MSc Program

Engineering Management

Challenges and Opportunities of Industry 4.0, with special insight on advances in smart health

A Master's Thesis submitted for the degree of

"Master of Science"

supervised by

Professor Peter Kopacek

Affidavit

I, **Florian Ott**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Challenges and Opportunities of Industry 4.0, with special insight on advances in smart health", 66 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, 17.04.2017

Signature

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Lastly, I would like to thank my family for supporting me throughout the entire program, giving me advice and motivating me in difficult times.

Abstract

We are entering the fourth industrial revolution at time when the third has not even finished, showing how rapidly technologies are evolving and barely giving time for people or companies to adapt. The german term for the fourth industrial revolution is industry 4.0, which is set to bring significant changes in not only production and manufacturing, but also offices and daily personal life.

Industry 4.0 relies on a symbiosis of new technologies which enables machines to become “smart”, a term used to describe machines independently communicating and making decisions. Production under industry 4.0 requires less human interaction and allows a much more flexible and customizable approach, while simultaneously reducing costs, waste and time.

Challenges of industry 4.0 include dealing with job losses on the one hand and lack of qualified employees, being able to cope with new technologies, on the other. By 2020 a new generation, the millennials, will be the major workforce, bring in a new approach to handling business and work and life balance. They will bring great change to structures in business, which have been existing for years.

The medical sector will also undergo significant changes, allowing patients to receive treatments from their homes and accumulation of large data amounts which allow doctors to diagnose and prescribe treatments far more efficiently. Smart hospitals, the hospitals of the future, are built to provide the best possible care to patients.

The goal of this thesis is to show which technologies enabled industry 4.0 and then highlighting the challenges and opportunities it presents, giving a closer look at changes and challenges in the medical sector throughout the thesis.

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1 Introduction

Industry 4.0 or the so called fourth industrial revolution is taking place right now and drastically changing how machines work, manufacture and communicate with each other. The third industrial revolution introduced robots, which now are becoming “intelligent”, meaning they can make decisions and communicate without human interaction. Their capabilities advance to an extent that they can learn independently and take over roles previously exclusive to humans, which will impact not only businesses but also personal life.

This thesis explores how industry 4.0 is being enabled, by examining the technological advances needed to reach this stage, going into detail on how far these technologies are existing today and discussing future challenges and opportunities which come with the rise of industry 4.0. To be successful, implementation of new standards requires a lengthy process, which in todays globalized and connected world must take place not only in an individual household or business, but in all connected systems as well. As industry 4.0 heavily relies on machines communicating with each other, it is essential for all operating systems to be integrated and updated to newest technologies for the revolution to be functioning and complete.

Future jobs will face a major transition, with many jobs disappearing due to technological changes and others being created, with specifications people yet need to acquire. It will be shown how the new generation, the millennials, having been brought up in the technological era, show a new approach towards not only technological devices, but leads a very different lifestyle in general. While often having the required education, they are very selective in their choice of workplace and often have difficulties interacting with senior employees.

This thesis will discuss the transition between the loss and creation of these jobs, as well as the necessary changes people face working this new environment. It examines which sociological changes in peoples work ethics occur, while discussing if a transition is already possible at this stage, or which adaptations must be performed. People living today and in the future, will experience this transition not only in their jobs, but also in their private lives as many aspects and new technologies will be

implemented in households and everyday devices such as smartphones, glasses or cars.

Alongside with technological changes, legal and security adaptations necessary to enable but also uphold the new era will be analyzed and discussed. As technologies are advancing at a rate much higher than ever before, it is necessary to interpret legal regulations and determining their impact on these new technological advances. Companies are struggling between finding balances of developing new products or optimizing their current production, while complying with existing regulations, which are held to protect consumers and keep markets regulated.

Big data is a key technology in the development of industry 4.0, which is already being used by many companies today and constantly developing further, as data storage and acquisition methods rapidly improve. Posing endless abilities, such as detailed analysis and forecast, big data is the ultimate tool businesses use to make predictions or doctors to make diagnoses. Dealing with sensitive data always involve risks and with the huge amount of data involved in big data, risks are much higher than before. It will be examined how big data acquisition can benefit businesses and people and how it needs to be handles to keep it safe and secure.

Technological advances in the medical sector always occur a few years after other industries, to guarantee safe use and minimize any risks, which makes adaptation to industry 4.0 in this field especially tedious. Current state of development will be analyzed, showing the opportunities but also challenges in the medical field. Home used medical devices which can have large impact on people health and the entire operation of today's health care system will be shown and discussed. Big data plays a great role in implementation of industry 4.0 standards throughout the medical sector and will lead to much more detailed personal data acquisition, which in turn enables doctors to diagnose patients more precise and give better treatment. Data storage and handling will be of huge concern in this sector, as medical data needs highest security prevalence and it must be examined how these huge amounts of data can be handled correctly.

All medical advances lead up and are set to be integrated into smart hospitals. Fully developed "smart hospitals", will be the greatest advance in the medial sector,

combining all relevant technologies and advances achieved in one place. It will be shown, what makes a hospital “smart”, how patients care differs from care they receive in hospitals today and whether smart hospitals are on the verge of existing or still a project for the distant future.

This thesis will first give an overview on the historical development which led up to the current stage, then discuss the technologies enabling the transition and go into detail about challenges and opportunities rising with the implementation. Aspects concerning the medical field will be mentioned in hand with each topic and later discussed in detail.

2 Fundamentals of Industry 4.0

Industry 4.0 is a german term describing the fourth industrial revolution, often also referred to as internet of things. It stands as a synonym for the age of digitalization in which machines are taking over not only physical labor, but also mental labor, by taking independent decisions and communicating independently with each other.

2.1 Historical overview

The process of industrialization can be divided into four stages, or four industrial revolutions. Overall the first three industrial revolutions came about because of mechanization, then electricity and IT. The first, or classical, industrial revolution started in the 18th century in Great Britain and then spread to other parts of the world. The term “industrial revolution” was introduced by the historian Arnold Toynbee and describes the chance from an industry dominated by agriculture and handicraft to one influenced mainly by machines.

