has to be made. For extremely time-sensitive applications computing capacity should be located rather close to the device that is producing and acting on this data. Contrary to that, analytics on historical data requires computing and storage resources from the cloud (Cisco 2015).

In any case, independently if simple or high sophisticated analytics is applied, there is a need for centralized storage and computing power. Especially if Artificial Intelligence is considered where needed computing power is enormous to process the huge amount of data that is generated through the massive amount of sensors deployed in the field (Amyx 2016a; Golden 2017).

Considering the different applications with all their different needs there is no right answer to the question where computing capacity should be located. Furthermore, almost every IoT application will use both computing resources, deployed on the device and centrally in the cloud (Golden 2017). And this is already happening as all mobile devices are becoming extremely powerful. Taking Tesla as an example where every car is more or less a data center on wheels. Virtual reality devices consume huge amounts of data and require tremendous processing capabilities which will lead to move the processing capabilities from the cloud to the device itself. Therefore it seems that in the future there will be a shift from centralized computing to a decentralized peer-to-peer communication (Bhartiya 2017) which is also in line with the needs of CPS where devices have to communicate with each other in order to be able to execute their tasks and distribute tasks among each other to fulfill tasks in time.

It has to be considered that cloud computing is just the starting point of a new wave of technology revolution where disaggregation is a concept that is not only taking closed systems and distributing the components with centralized control, moreover it is more about modularity. Important to note is that once intelligence is modularized, it can be reassembled into functional blocks which are optimized for both, centralized and decentralized architectures. Also important is the fact that cloud is enabling the flexibility of disaggregating, composing, centralizing and distributing intelligence. Additionally, it provides the flexibility to developers to develop, test and operate applications without limitations from infrastructure as by removing the restrictions of traditional infrastructure, cloud and Software Defined Networking (SDN) technologies account for totally new levels of innovation that were not possible before (Bhartiya 2017).

It seems that it is even challenging for experts in the field to comprehend the tremendous amounts of data and computing that the future IoT saturated world will bring. Most probably there will be a lot of computing power at the edge of networks and accompanied by computing capacities at central cloud locations serving to bring closer the device networks and analyze the flood of data that it generated and streams (Golden 2017; Levine 2016b).

But, the increasing amount of generated data and the need of back-end computing power needed to process raises a very important question for enterprises and their IT executives: where to operate the back-end computing? Mainly the preferences are to have this within the organizations own data center or at a large-scale cloud provider. It is important to note that whatever choice has been made it is not easy to migrate once they are operating (Amyx 2016b).

What has to be considered when making the decision if using the own data center infrastructure or using a cloud provider:

- Using the own data center:
  For certain security or regulatory issues it might make sense to keep some IoT functions in house. Also, if an organization believes that it possesses significant technical expertise or is able to operate data center infrastructure less expensively than cloud operators running an own infrastructure makes sense. But, critical in this case is the ability of forecasting data and computing capacities, especially during peak times due to the flooding nature of many IoT applications it is absolutely adamant that enough computing power is available to make sure that no device interaction or data gets lost (Golden 2017).

- Using a cloud provider:
  This will definitely shorten the time-to-market as cloud providers are offering already pre-integrated services that make the end-to-end offering much easier. Taking into consideration that there are a lot of moving parts in an IoT application this often requires a number of different software components which have to be installed, configured, updated and managed where a smooth data flow through the entire system calls for integration between all components. Outsourcing this to a cloud provider allows the IT organization to focus on the parts that add value to the IoT application which a lot of organizations found attractive (Golden 2017).

Although it seems that many organizations are moving to the cloud there are good reasons for organizations to take care about the infrastructure by themselves when it comes to IoT deployments. In contrast to previous computing paradigms the mixed environment will not be about where generalized computing takes place. In an IoT environment edge computing will address mainly device- and application specific processing whereas general computing will still be processed in a centralized environment (Golden 2017).

Benefits of distributed computing capacity are:

- **Higher business agility:** Applications for edge computing can be developed quickly and deployed wherever they are needed. This gives machine manufacturers for example the possibility to offer Machine as a Service as the application deployed at the edge of the network provides the possibility to operate and configure the machine however the customer needs it.
- **Higher security:** Deployed nodes can be protected in the same way as all other parts of the IT environment by applying the same security and cybersecurity solutions.
- **Deeper insights, with privacy control:** Sensitive data can be analyzed locally instead of sending it through the entire network to the cloud. Furthermore, the IT department has the possibility to monitor and control all devices that collect, analyze and store IoT data.
- **Lower operating expense:** Due to the fact that data is processed locally the entire network is relieved which saves bandwidth for other applications and use-cases (Cisco 2015; Dickson 2016; Sprecher et al. 2014)