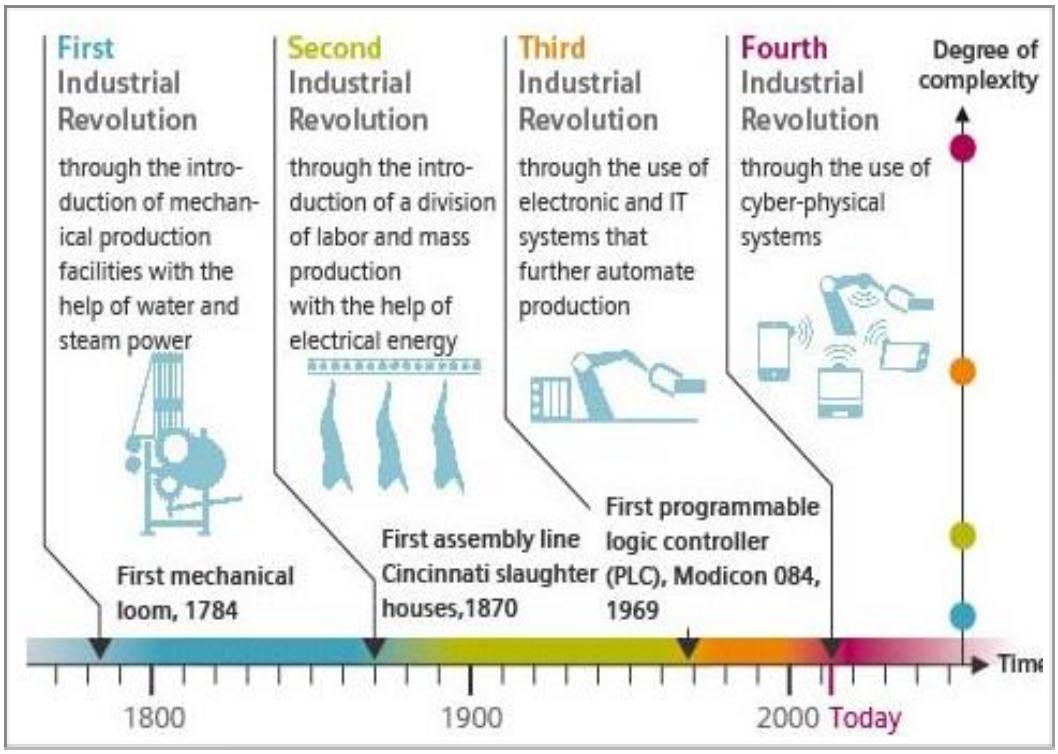

Figure 1: The four industrial revolutions (Joapen, 2016)

Many major technological changes enabled the first industrial revolution, such as the use of new basic materials such as iron and steel, the invention of new machines and the application of new energy sources, like water and steam power. The first industrial revolution also influenced social and political aspects of everyday life, such as increased international trade and a wider distribution of wealth.

Although it is difficult to isolate the first two revolutions from another, the start of the second industrial revolution is considered around 1870. The first assembly lines were first used on a large scale by slaughterhouses of the meat-packing industry in Chicago and Cincinnati. These used monorail trolleys to transport carcasses past workers, each of whom did one specific task. This method increased productivity immensely and enabled companies such as Henry Fores automobiles to present products at lower costs. New basic materials were discovered, such as lighter metals and synthetic material such as plastic. These discoveries were combined with developments in machineries, which enabled significant changes in the automatic factory. Automatic operations played a major role in the second revolution, especially in the late 20th century. Ownership of means also alternated; the common purchase of stocks by individuals or small companies was introduced. Revolution 2.0 brought modernization and a higher quality of life, such as population growth across the world.

The third or digital revolution began with the 21 century. Internet and billions of connected devices changed the way of basic communication, while renewable energy is becoming more important than fossil fuels. Transportation was redefined by modern technologies such as hydrogen powered drones and autonomous vehicles. Once again, new basic materials were discovered and replaced the previous ones, such as carbon nanotubes and bioplastics. Artificial intelligence is replacing human minds in many fields, which allows robots to replace mankind and lower labor costs. The digital revolution has come with brutal speed due and has now started to give way to industry 4.0. (Roth, 2016) (Brühl, 2015)

2.2 Big Data

Data is taking over our private and business world and increasingly dominating many aspects of both. Big data describes very large amounts of data, structured and unstructured which is being generated at very high speed, variety and originates from multiple sources.

Big data sources have existed for a while, but up until now it was impossible to store and manage these large amounts of data. Apache Hadoop is the most commonly software used to manage big data. It is an open source software platform designed to store data and run applications from clusters of commodity hardware. Clusters of commodity hardware are standard computers, which are joined togethers, enabling high parallel computing power at a low cost. Most companies prefer this method, in contrast to developing super computers, as it is cheaper and less vulnerable. (Hortonworks, 2017)

Originating from the creators of search engines, looking for ways to quickly and efficiently retrieve data from large sets, Hadoop now delivers very high processing power and the ability to manage immense sets of data. Hadoop is not used to analyze the data, its function is to store and organize the data, giving companies the ability to work with it. Hadoop and other similar software play a huge role in big data, setting the foundation for companies to work with the data.

Commonly there are four key characteristics which have been defined for describing big data, the so called “four V’s”.

I) Volume

Volume describes the amount of data. Big data is considered huge amount of unique data, which is unstructured and often difficult to define. Most data sets are constantly growing and size can vary for each company, for some it lies in the range of terabytes other companies are working with data set the size of hundreds of petabytes. (Oracle, 2017)

II) Velocity

Velocity describes the speed at which big data is created and or processed. A lot of data is required to be reacted upon immediately, this data includes images or text subject to censoring, financial data or health data. In production sites, RFID equipped products and machines deliver large amounts of data close to real-time which have to be stored and processed immediately.

III) Variety

Critical to big data is that it originates from a variety of sources and data can be a variety of types. Data can often originate unstructured or from unknown sources, challenging companies on security and privacy issues. (Oracle, 2017)

IV) Value

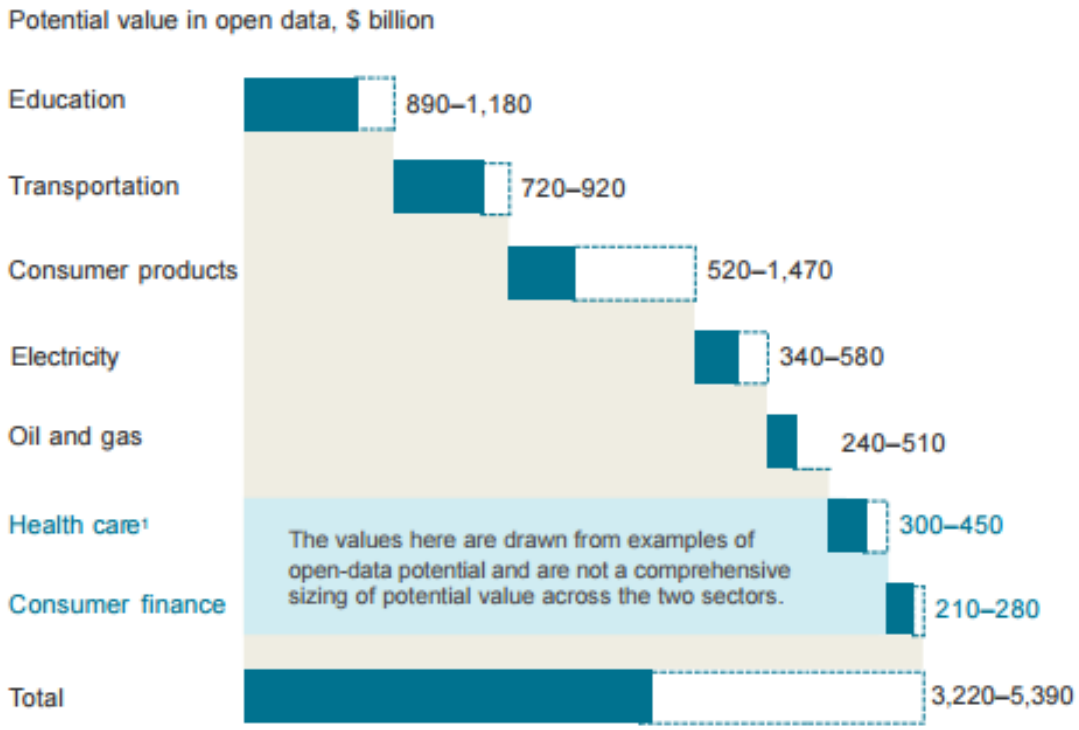

Figure 2 Potential Value in open data (McKinsey, 2017)

Data has value, it is often subject to debate how much data is worth but data can give companies the desired information for new development and analysis of the current market. Figure 2 shows the potential value of open data, found in a McKinsey study over various business fields. Enormous potential value lies in open data, the total sum accumulating to 3,220-5,390 billion US Dollars and companies are realizing this value and progressively extracting more value out of the data they manage to accumulate. Consumer products show the greatest potential, as through these it is possible to gather the most data through a wide population group. Smartphones play a huge role in gathering data through consumers, as most people in the developed world have smartphones and they can measure and record a very wide range of data. (SAS, 2015)

2.3 Five pillars of Industry 4.0

The launch of Industry 4.0 is often reduced to the simple implementation of new technologies, which then will seamlessly work together automatically and relieve all previous work. In reality, most of these technologies, such as High-Speed Broadband Internet Access, RFID Chips or Mini Computers, already exist today. The true challenge of Industry 4.0 is to combine all these individual, single purpose technologies into a unified solution which combines both the aspects of communication and control. This bond is described by the five pillars, which set a new approach to industrial fabrication. (Siepmann, 2016)

2.3.1 Vertical and horizontal integration

Reliable access to and efficient use of data, starting from management to factory floors, is essential for companies and can only be realized through successful vertical integration. Vertical integration defines that all systems within a company must be placed in hierarchical order and gateways for data exchange must be implemented between all levels. This creates a unified system in which flow of data can be directed in its proper hierarchical direction and close to real time. For data flow to occur close to real-time, standardized ports and norms must be used throughout the entire system enabling precise Machine to Machine communication. (Siepmann, 2016) (Kunz, 2016)

Figure 3: Pyramid of automation, showing hierarchy within a company and data flow (Automation, 2016)

As seen in Figure 3, the pyramid of automation is used to visualize and reduce the complexity of data acquisition in industrial production.

Starting at the floor of the pyramid is the manufacturing/process level in which data about product properties or state of development can be acquired through intelligent products or RFID chips. Next follows the field level or production level. Information here is gathered through various sensors (temperature, photo-electric guards…) and processed in through in- and output signals to the operational level(SPS)[1], which analyzes the data and sends feedback back to the field level SCADA(Supervisory control and data acquisition) based on standards and controls set by the process control level. The MES (Manufacturing Execution System) acts as a tie between machine control and human management, it records and documents all current data, is used to optimize current production and planning of future tasks. The company level is the highest level of the pyramid in which orders as processed and rough planning is conducted. (Bowers, 2016) (Manufacturing Execution System, 2016)

In Industry 4.0 communication not always follows this strict pattern, which makes it necessary to create standards and normed ports so all actors of each level can communicate with each other. It also facilitates decision making by evaluating data autonomously and reacting independently. “Data that become information reduces the amount of work required to get value from systems-moving up the pyramid, from process equipment to business decisions.” (Marcy, 2016) (Lichtblau, 2016)