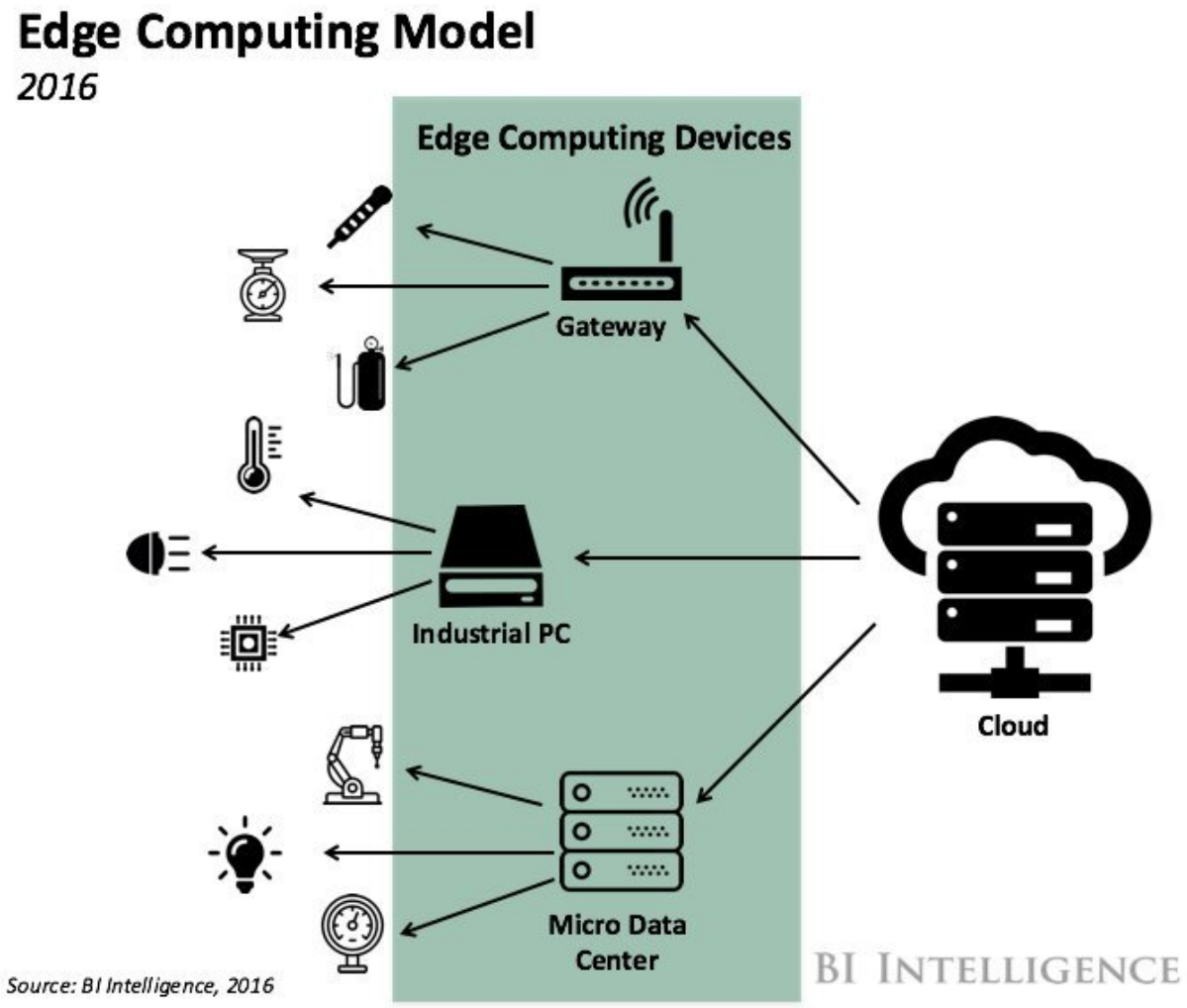

Figure 6: Edge Computing Model

Figure 6 shows a possible model of edge computing like it is deployed already in several cases to allow users to take benefits as mentioned above.

But, when deploying such distributed computing architectures, it is important to ensure that the data which is generated and processed remains available even at very remote locations. Furthermore, companies that are deploying such architectures have to keep the end-user in mind in order deliver against their expectations and needs. Taking a weather company and their sensor network as an example where the network generates data from each deployed sensor that has to be analyzed and sent in real-time to the weather application running on a mobile device of an end-user. These sensors are collecting data frequently at the local sensors processes some of the generated data close to the sensor and sends some data also to the cloud for core analysis. Data that is processed at the edge would be for example conditions like barometric pressure drops that are responsible for weather alerts. In order to ensure usability such weather companies are operating a distributed sensor network and processing capabilities which are executing analytics for a cluster of sensors (Wray 2016). This becomes also important when such weather companies

start cooperating with health institutions as such immediate changes in weather conditions can have a huge impact on the health status of patients and especially these who are suffering of heart deceases.

In general, it can be said that computing capabilities distributed across all different levels of the architecture have a positive impact on IoT deployments. Some lie in internal optimization as processing data at the edge minimizes cost for connectivity. Other benefits can be found in the fact that distributed computing capabilities allow totally new business models where it is absolutely crucial to be able to analyze data in real time at the point of capture without to need to send data through the entire network to the central cloud to be processed and back to the edge where some commands have to be executed. This means also that distributed computing capabilities also account for more smartness of devices which is explained in the following section more in detail.

Smartness:

Considering the huge number of devices such as sensors and actuators in a single CPS calls for some intelligence on device level. Having this large number of devices will require the development of approaches that allow the individual device to operate without the need of interaction of a human operator including self-localization, self-organization, self-configuration, self-healing, self-optimization and the capabilities of self-awareness. Although an individual device might have only limited capabilities, in combination the system is required to show a more rational behavior. The capabilities might range from simple discovery and self-localization mechanisms to capabilities with higher complexity like learning, information exchange and self-adaptation mechanisms to deal with changing environments (Software- & Systeme 2010).

Furthermore, large numbers of devices introducing different levels of smartness are considered as a benefit due to the fact that different situations might call for different capabilities. The mix of a huge variety of capabilities provided enable coping with different problems and selection of the most appropriate ones for the given situation without consuming resources that are too powerful (Esterle & Grosu 2016).

All these capabilities are supported by deploying analytics capabilities in the system which provide different possibilities and functionalities. Hence it is important to understand that the term “Internet of Things” is used to describe the extension of the internet and the web into physical reality by deploying devices with embedded identification and sensing and/or acting capabilities. Furthermore, IoT envisions a future where every physical system will have its digital twin which are linked to each other by using appropriate information and

communication technologies in order to enable a whole new class of applications and services (Miorandi et al. 2012).

Furthermore, the Internet of Things offers the possibility to collect data in real-time about every physical operation of a business. Starting from the temperature of assets or any other conditions that are important for operations, IoT sensors make data available in real-time. This provides a huge opportunity for those businesses that can convert collected raw data into business insights whereas the key to doing so can be found within effective data analytics (Haight & Park 2015). This becomes crucial when services are offered based on products and the vendor needs information about the actual status of different assets deployed in the field and offered as a service to end customers.

Senior leaders all over the world across all different industries wonder if they are getting the full value out of the massive amounts of information they already have within their organization and the data they are collecting through different IoT deployments. Still many organizations are looking for ways to generate value out of collected data and compete in their market place. Still there remains the question what the best way would be to generate value out of available data (Lavalle et al. 2011). Some businesses are reselling generated data to third party companies which are using the data to develop new services. One example would be vendors of vehicle tracking services based on GPS data, as they are reselling in many cases collected data from all vehicles in their ecosystem to traffic information provider companies. This means that they have achieved two revenue streams based on one product that is offered on the market. One revenue stream comes from offering tracking services for vehicles and the other revenue stream is enabled by selling anonymous data to traffic information providers. This could serve also as a perfect example for the need of having the possibility to create flexible systems having the capability to add and remove devices from the ecosystem as cars also have a scheduled end of life in many cases. And adding and removing new cars to and from the system must not have any impact on the functionality of the entire system.

“Analytics is the process of developing actionable insights through problem definition and the application of statistical models and analysis against existing and/or simulated future data” (Cooper 2012). Data analysis provides insights in patterns, trends, areas of inefficiency and potential risk which helps manufacturers to improve different areas across their business like manufacturing processes, production control, business processes and not to forget customer service based on past, real-time and also expected behavior. Therefore it is important to understand that big data for manufacturing is using different sources like machines and equipment with sensors that are able to automatically monitor and collect

information on the operational status and performance data, are able to identify radio frequencies and bar-code readers but also financial transactions, market statistics, internet, social media and also subject matter experts (Shao et al. 2014).

Actionable means that analytics is focusing on the potential for practical action rather than either theoretical description or mere reporting. Hence, this means that the conclusion of the analytics process may lead a person to initiate actions according to the values and factors not accounted for in the analysis. Furthermore, it means that conclusions are qualified with measures of their validity or reliability like statistical significance or confidence level, an acknowledgement of limitations or bias as these are necessary to judge if action is warranted or not. Very often, management reports are not able to provide this level of clarity which leads to actionable insights and missed opportunities (Cooper 2012).

IoT drives the development of countless industry and user specific applications where devices and networks provide physical connectivity and IoT applications enable device-to-device and human-to-device interactions in a reliable and robust way. It is important that applications deployed on devices ensure that data and messages are provided to the right recipient and processed in a timely proper manner. Although device-to-device applications do not require data visualization it is different when it comes to human-centered applications. In this case applications provide visualization to display information to end users in an intuitive and easy to understand way while providing the possibility to interact with the environment. Therefore, applications should provide intelligence in order that devices can monitor the environment and identify problem, communicate with each other and in case resolve problems without the need of human interaction.(Lee & Lee 2015)

Therefore, three enterprise applications have been identified: (Lee & Lee 2015)

1. Monitoring and Control:
   Monitoring and control systems provide managers and automated controllers the possibility to track equipment performance in real-time anywhere by collecting data on performance, energy consumption and environmental conditions. Furthermore, advanced monitoring and control technologies reveal operational patterns, indicate areas of potential improvement or predict future outcomes and optimize operations which in return leads to lower cost and higher productivity.
2. Big data and business analytics
   IoT devices generate and transmit data to business intelligence and analytics tools to enable humans to make decisions, whereas these data are used to discover and resolve business issues like changes in customer behavior and market conditions in order to improve customer satisfaction and to provide value added services to

customers. Business analytics tools can also be deployed on IoT devices so that real time decision making can take place right at the source of data.

3. Information sharing and collaboration
   Information sharing and collaboration in IoT can take place between people, people and devices and between devices where identifying a predefined event can be seen as the first step for information sharing and collaboration.

To address the different needs different types of analytics are available. In each case, value to an organization may it be from cost savings or new revenue opportunities, is enabled by the analysis of collected data. This means that individual signals from sensors become actionable only by applying analytics (Haight & Park 2015).

Depending on the starting point of a business four or five different stages that represent the maturity of IoT analytics can be identified. Taking into account that data generation was not automated yet there are five different stages (Davenport et al. 2010). If data collection is already automated this step can be skipped and there are four more stages of IoT analytics, as shown in figure 1, starting from descriptive analytics, moving to diagnostic analytics followed by predictive analytics and the last stage which provides the highest value for enterprises is prescriptive analytics where each stage builds off the previous one and differs in regards of complexity and value creation (Shao et al. 2014).

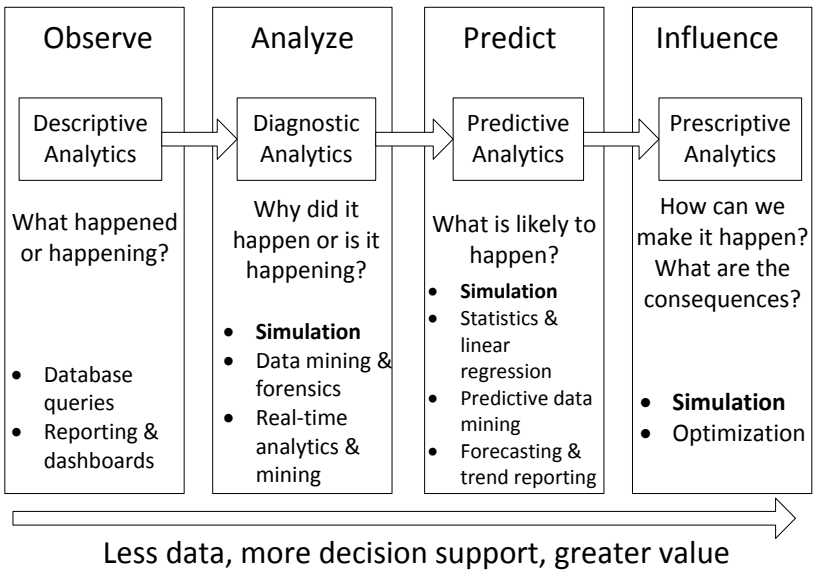

Figure 7: role of simulation in major data analytics applications (Shao et al. 2014)

Figure 7 shows the different steps of analytics.

Replacing traditional data collection:

The use of sensors and wireless networks to ease the data collection process is fundamental to all IoT analytics undertakings. Therefore, enterprises have to understand the scale of data they are generating. It is important to consider that sensors are generating a persistent stream of readings, which is magnified by the large scale of monitored devices included in any IoT initiative. Even if data is filtered prior to storage, the amount of data still requires an investment in a data storage environment. As so, the primary consideration for choosing an analytics software to enable all these initiatives data storage capacities and the ability to integrate with existing systems is absolutely necessary. Even as this is can be seen as relatively straight forward the potential value add at this stage should not be overlooked. The long-run cost savings potential for organizations that are already investing significant time and effort into collecting and aggregating sensor data (Haight & Park 2015).

These types of analytics can be applied for example in the field of metering where data on used electrical energy, heating services or water is automatically transferred to the vendor which allows for a more efficient billing application as all needed data are automatically transferred to the central data base and from there processed further for different types of applications.

Descriptive analytics:

Descriptive analytics which are also called business reporting, is using the data to answer the question “what happened and/or what is happening?” This considers standard and periodic reporting, on-demand reporting but also dynamic reporting where the main output of descriptive analytics is the identification of business opportunities and problems (Delen & Demirkan 2013). Furthermore, IoT undertakings show a differentiation as this analysis can be handled on ‘at-rest’ data as well as on live ‘in-stream’ data. Considering the fact that with IoT sensors organizations get the opportunity to monitor key metrics and key performance indicators in real-time by integrating live data feeds into their analysis which in fact provides the most up-to-date understanding of operations and enables decisions to be made on the most relevant data points. Still not all analytics undertakings rely on real-time decision making although the analytics system delivers live streams of data from the field, some organizations might prefer to review stored data at the end of specified time periods.

Important to note is, that only the ability to analyze all relevant data provides full advantage of applying descriptive analytics. Doing so can be a huge challenge considering the large number of different data sources and informational silos that organizations develop as new data sources must be integrated with existing system in a consistent and unified way to make sure that insights can be understood within the context within the whole organization (Haight & Park 2015).

This is type of analytics is crucial when it comes to offering services instead of products as the expectations are different on customer side. When it comes to acquiring services, customers expect that the services are available exactly when and where needed. Therefore, the vendor has to understand what the current status of the asset is that is used to deliver these services.

Diagnostic analytics:

Diagnostic analytics describes the science of understanding why something happened or is happening. It supports identifying causes which are leading to the realized performance. This can help to understand the impact factors and operational policies on performance measures in an easier way like the increase in cycle time of product can be tracked down to any or all of the multiple factors including machine breakdowns, absence of workers, material defects causing rework and the increase in priority over other products on shared machines and transporters. Diagnostic analytics can benefit from sensitivity analysis using a simulation model of the manufacturing system that shows the current operation (Shao et al. 2014).

Businesses should focus also on gaining proficiency in data quality and app integration, provisioning data for fast access by different users, implementing new technologies like Hadoop which is addressing unstructured data, optimizing the data warehouse and starting to implement a master data engagement strategy in order to enable the organization to make standardized reporting on a single platform available across different organizations across the business (de Onis 2016).

At this stage, the venture is using its resources in a more efficient way and is ready to benefit out of the promise of data analytics namely the way how it operates.

For businesses, this means that they can use this gained knowledge also for other deployments and so constantly improve their offering towards end customers and so increase reliability and efficiency of systems offered as a service.