This automated evaluation of data is already deeply integrated in the bottom layers of the pyramid, where human interaction is often very minimal. Moving higher up the pyramid, more human interaction is involved and data takes longer to be transferred and processed. Through Industry 4.0 human interaction is pushed further and further to the top of the pyramid, leaving lower levels completely automated. (Automatisierungspyramide, 2016)

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[1] SPS is a german abbreviation for Speicherprogrammierbare Steuerung. in englisch: PLC Programmable Logic Controller. The german abbreviaton resulted as the graphic was obtained from a german website

As vertical integration reaches high levels of flexibility, enables large amounts of data and control without the need of human interaction, it set the foundation for horizontal integration, which is the integration of external systems such as customers, suppliers or producers. Successful horizontal integration enables real time exchange of data between different companies. Using this information companies can adapt to very individual needs, cut idle times and exploit their full potential. (Lichtblau, 2016)

2.3.2 Decentralized intelligence

Decentralized intelligence is a basis for decentralized control, it describes the important feature of production machines to individually and independently of their location, send relevant information to a decentralized control system.

To realize decentralized intelligence, all machines and products must be equipped with modern communication devices, such as Bluetooth or access to the internet of things and single parts should each be equipped with RFID-Chips. (Roth, 2016)

Of special use are products which can be equipped with energy-efficient and low interference chips. All necessary information for the product-cycle such as color, preceding and following step or passed tests can be stored on the chips. These features enable production plants to act through sensors and actors with decentralized intelligence to plan and determine future production steps, analyze status and correct any mistakes. (Siepmann, 2016)

2.3.3 Decentralized control

Classic control systems usually consist of a main control center, located centrally in the plant with cables running to all actors of the plant. Control was previously focused only on the machines, with very little information on the products themselves, as these would have to be entered manually, a tedious process used often only for larger parts. The control systems were often unable to process all the information in real time, and being location-bound, resulted in very inflexible production. (Yakoob, 2017)

As industry 4.0 is based on flexible solutions, control systems had to be adapted to meet the standards. The control centers are being set up in the cloud, enabling them

to be accessed from any location and even connecting several plants at once. As computer performance has largely increased, real time control is possible over cloud servers. This system allows great flexibility as it can always be adapted to current production needs. As these new systems store all data in the cloud, managers can access the data from anywhere, making it much easier for them to control production and act in case of error. (Hirsch-Kreinsen, 2015) (Yakoob, 2017)

2.3.4 Digital engineering

Digital engineering describes the digital illustration of complete physical production processes. It is a seamless interaction between the virtual and real world as all steps can be visualized in real-time.

Digital engineering is especially useful in analyzing and optimizing current production. Real case scenarios can be tested and various adaption can be made all in matter of seconds, allowing even short test prior to decision making steps. This enables production managers to analyze ideas much more carefully and produce more efficiently with less waste. (Siepmann, 2016)

2.3.5 CPS (Cyber-Physical -Systems)

Cyber Physical Systems mainly rely on embedded systems which can be defined as “special-purpose system in which the computer is completely encapsulated by the device it controls.” (EDE, 2017) Embedded systems are found in various devices in all industries and household products today. Input unlike traditionally not given through peripherical devices, but by monitors or switches on the device itself. Using embedded systems, the use of products can be simplified and automated.

CPS are created by connecting Embedded Systems with the Internet, creating physical acting systems which are connected to cyber objects or processes. This connection creates Information-grids which allow a much wider range of applications and control mechanisms. (Brühl, 2015)

The future approach is based on self-optimized processes, this enabled different goods to be assembled on the same line as machines can interact with the products and coordinate the necessary steps independently.

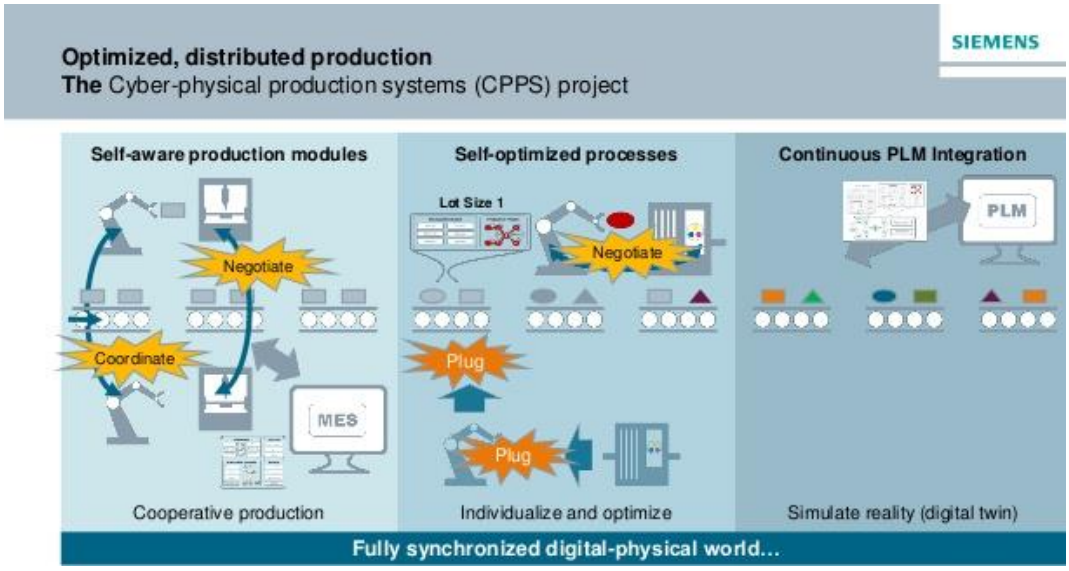


Figure 4: Optimized, distributed production (Siemens, 2014)

Figure 4 illustrates the use of Cyber-physical production systems, shown in an example by Siemens. In self-aware production modules, cooperative production step production machines coordinate and negotiate current and following production steps, in order to achieve optimal timing and workflow. They are synchronized over the MES (Manufacturing Execution System), a system which tracks ongoing production, use of raw material and executes new steps.

Throughout production a simulation will be following the entire process, which enables a real-time overview and control. The simulation and all its actors are controlled and give feedback to a PLM (Product Lifetime Management), a system which follows and coordinates the entire production span of each product.

2.4 Characteristics of the term industry 4.0

Defining industry 4.0 can be difficult, as it acts within so many operations and systems and in many cases, influences a variety of components.

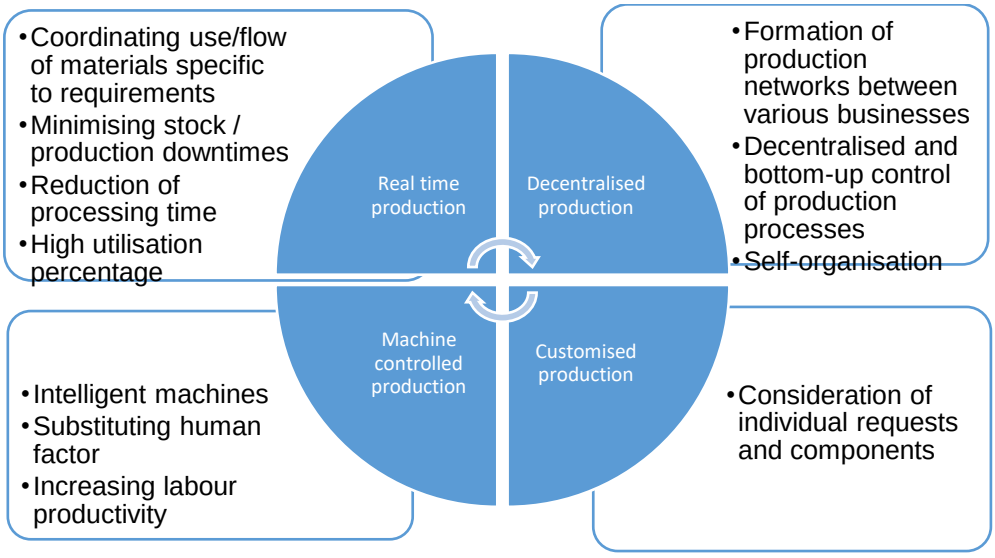


Figure 5: Characteristics of industry 4.0 (IAB, 2016)

Figure 5 illustrates all key characteristics found in industry 4.0, which can be applied to all systems introduced. Processes in industry 4.0 will be connected through various levels and systems, all interacting with each other. Calculations for material, utilization or required workers will be done autonomously, with constant goal of optimizing every step, while taking all cost and time aspects into consideration. For all aspects of industry 4.0, information needs to be processed in real time, as systems all rely on each other and need to act based on real time information. Production management undergoes drastic changes as previously defined hierarchies are broken up and products themselves know where they belong and decide future steps, leading to a self-organized production.

3 Opportunities

3.1 Jobs

In context with Industry 4.0, jobs are a controversial topic, with many expecting loss of jobs throughout all industries as robots and computers take over. As with all previous industrial revolutions, certain jobs will be replaced, but this does not necessarily mean an end to people working in the digitalized world. Potential for technical renovation is rising at a very rapid rate and it will show in the future, if people will be able to use this chance for growth and jobs.

It is certain that industry 4.0 will lead to an even greater shift in need for highly qualified workers and a steady decline of unqualified workers, as those jobs are being replaced by computers or robots. A study conducted by the European Center for the Development of Vocational Training has conducted a study which states that by the year 2020 high qualifications will be required for 35,2% of all employees, middle qualifications for 50,3% and low qualifications for only 14,4%. This is a sharp contrast to 2000 where the requirements were 22% high, 48,2 for middle and 29,8 for low qualifications throughout all jobs. Many companies are seeing this impact of qualifications in the workplace and are reacting by offering training for employees to cope with competition. (DIS AG, 2016)

3.1.1 Workplace culture

The shift to industry 4.0 does not only influence qualifications needed for a job, but also has a steady impact on workplace culture. Important to note with analysis to today's workplace culture is the financial crisis of 2007-2008, which had a large impact on most businesses and brought changes to the workplace, as people still feel less secure about their jobs and the economy. In these times of uncertainty people adapt by becoming more flexible and taking greater personal responsibility, as they have learned not to rely completely on others. These personal traits also show in their work as employees are becoming more flexible to travel and to take on tasks which would previously have been outside their set jobs. Jobs today are becoming more interdepartmental, meaning that employees often work, and need knowledge of various departments and fields in their company, rather than focusing on specific areas only. (EY, 2016)

Flexibility also shows in the working hours, it is becoming increasingly common to work outside of the typical nine-to-five hour routine and instead adapting hours to personal and company needs. Home office days are also increasing, where employees get the opportunity to work from home, which before its introduction was doomed as extra vacation but has proven to be very successful. Not only have employees working at home shown to use their time efficiently, in general their rate of job satisfaction has increased which in turn elevates their general work productivity. (Forbes, 2015)

As companies are struggling to compete with the market today, constantly looking for new fields and investment opportunities, the answer for many lies in creativity. Previously creative jobs were considered actors, artists or designers, but today creativity is required in far more fields. Creativity is reaching all businesses and is required for many jobs today. It is no longer deciding what and who is producing, but increasingly which steps companies take and which output they create, setting them apart from their competition and securing their position in the market. Going back to flexibility in the work place, these two factors are often linked as creativity can seldom be achieved in a small office cubicle, where all distractions must be blocked and thoughts are rather forced than natural, but must be inspired by surroundings in a relaxed environment.