Predictive analytics:

Accurate forecast of factors like operations, budgets, supplies and even product demand is crucial to the success of any organization where predictive analytics can contribute tremendously. Predictive analytics is a broad term that describes a variety of statistical and analytical techniques which are used to develop models that are able to predict future events and behaviors whereas the predictive models vary in regards to the behavior or event that they aim to predict (Nyce 2007). Using available data to develop forecasts and predict future results is the next step in extending the value creation by applying analytics. Predictive modeling and machine learning algorithms base and are trained on historic data which have

to be continually refined based on realized outcomes whereas the used data can be stored data at rest and with live in-stream data. Systems using stream data are able to provide dynamic forecasts to critical decision makers in real time. This in fact enables the potential for substantial competitive advantages and efficiency gains just by reducing response times and generating more accurate predictions (Haight & Park 2015).

To be able to apply predictive analytics an understanding of what statistical insights are possible and the tools to create accurate projections which means that statistical fallacies have to be avoided like error, interpolation, extrapolation accurate regression modelling to build a portfolio of outcomes (SAP 2016).

Predictive analytics also enable to offer more strict service level agreements which are usually charged with higher prices as the vendor has to react much faster on case of any failure on the offered system. Businesses are gaining the possibility to understand which system has to be maintained when and which spare parts would be needed in order to avoid any unplanned downtimes on customer side. Another positive aspect is that by applying predictive analytics businesses are becoming able to offer services based on reliability and so totally new business models are enabled.

Prescriptive Analytics:

The highest value of analytics in IoT is provided when actions are set based on incoming data without the interaction of human beings which leads to a data driven business. This is already the final stage of data maturity but it also means that if no data is available no decisions can be made. The aim is to scale the data strategy while cost is taken out continuously and IT and business work as a tight and cohesive unit where It has integrated all data sources and applications and has implemented an advanced analytics platform. Furthermore, business has set a strategy where and how to implement analytics in its processes to constantly improve and react faster based on changing factors. The most challenging part in remaining data driven and realizing competitive advantages is to embed analytics seamless into all business processes (de Onis 2016).

By applying prescriptive analytics enterprises can make sure that all processes are initiated fully automated without the need of any human interaction. This not only shortens process times, but also makes sure that everything that is needed is available exactly when needed and where needed. Not only the fact that new business models can be deployed, prescriptive analytics also make sure that all related process are executed in a proper way which positively impacts operations. So in this case not only benefits from new business models are gained but also internal optimization plays an important role.

To derive proper decisions enterprises have to apply industry-specific analytics which translate mathematical outcomes into action where the recommendation has to provide a specific course of action (Haight & Park 2015).

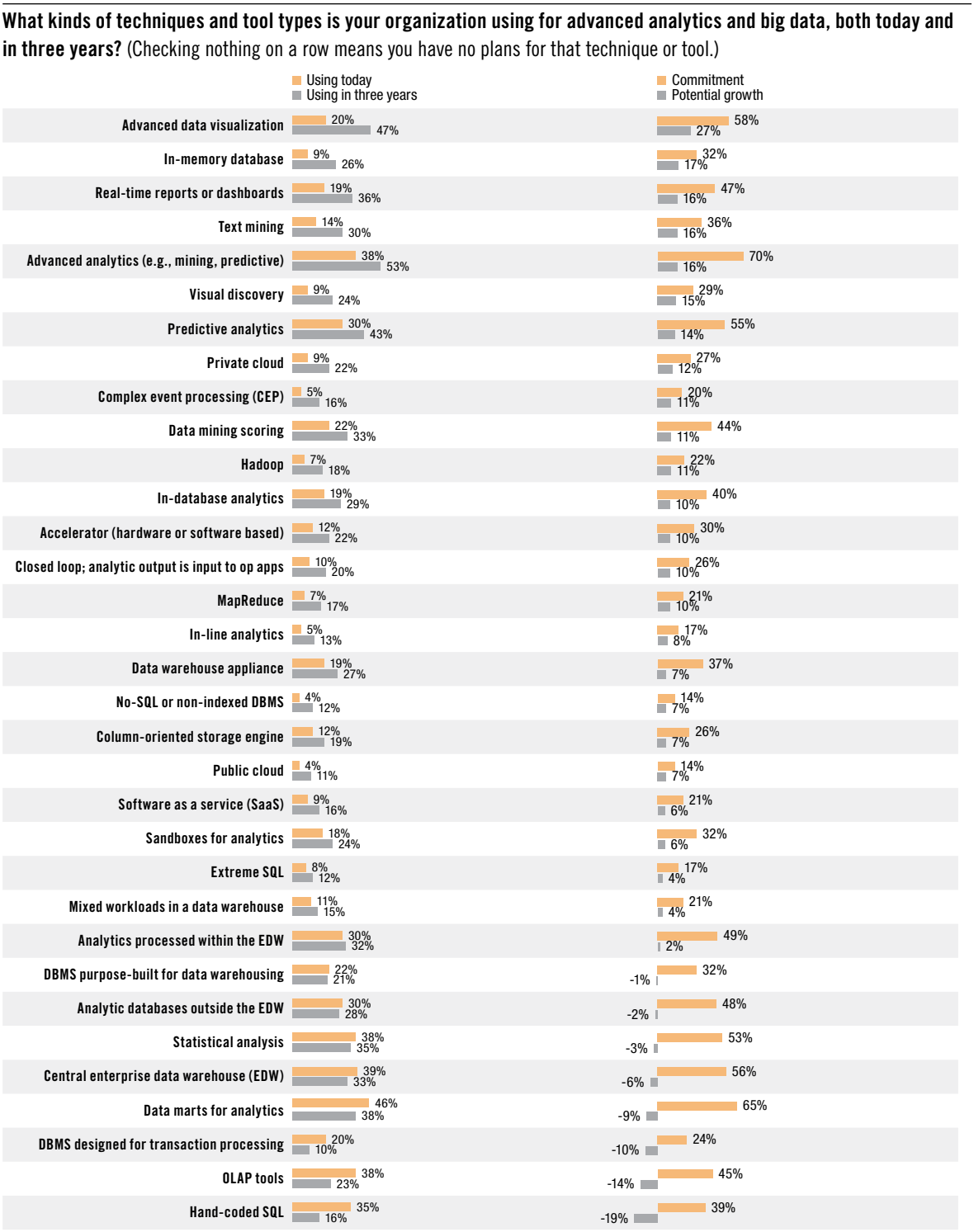

Figure 8: Charts sorted by the "potential growth" column of values (Lavalle et al. 2011)

Figure 8 provides an overview on which types of analytics are most common today.

What has to be considered in applying analytics is that every business follows a unique approach to analytics and data science. Still there are very few best practices known and the world is still learning (Kaduk 2017). Furthermore, 210 surveyed companies agree that the importance of analytics is very high and more than 40% of these companies' state that advanced analytics is crucial for them already now. 94% commit that advanced and predictive analytics will be crucial for them in the future. Currently 37% are applying advanced analytics but out of these only 5% continuously and 32% only sporadic. Along these companies 24% are planning to implement advanced analytics on a short term and 21% on a long term. Still there are 18% of companies that still do not have any plans in applying advanced analytics in their business (Iffert et al. 2016).

4 Examples of successfully deployed business models based on analytics and IoT

In this chapter, insights and details of successful deployments of IoT and analytics is provided. Based on the findings described above it provides an analysis why these companies have started their journey toward digitization and what measures have been taken to overcome the challenges when it comes to deploying these new business models.