Companies are also adapting to the new generation of workers and enabling their creativity by changing of office design. The prior mentioned cubicles are becoming a setting of the past as offices tend to develop open spaces, affluent with light and filled with common spaces and even recreational activities. Millennials tend to show less needs for private spaces, but show greater productivity in relaxing surroundings. The new technologies enable this shift of office design, as employees can work from anywhere and an own office is rarely required. (BDC, 2016)

3.1.2 Productivity & Resource Management

Companies are constantly focusing on raising their productivity and being more efficient by using less energy and raw materials, while still delivering the same output. Figure 6 shows expectations of companies over the next 5 years regarding the benefits of Industry 4.0 for their business.

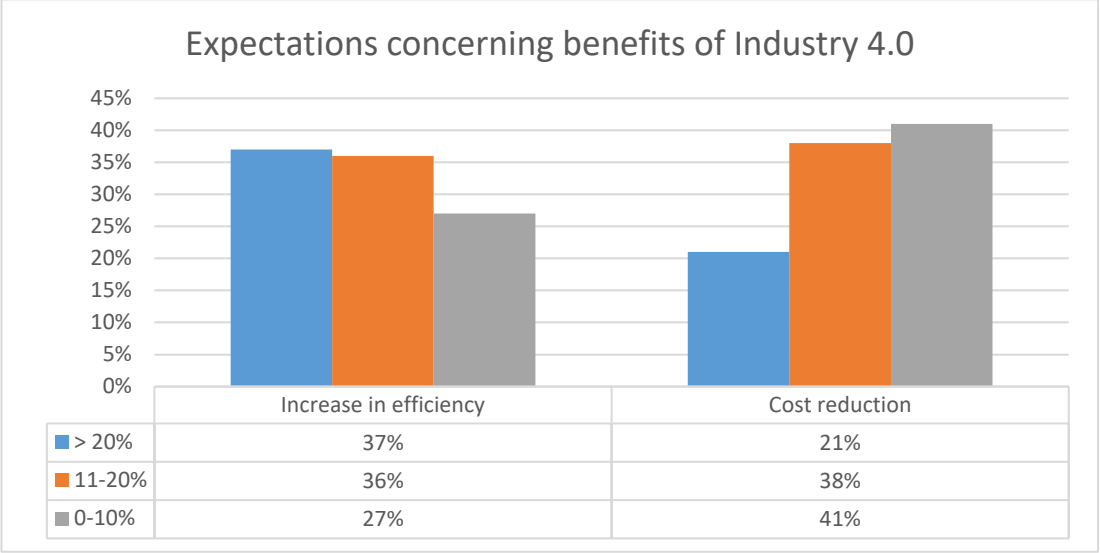


Figure 6 :Expectations found in PWC study over multiple companies (PWC, 2016)

The average assumption in increase in efficiency is 18% over the next 5 years which corresponds to an annual increase of over 3%. Over one third of the companies expect an even larger increase. The benefits can to the most part be linked to improvements in digitalization and the constant implementation and development of industry 4.0 standards throughout companies. Technologies enable the reduction of quality losses, which in turn minimizes material cost and reduces labor time dealt with compensation, but also enable flexible production and focus on core areas.

The biggest enabling factor is transparency throughout the production process, which in turn is allowing all benefits of digitalization as production can be made transparent and thus intelligently optimized and used efficiently.

Expectations regarding cost reduction are more conservative compared to increase in efficiency with only 20% of all companies expecting a reduction of cost above 20%. Both factors, increase in efficiency and cost reduction are linked together, but do not necessarily correspond as investments must be made to increase efficiency which might take more than 5 years to pay off. Heart of industry 4.0 is also the interconnection between multiple companies, which in this case means companies must wait for their customers and suppliers to also implement the same technologies for full benefits to take place. (PWC, 2016)

3.2 Enabling Supply Chain Management 4.0

Supply chain management describes the construction and administration of logistical chains over the entire value chain, starting from acquisition of raw materials up to the customer. In contrast to logistics, supply chain management includes not only physical activities but also order processing and accounting transactions. Grouping all data and processes together allows for companies to have much greater insight and overview in their production and they can deal with adaptations and disturbances quicker and more efficient.

Industry 4.0 will require a shift in supply chain management as cyber physical systems and other technologies are changing production and acquisition processes. Cyber physical systems will connect with operators and each other and decentralized control will change the way companies purchase goods. In the future single entities, will have higher priority as do the centralized controls today, as the entities themselves can evaluate and send data. To manage logistic tasks efficiently, supply chains must adapt from acting based on information from single sources, to being able to handle a constant information stream from multiple sources. (WLW, 2016)