4.1 Rolls Royce

Rolls Royce, a British manufacturer of jet engines that is producing high quality and high priced jet engines where the commercial aero-engine business is operating in two different market segments as:

- Selling new engines to airplane manufacturers like Boeing and Airbus Industrie as well as airlines for replacement of outdated engines
- Spare parts to airlines that take care about service and maintenance of the aircraft

Although there have been some adjustments to the business model in regards to different financing options and leasing agreements, the main idea stayed the same, which was selling the engine and after-sales services (BlueCanyonPartners n.d.; BusinessCaseStudies n.d.).

Considering the part of selling new engines Rolls Royce was constantly working on improving quality of its engines in order to increase customer satisfaction which was done very successfully, but even with improving quality and reliability of its engines Rolls Royce could be ahead of competition only for maximum a decade as all other manufacturers tried to catch up with their developments and did this successfully (TheEconomist n.d.).

Furthermore, the new engine market is the entrance to the service and spare part market (BusinessCaseStudies n.d.).

But also on the services part Rolls Royce was facing more and more competition as other companies realized that this is a very profitable business and started producing and marketing spare parts providing more or less the same level of quality as the OEM manufacturer itself (BusinessCaseStudies n.d.; BlueCanyonPartners n.d.). Facing this situation Rolls Royce decided to change its business model and instead of selling the equipment itself they began selling the utility of the equipment (BlueCanyonPartners n.d.).

Rolls Royce successfully implemented the business model called “power by the hour” where they were providing the engine based on operated hours including services and spare parts needed to keep the engine up and running (BlueCanyonPartners n.d.). The first customer Rolls Royce has sold this business model to were the US Navy in 2003 (Smith 2013).

It seems that this was the only possibility that Rolls Royce had to improve their margins as all other measures have been implemented. They have tried to reduce their cost to a minimum and even entry barriers for new engines where high due to the very high development cost of such engines. So, in order to improve their profits Rolls Royce had to fulfill customer needs in a better way which would make it impossible for competitors to to replace them. In other words, Rolls Royce was looking for a solution that introduced very high switching cost for the customer just by constantly monitoring the performance of jet engines and making sure that they are available whenever their customers need them.

In any case, customers of Rolls Royce were looking for more complete services. Although the engine itself will always be important, customers were expecting a service which was easier to plan against regarding cost as so far, some costs occurring during operations could not be incorporated in planning due to lacking possibilities of predicting which part might break when and where. This makes it impossible to calculate such cost in advance. Therefore, customers were looking for services that include all cost that might occur during operations and where it is made sure that the engine will be operational with minimal downtimes which also increases satisfaction of passengers as less flight delays occur (TheEconomist n.d.).

To be able to offer such services Rolls Royce had to deploy new technologies that were able to capture data during flight operations and so adjust settings during flight. But furthermore, as they began marketing operating hours and had to guarantee this, there was also the need for predictive analytics that allowed Rolls Royce to understand which engine

might break when and make sure that all spare parts are available as soon as the aircraft can be serviced in case it is needed (Smith 2013).

This case serves also as a great example that computing power has to be distributed across the entire architecture because of limited communication capabilities of devices during flight. Hence, the full processing of captured data has to be done on the plane itself and only critical data to be sent to the central cloud as well as information about needed maintenance activities as soon as the aircraft hits the ground at the destination airport. Computing power at the edge provides the possibility to safe cost for cost-intensive data communication during the flight.

One could easy imagine that in this case product-lifecycle management is crucial as Rolls Royce is selling flight hours and they have to be aware of the actual status and all activities of the jet engines that are offered as a service. For different analytics applications, it helps if more data can be used to develop some new analytics models and so gain more and new insights into operations of jet engines in real environment. Linking then operational data with maintenance data for engines could provide totally new insights for engine manufacturers that can be used and applied for development of new product generations. Such data collection and linkage of data can be realized through horizontal IoT platforms that are able to aggregate data from sensors and devices deployed on the aircraft and data from maintenance activities that are integrated through interfaces that enable communication between different applications.

Another important aspect which is crucial to make such projects and deployments successful is the analytics model that is applied to the critical parts of the jet engine. This helps and supports identification of possible failures on time. In return it provides the possibility for the maintenance team to prepare everything needed on time and so keep the ground-time of the aircraft as low as possible and so minimize occurring cost for airport usage. Hence, not only benefits for the customer is gained but also for the maintenance team as they are aware on time and so able to prepare everything needed to keep the internal cost as low as possible and so maximize the own profit as well.

But deploying and using new technologies is not sufficient to be able to serve customers in such a way. Rolls Royce had to adopt also its business processes accordingly to be able to act accordingly. They had to understand that offering such services require relationship marketing which allows them to understand customer needs better and develop activities and services that exactly fit these needs. Rolls Royce understood that if they are able to provide efficient products together with total customer care, occasional customers become regular customers and regular customers become advocates and support marketing activities for

Rolls Royce. To be able to respond to the change of the business Porter's 'Five Forces' model of industry competition was applied in order to understand the entire market including the degree of competition, the potential threat of new entrants, the power of buyers, the power of suppliers and the threat of substitutes (BusinessCaseStudies n.d.).

As one can easily imagine not only the way how the interaction with customers takes place is important to be able to offer such services, also other business processes play an important role. Important is also to align all other processes with the newly gained knowledge and adjust functions like logistics which make sure that the needed part is at the right place at the right time in order to keep aircrafts on the ground as short as possible. Furthermore, also the integration of the supply chain plays an important role as it has to be made sure that raw materials for producing spare parts are available at the time when needed which again allows to fulfill guaranteed service level agreements.

4.2 Kaeser Kompressoren

Kaeser Kompressoren is a German family owned business that is producing air compressors with a huge variety and even tailored exactly to customer needs. Kaeser is also one of the first industrial manufacturers of machines that has understood how important the product they are developing, manufacturing and selling is to their customers and their daily operations. As a very innovative company Kaeser has decided to put their customers even more in the center of their business and help them to fulfill their tasks without any break-downs that occur unplanned and would so have an impact on the operations of their customers. But not only the product itself is crucial to allow customers smooth operations but also the entire after-sale-service is an important part to which Kaeser is highly committed. This commitment has led Kaeser to make a significant investment in order to serve their customer and fulfill their needs even better than it was (Gibbons Paul 2017).

But not only improving the after-sales service was a reason for Kaeser to make this investment, furthermore, they were looking for a possibility to differentiate even more from their competitors. Not only through offering high quality machines, but putting really the customer in the center of their operations which led to a new after-sales service offering where Kaeser is able to predict when a machine they have produced might break down. In addition to improving their after-sales service they also gained the possibility to change their business model so that they are now able to offer "Compressed Air-as-a-Service" and to be the first company in this segment on the market to implement such offerings which allowed Kaeser to differentiate even more from their competitors (Gibbons Paul 2017; T-Systems 2016).

To be able to implement a new business model Kaeser had to deploy an IoT solution that allows them to constantly gather data from their machines. As already mentioned, data is the new oil but has to be refined in order to provide value, Kaeser is feeding a predictive analytics model with these generated data which allows to predict possible failures of any part of the compressor before it breaks down and causes damage on customer side due to unplanned down times of the equipment which is used for mission critical applications across all industries all over the globe (T-Systems 2016).