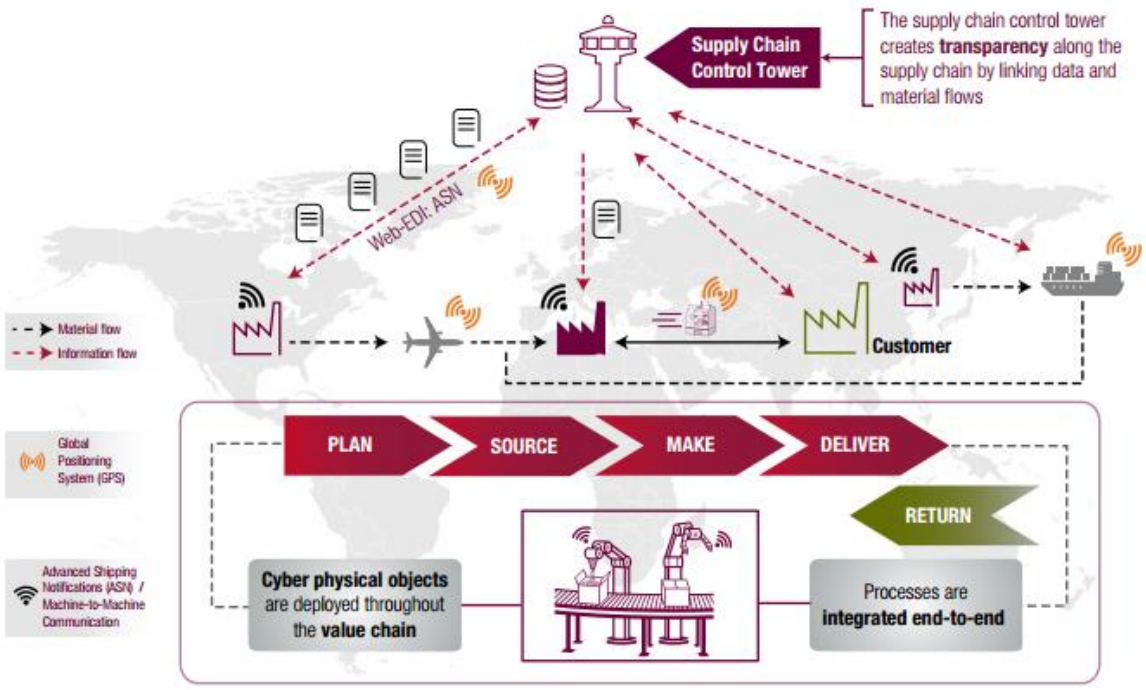


Figure 7 : Structure of a supply chain (Capgemini, 2014)

Figure 7 shows the Structure of a supply chain acting in industry 4.0. Cyber physical object build the core of the chain, as they are deployed throughout the entire chain and processes are integrated end-to-end through their use. The supply chain control tower is the core of the chain, linking all actors, the consumer, production and delivery systems together. Data is received constantly, delivered by all systems, mostly close to real time.

Capegemini, the largest consulting group in the IT sector in Europe has identified four pillars which supply chain management of the future is based on.

I. Identification

Identification sets the foundation for cyber physical systems and connected supply chains, most important technologies enabling identification are RFID Chips, and barcodes.

II. Localization

Localization technologies for tracking Objects and transporters make logistics more transparent and easier to control. Technologies used include GPS-based solutions and remote positioning.

III. Sensors

Sensors enable control and monitoring of processes in regards to safety and quality. Sensor are connected through wireless technologies forming a web, constantly communicating with each other.

IV. Communication and Networks

Communication between all actors in the chain, which is enabled through Cyber physical systems, is the core of new supply chains. Enabling CPS to communicate with each other and acting machines and delivery systems makes a decentralized supply chain control possible. (Capgemini, 2014)

3.3 Mass customization

In the early stages of customized manufacturing, only small changes in products were possible, for example color changes on cars or keyboard changes on laptops and even those presented limited options, usually involving high surcharges. Today's manufacturing looks to achieve individualizing each product per personal need, all at an affordable cost.

Industry	Example of configured customization	Example of individualized customization
Apparell	Sports shoes with the option of choosing different colors for different elements	Suits/shirts fit to body measurements or scans
Food	Frozen yogurt with custom topping choices	Personalized food and vitamins based on nutritional needs
Consumer electronics	Laptop with choice of color, size of hard drive, and keyboard language	Individualized colors and graphics
Automotive	Vehicle with choice for colors, seats, accessories, and so on	Individualized colors, artwork, and body shapes
Health care	Drug combinations customized for the patient	DNA-based personalized medicine

Table 1: Customization throughout industries (McKinsey, 2013)

Table 1 shows the possibilities of customization throughout major industries, highlighting the difference between configured individualization and individual customization. Configured individualization exists in many markets today, with companies selling a variety of products with different specifications. Individual customization is slowly rising and dependent on the industry coming to the market. Sports goods manufacturer Nike for example is already giving customers the option to fully individualize their shoe, letting them create products exactly to their specifications, all at reasonable cost. (NIKE, 2017)

Two factors are necessary for companies to successfully manufacture products which each individual customer can customize to his requirements. First opportunities for the customers must be identified, allowing the customer to add value to his product, all through an efficient platform and transaction. Secondly, the company needs a manufacturing line which can handle producing at a high complexity, while balancing costs and production time at a reasonable level.

Industry 4.0 allows companies to take major steps toward individual customization by firstly presenting the technology for an efficient platform in which the customer can individualize his product with smooth transaction and ready calculations. Secondly and more importantly, new automated machines can handle the highly-customized products, logistics for very high amounts of production parts and complex manufacturing steps can be dealt with. This presents factories with several orders and complexity never seen before and not achievable without smart machines, other than with immense cost increase. (McKinsey, 2013)

Flexible production systems are essential for profitable production of individualized products which need to be produced individually or in small quantities. Big steps are taken in the automotive industry, which is introducing dynamic robots with interchangeable tooling, to enable placement of different parts without loss of efficiency or need for further machines or human interaction.

3-D printing is introducing new manufacturing methods which allow greater customization than ever before, with technologies advancing which allow printers to work with many materials such as ceramics, metal or even foods. Up to now these printed objects are mainly used for prototypes, but in foreseeable future they can be introduced in mass production. Shapeways, a design company producing vases, allows customers to individually modify their product and add texts to their vases, which they then 3-D print and ship in a few days. It is up to companies to introduce innovative concepts so that customers can engage with their product and take advantage of new customization options. (Shapeways, 2017) (McKinsey, 2013)

With individual customization entering part of many manufacturing processes, new technologies are often capable of performing tasks, but companies still need to adapt in other areas for complete transition to take place.