The solution that Kaeser has in place consist of several components that all together build a Cyber Physical System which contains of sensors that are deployed in the machine for data gathering, computing capacity at the edge that allows to run predictive analytics in real-time, connectivity which enable to transfer data from the edge to the central cloud which is deployed on premise at Kaeser to consolidate all data from all different machines out in the field (Gibbons Paul 2017; T-Systems 2016).

The case of Kaeser proofs that only a perfect interplay of different technologies lead to the desired success of such undertakings. One can easily see that to be able to initiate all tasks connectivity is needed that enables data communication from the device to the central cloud where data is stored after processing at the edge This provides the benefit that less data is transferred through the network which has positive impact on the efficiency of operations in a company. Most probably Kaeser is working with different suppliers which calls for device management capabilities where devices and protocols from different suppliers can be incorporated which is absolutely adamant in order to remain flexible when it comes to developing the supplier network and supports to keep the balance of power between supplier and customer. This is important for other reasons as well, especially if the technological evolution is considered which is gaining more and more in speed. Therefore, OEMs such as Kaeser need the flexibility to integrate new devices as well as legacy devices into one single system to gain the most benefit out of such activities. All these needs are today supported by several horizontal IoT platforms and so a fully flexible environment is supported. At least equally important is the analytics model that has to be up-to-date where all newly acquired knowledge is incorporated and so predictive analytics become more precise which leads to better decisions by the system itself or by managers in order to improve business results.

But, only connecting machines and running analytics against the enormous amounts of data is not sufficient enough to keep the promise towards the customer for nearly 100% availability. To be able to fulfill all tasks, Kaeser had also to adopt their internal processes. To be able to do so, Kaeser had to combine the data generated from the machines with data

from daily customer operations which allows them to analyze the entire lifecycle very carefully starting from lead management to requirements analysis to solution planning and finally solution deployment. This move allowed also to integrate the entire supply and gain the ability to fulfill constantly changing customer needs (Gibbons Paul 2017). In addition to that Kaeser has equipped all service technicians with mobile devices like smartphones or tablets to provide the health status of machines and compressors deployed in their region of responsibility in real-time or check the status through the web-application which was designed to ease the entire process (Gibbons Paul 2017; T-Systems 2016).

Of course this has an impact also on the margins generated as the entire business model is carefully thought through because linking the supply chain with customer needs not only allows to squeeze bounded capital in the warehouse in form of possibly needed components but also provides the possibility to react on changing customer needs without increasing prices from supplier side. Basically, in this case money is spent only when order is coming in.

This applies only for machines that are sold in the old way and is not applicable to the model where “Compressed Air-as-a-Service” is offered to the customer as in this case the machine or compressor is still belonging to Kaeser where an upfront investment has to be done. But, in this case the business model is different as it is offered as a service which usually allows for charging higher prices as customers are expecting the machine or compressor to be available whenever needed in order to keep their operations up and running.

Changing the market approach, adopting the business model and integrating the entire supply chain into the business processes at Kaeser not only brought the benefit of further differentiation from their customers, but also led to improve their margins and improved customer satisfaction. Furthermore, it enabled Kaeser to improve their operations of field service technicians as they gained the possibility to schedule their work according to alarms coming in from customer side without the need of interaction from after-sales back-office as the needed information was provided to them in real time (Gibbons Paul 2017).

Due to this undertaking Kaeser is not only a role model for digitalizing business, but it also proofs the benefits of digitalizing the own business in regards to improving margin, increasing customer satisfaction, differentiating from competition and constant innovation as gathered data can be used also as input for further developments in order to improve quality and reduce maintenance cost for machines deployed in the field.

To be able to deploy all these new technologies that are needed to make such developments possible they clearly had to gain knowledge which would help them. As knowledge development takes a lot of time, especially if these skills are developed from scratch, Kaeser was relying on experienced partners who have a lot of experience in digitization including connectivity, device management, data aggregation and applying analytics. The partners that supported Kaeser are T-System who provide vast knowledge in how connectivity works and which access technology can be applied for which use case but also device management as they are offering mobile device management as a service for enterprise customers. And there is not much difference in managing mobile phones or other devices that are connected to the web. SAP brought the knowledge on how processes can be optimized as this is one of their key focus areas coming from enterprise resource management. But also, predictive analytics was supported by SAP which was needed to better understand what is going on and when services might be needed.

Most probably there was a joint support of T-Systems and SAP in developing the new business models as both firms have their clear focus on how to provide services that are increasing customer experience. Both companies have experience in how investments can be turned into profit as T-Systems has to build the entire network infrastructure which is offered as communication service to customers. SAP has to invest enormous amounts of money into their data centers in order to be able to provide ultra-fast storage capabilities that are needed to process data in almost real-time which is offered as a service to their customers as well.

But, one can easily see that Kaeser has used state of the art technologies to connect their devices and so change their business model towards a fully service oriented business model. But still Kaeser is offering both options, buying the product and acquiring the service. Unfortunately, there is no evidence available that would prove if the margins of the new business model are evolving as expected and improving over time which would make it much easier to fully replace the conventional business model. Maybe, also the market is not fully ready yet to accept only these new business models. One of the reasons therefor might be that in Europe people and enterprises are more careful when it comes to sharing data on what is happening on shop floor because there might be the fear that data leaks and could become available for other enterprises as well which would diminish competitive advantage.

4.3 DriveNow

Drive Now is a car sharing joint venture which was founded by the BMW Group and SIXT AG in 2011 where the BMW Group is contributing vehicles and necessary vehicle technology and SIXT is providing the premium service, the rental expertise, the necessary IT system and the infrastructure of stations for the registration of customers (Vodafone 2014).

Drive Now has also changed the way how cars a rented by introducing a free-floating car rental model where the cars do not have to be picked up anymore from fixed rental stations but from anywhere across the city. Therefore, customers are using a smartphone application which shows all cars available in close proximity displaying the exact address where the car is located and providing an overview on the status of a car in regards of fuel level and if there are any damages. But also the car configuration is provided to the customer indicating if the car comes with a manual gear box or an automatic on so that the customer can make his choice according to his preferences (Vodafone 2014). Basically, the BMW Group and SIXT are creating digital twins of the cars they are providing to their customers where they have a full and detailed overview on the entire fleet which is moving around the city with the possibility to add new cars to the fleet and remove them. This is absolutely necessary as in this case the joint venture is providing a service which is operated fully remotely due to the fact that the cars are not returned at the car rental stations and serviced on a regular basis. So, it had to be taken care of that the service can be provided at any time based on real-time information generated from the entire fleet which allows proper planning of maintenance and cleaning services according the needs of any single vehicle of the fleet.

Also in this case, some adoptions to the IT system where needed. First the health status had to be integrated into the IT system as this information indicates exactly which vehicle has to be maintained and cleaned at a point in time, so the entire vehicle had to be mirrored and digitalized. To retrieve information from the vehicle special devices where deployed that allow communication with an IoT platform which provides the needed flexibility to add and remove cars to and from the system without having a negative impact on the functionality of the entire system. Furthermore, data communication had to be established which allows the car to share information on driving time, route and actual location with the IT system which are mandatory for a proper billing process as Drive Now is charging based on minutes of driving and if necessary also parking. The route is needed to be able to understand if a driver was really driving along a road when it comes to fines caused by speeding or unauthorized parking. Furthermore, in some cities it has to be paid for parking services on public roads and streets which calls for the capability of the car to issue such parking payments fully automated with requiring human interaction, so it has to be done fully automated. To make

these payments possible there is also a need to connect the systems of Drive Now to the systems of different cities (Vodafone 2014).

Also this case proves that changing a business model requires more than just changing the payment method. It shows that integration of the entire eco-system is absolutely necessary in order to provide real customer service that is addressing the needs and wishes of customers. Furthermore, also in this case the customer in the center of all activities as the solution provides detailed information on available cars around the customer with the freedom to choose which car would fulfill the needs and wishes of a customer at any time, may it be the desire for a convertible, or a car that allows to travel to the airport with the entire family while providing enough space for family members and luggage that is required during a trip.

To make this happen not only the information regarding location is needed, but also full integration to business relevant IT systems for fully automated billing processes and fully automated calls in case maintenance is needed but also information about some accidents have to be shared with the renting company in order to avoid any losses caused by incautious drivers in case they hit another car or cause any types of damages to the rented car. Furthermore, the entire process of renting cars has changed due to this approach as cars are not rented at dedicated car rental stations anymore, they can be reserved by using an application for a smartphone or over the internet and even the car can be opened through this mobile application. And the renter has the possibility to leave the car again at any place as long it is inside the business area of the particular city where the car was rented.

All this has become possible by deploying state of the art technologies like the proper access technology that allows data communication between the car and the central data center. Beside access technology also the management suite is of importance as in this case several products from different brands are integrated in the business model. Although BMW and Mini are part of the BMW group both manufacturers might have different requirements to equipment installed in their cars which could lead to different specifications and functionalities incorporated in their products. In this case, the possibility to incorporate different devices and products is crucial for operations as all cars have to be managed independently from manufacturer in order to achieve customer satisfaction. Therefore, IoT platforms are applied which support the integration of different devices into one single system. These IoT platforms make data for analytics applications available which can run different analytics models across the different stages of analytics. Starting from replacing data collection to make data available whenever needed over descriptive analytics which provide a real-time overview on the health status of all cars in the fleet. Diagnostic analytics

play an important role when it comes to understanding why different things are happening, for example analyzing why some special car types are not rented in some areas or why damages occur more often in other cities where the business is operating. Predictive analytics supports in understanding which car would have to maintained in order to minimize downtimes of cars and prescriptive analytics which already initiates processes without the need of human interaction.

By deploying this new business model Drive Now has also changed the way how people are moving around. It became a real alternative how people are moving around instead of using public transport, bicycles or even taxis can be replaced by this business model.

One can see that Drive Now was also relying on partners that would bring the missing knowledge that is needed to make this business model possible. For connectivity and device management Vodafone was chosen as a partner who brings vast experience in connecting people and things as one of the largest communication service providers on the globe. Probably the knowledge on how to provide services and improve processes was provided by SIXT as this part of their core business as cars are offered as a service for a predefined period of time. Also logistics plays an important role in renting cars as all of these cars that are returned have to be cleaned and checked if they can be used in a safe way.

Although there was sufficient knowledge on how cars are provided as a service it seems that Drive Now was established as joint venture between the BMW group and SIXT to overcome internal resistance to this new business model. As if a company is newly founded there are no processes that could hinder the development and deployment of such new services. In such a case also required knowledge can be acquired in an easier way by hiring external people who bring this needed knowledge in order to start activities much faster which allows faster monetization of investments made upfront to make this new business model possible. Furthermore, this newly founded venture might have had the possibility to benefit from the huge organizations that are staying behind and get all necessary support from business support functions like billing, accounting, legal advice and financial support. This approach can be seen also from other companies as a possible way to overcome challenges a huge organization brings with it when it comes to implementing changes and overcoming resistance to change.

5 Conclusion

In general, it can be said that business model innovation is vitally important for businesses in order to remain competitive and profitable on the market. And still this is difficult to achieve as the barriers organizations are facing when it comes to business model innovation are real. It is not only about having a map and a checklist and work through all these points and when having a check on every task the new business model is implemented (Chesbrough 2010). As successful business change is not a matter of implementing fixed plans as so many parts of a business are involved like IT, sales, marketing, services and others, also processes have to be adjusted in order to make such projects successful and profitable. Hence, it requires a top-down strategic guidance as well as bottom-up collaborative improvement. Even more challenging is the fact that these people from different bring different knowledge and use different languages in communicating, and have by nature different focuses in daily business. But their knowledge is absolutely vital as they provide the necessary knowledge and skills, and use high- quality information to support decision-making, design and implementation. (Lankhorst et al. n.d.)

Companies must understand that not every new business model will be successful, therefore an effectual attitude towards business model experimentation should be adopted as all projects will generate new knowledge and understanding for following projects which might compensate all previous efforts. And still knowledge is one of the most important resources inside a company which has to constantly evolve inside a company over time. This approach brings also the benefit that enterprises can model the uncertainties and so update financial projections as all new experiments bring new data (Chesbrough 2010).

To make such projects successful companies will have to identify and nominate internal leaders for business model change and innovation which will have to take care about managing the results of all these processes and so deliver a new and better business model for the company where all different representatives from all different functions inside the business have contributed. In parallel the culture of the organization has to find a way to embrace these new business models while making sure that the effectiveness of existing business models remains until these new business models are ready to take over completely. This is the only way how companies can escape the ‘trap’ of their earlier business models, and renew growth and profits (Chesbrough 2010).

But developing and implementing such new business models requires further changes inside an enterprise. Missing knowledge has to be acquired, silos have to be removed in order to enable cross-functional communication and collaboration which is absolutely crucial to make such projects successful. Furthermore, new technologies have to be applied and

understood in order to enable these new business models. These new technologies are all already in use today especially in the internet of things. The IoT can also be seen as the main driver behind the development of new business models as these new technologies enable totally new functionalities of products that humans could not even imagine so far.

In some cases, the best way might be to have the new business model running in parallel to the old model which would help testing and evaluating the newly developed business model in real life while having the possibility to adjust the business model if needed like it is in the case of Kaeser. In other cases, we see that new organizations are established in order to overcome challenges organizations could be facing when it comes to deploy changes related to new business models like the BMW Group and SIXT did with Drive Now. Whichever option organizations might choose still the business model has to be tested and further developed until it could create that much in revenues until all costs can be covered and so the conservative business models can be replaced fully by new business models.

Although IoT is still at the beginning one can see that it has the potential to change the life and world humans have known so far. Already today improvements by different types of IoT projects can be seen, may it be in daily life of humans where all types of information are available already on the smartphone. But even some apps installed on the smartphones we are carrying with us are relying on IoT deployments like the weather application where a vast number of sensors is deployed all over the world and where the data is sold to weather service companies. These companies are in need of these data which means that a stable eco-system has to be developed which supports data collection and data transmission to a central analytics application. This application provides then the information all of us are looking for.

To enable smartphones and other devices for data aggregation and distributed computing some functionalities are required. First all the devices deployed in the field need the possibility to transfer generated data from the device to the computing unit where the aggregated data can be transformed to information and so create value out of generated data. Already today several access technologies are available that serve as a communication channel to transfer data providing the functionality determined by the application in regards of bandwidth, robustness, coverage, mobility and latency. Hence, different access technologies are already available and also currently evolving to address exactly these needs. For the first time in history communication technologies are developed to connect things and not people anymore like it is the case for the 5G network technology. Therefore, access technology can be seen as the link from the sensor that captures data to the computing unit which is then generating information.

Therefore, when making the decision where computing should be located one should think of the location that best serves the IoT devices specific functionality in order to run different types of analytics on remote places where also processing tasks could be split up between several computing stations to achieve common goals in regards of timing and speed. Important to understand is also the fact that every IoT device regardless of how remote, smart or fast-responding it is, will need centralized computing capabilities for backups and restoring capabilities. Hence, cloud will play an important role when it comes to IoT and deploying new business models based on new technologies which are currently evolving very fast. But still, the choice of where computing capabilities are deployed implies a trade-off between ease of implementation and user-control. Therefore, it has to be considered very carefully where to deploy these computing capabilities as an already made decision is very difficult to reverse (Golden 2017).

Considering the huge number of devices that are and will be deployed over time enterprises have to take care about managing the entire device fleet which is absolutely necessary to protect data from different sensors and machines. In addition, the possibility of integrating different types of devices from different generations has to be ensured in order to create the highest value for enterprises. This is usually done through horizontal IoT platforms that support several communication protocols, device management protocols and take care about security. Furthermore, such horizontal IoT platforms ensure privacy as they are providing data from the devices to the different applications. This requires also that data is anonymized which ensures that nobody can link data to a specific device or person.

We can see this also in the cases described above where in all cases it is absolutely necessary to be able to connect new devices to the entire system because of growing business. This applies for all IoT based projects where an enterprise aims to deploy new business models as the number of customers will hopefully be growing which means that new devices have to be integrated into the system for data collection and data processing. Over time when the new business model is considered as successful also new services might be offered to customers also other devices might be integrated. Therefore, it is important that a business thinks carefully about the entire ecosystem is building up in regards to the IoT platform they choose. Hence, it seems to be better to deploy a horizontal IoT platform that provides the flexibility to integrate new devices upon need and so get the possibility to constantly evolve in developing new services for customers.

Another very important part when it comes to developing and deploying new business models is analytics. This part is transforming data into information and so creates value. Considering the different steps and levels of analytics starting from automated data

generation which is also driven by the IoT, over describing the current status, understanding why some things are or were happening, predicting what might happen and initiating processes without human interaction. Having analyzed the cases described above of Kaeser, Rolls Royce and Drive Now, they all rely on analytics and especially the functionality of analyzing what might happen and what the impact on the business will be but also what the impact on customer side will be. It seems absolutely clear that without analyzing aggregated data all efforts would be worthless. All enterprises would just generate and store new data without knowing what to do with them. Therefore, some estimations say that the value that analytics add to such projects is somewhere between 35% and 45% which represents already a huge part of the entire cake. They are more and more taking care about everything without the need of human interaction.

Also, analytics can be considered as important as customers who are sourcing services instead of products expect that the service is available exactly when needed which means that enterprises have to have a full understanding on the status of all devices deployed in the field as this is the only way to ensure functionality of devices and machines that are offered as a service. Hence, predictive analytics, which are analyzing what will happen in the future based on historical data might play a crucial role in the future. But, not only for predicting the status of machines and assets. It might be even more interesting to predict customer behavior and understand when, where and why customers might be in need for the service a business is offering as this might define the competitive advantage in the future.

But this development towards a fully autonomous world brings also some other challenges beside technology and knowledge inside a company. As there is the trend towards more and more autonomous decisions by machines the entire education system will have to change. Today it is still taught how to operate machines, but in the future it will become important to understand how to live with machines (Bosch Software Innovations n.d.). This requires totally new skills and ways of thinking as machines are becoming more and more intelligent which is driven by analytics and artificial intelligence. Especially as machines will take decisions fully on their own without any human interaction. But not only the educational part is of importance. It is absolutely necessary that policy makers define and set some guidelines how artificial intelligence will be used in the future and to what extend power will be transferred to machines.

Even more important will be to analyze und understand what will happen in the future in regards of human workforce. Over time as automation is evolving more and more human workforce is replaced by machines. But still there is the need for humans to operate these machines which might become obsolete in the future as machines will have the possibility to

initiate all processes on their own which might then be executed also by machines. This means that governments -might have less income which is provided through taxes from employees. Some countries are already thinking about “machine taxes” to compensate these losses that might occur over time. Some examples where analytics is replacing human workforce are the Japanese insurance company Fukoku Mutual where the workload of 30 administrators has been transferred to the IBM Watson system. The French railway company is planning to use analytics to analyze data from sensors deployed along the 300.000 km railway system (Finsterbusch 2017).

It seems that we will face new exiting but also challenging times in the near future and a lot of things we have been used so far will change tremendously, some for the better and some not. But as it is with innovation, it cannot be stopped. It is constantly happening as soon as somebody faces a problem he wants to solve. But, this innovation has to be driven with care, especially in regards of privacy, safety and security as the new business models driven by new technologies could have an impact on all aspects of life. These we have considered but also these we did not even think that this would be possible.

Therefore, it is important to understand that:
“You can’t simply read a book and then have all the knowledge and ability to apply it. You have to find your own way, by driving and experiencing the transformation in your organization.”
Felix Hieronymi, Corporate Project Leader, Agile Company in the Digital Age, Robert Bosch GmbH

Anyhow, when a business starts is activities in digitization some steps should be considered.

- It is adamant to understand where the journey should go to. Does the business aim to improve internal processes or to put the customer in the focus and therefore deploy new business models.
- What are key metrics of these activities. This becomes very important when it comes to evaluating if the project was successful or not.
- What is already available and what has to be sourced. This applies for knowledge, IT systems, components needed. In parallel a business should look for reliable partners that could provide missing components which can be assembled to get a full working system.
- Rules and laws in regards to data privacy and security as this is varying from country to country. Some countries have stricter laws when it comes to data

protection than others. This has to be considered prior to offering any service or solution based on data especially as digital services can easily be scaled over the globe without tremendous efforts.

- Understanding that in the future services will be sold instead of products which means that the entire customer interaction might be different. It might be the case that a business will have far more customer interaction when offering a service instead of a product. Of course, this depends very much on the business model and the customer group a firm is aiming to serve.
- Patience is needed in order to develop and deploy a new business model as the entire organization might be affected by such undertakings.
- The venture has either to be flexible enough to deploy these new business models or it has to create a new entity where totally new processes can be developed and implemented which can be migrated then to the mother company in case of success.
- Start small and think big is crucial. Every business should start with small experiments and projects which enables learning for bigger projects. But still, how small the experiments might be a business must always think big as every experiment might end up in a successful project which could be marketed on a global level and therefore the entire ecosystem has to be capable to allow such scalings.

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