	Increase value to customer	Control cost of customization
Marketing	Provide option for customers to market products to their friends in return for store credits	Provide free marketing by giving customers opportunities to easily share and express their individualization experiences on digital media
Sales	Turn those in customer-facing roles into customization advisers; turn "stores" into "showrooms" Use dynamic promotions to manage capacity	Offer simple and fun online configurators to gather preferences
Product/service development	Leverage big data and ancillary developers to develop and curate customization options, eg. via social media Curate "recommended configurations"	Undertake modular approach in product development Tightly integrate new-product development with manufacturing/ service process design
Manufacturing/ service operations	Implement modular approach with a limited number of standard baseline specs and a menu of options that limits complexity for consumers	Postpone customization to latest possible point Build flexibility in low-capital intensive process steps
Supply chain	Provide visibility (via radio-frequency identification or scanning) to keep customers invested in "their" creation	Catalog total cost to serve for each option and manage capacity accordingly
IT Structure	Increase investments in customer-facing, data-warehousing, and data-analytics technologies Upgrade enterprise-resource-planning and legacy systems to manage additional complexity of product and service attributes Tightly integrate e-commerce and digital strategy with back-end IT Support operations with technology that helps control complexity of inputs	

Table 2: Business functions and coordinated changes needed for mass customization (McKinsey, 2013)

Table 2 highlights changes needed for mass customization to be successfully implemented in companies. Through various areas increase value to customer is compared to control cost of customization. It can be seen that most changes are linked to new technologies introduced with industry 4.0, integrating IT development in all sectors. Mass customization needs IT improvements and upgrades in order to be performed at a reasonable price, this includes all sectors of the company ranging from the website with user interaction over production machines to warehouse handling. (Roth, 2016) (McKinsey, 2013)

4 Challenges

4.1 Data Privacy in Industry 4.0

Data privacy has been an issue ever since data has been recorded. With the rapid growth of data and the possibilities of data exchange, the topic is becoming increasingly relevant for governments who aim to protect individual rights, while keeping the country secure, but also for companies who need to protect data from hacks and oblige with current regulations.

4.1.1 Legal impact

The rapid digitalization is challenging the law as lawmakers and lawyers must constantly adapt to changes, new technologies and set guidelines in previously unknow territories. More and more companies are including legal teams in their development in order to ensure correct proceedings and prevent future damage. In a study conducted by the german law firm Noerr, companies were asked if the legal department was involved in the future planning regarding digitalization with the results shown in Table 3.

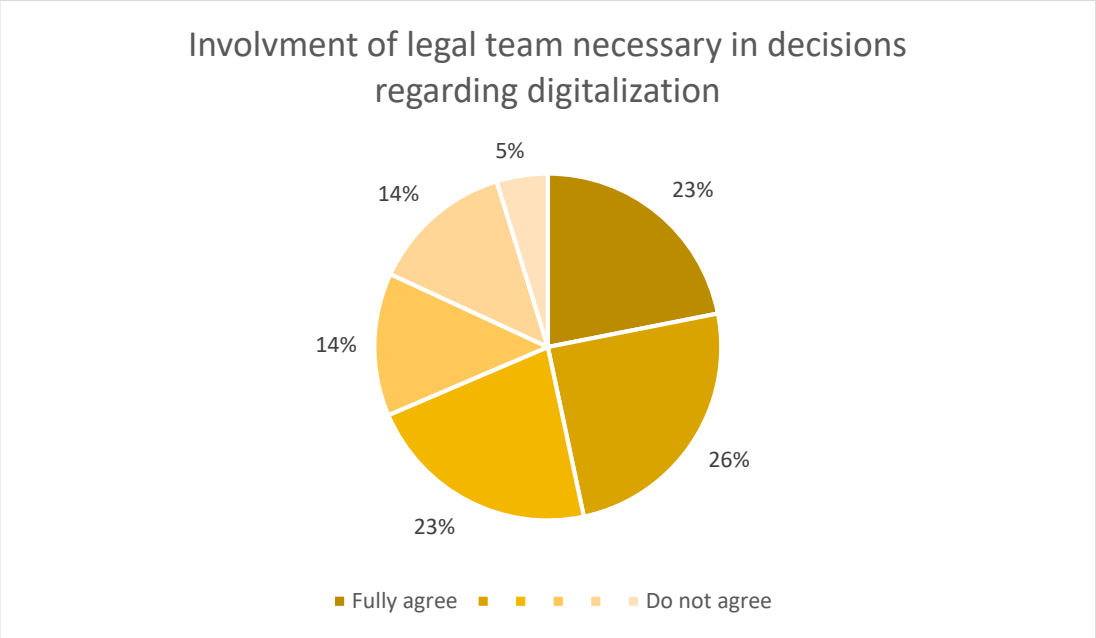


Table 3: Involvement of legal team necessary regarding decisions of digitalization (BDI, 2015)

It is clear that legal aspect play a significant role as almost 49% fully or almost fully agree that legal involvement is necessary in future development. The involvement of legal teams is required in early production stages, to ensure proper implementation throughout the entire process. (BDI, 2015)

4.1.2 Privacy enhancing technologies (PET)

In Industry 4.0 Cyber Physical Systems are connected with each other, allowing data flow between them and other system, which is not handled by centralized control but controlled by the systems themselves. Employees will find themselves surrounded by an environment of constant data flow and data analysis in which his personal related data is included, mostly to maximize efficiency. This effect becomes increasingly complicated when data is transferred outside of the company.

In the future, the employment of humans in certain field will decline and thus the remaining jobs will require higher complexity and greater interaction with the system, which will ultimately result in even greater data acquisition from the people involved. Scenarios include the recording of location or vital data from interacting people, which poses juridical difficulties but may be necessary for the system to work efficiently. (Hirsch-Kreinsen, 2015)

More and more data is being held by companies, many of it containing personal information. Data protection laws are being increased and more strictly enforced year by year as consumers put pressure on securing their rights and governments and law makers are seeing the increasing impact of companies storing personal data.

The most efficient way to protect data privacy is by implementing policies in technical systems. This eliminates or greatly reduces the need to rule by individual cases, which can be very time consuming and costly. PETs have the advantage that they can be designed in accordance of the data security authorities and be progressively adapted whenever changes occur. (Hirsch-Kreinsen, 2015)

An efficient approach all PETs include is encryption. Encryption tries to ensure that data is read only be designated receivers and allows data to be sent across multiple channels without the fear of interception by third parties. Encryption is widely used

throughout all businesses to protect data, but is also playing a major role in consumer services. Whatsapp, a popular messaging service, implemented end-to-end encryption for all devices in late 2016.

> *" Privacy and security is in our DNA, which is why we have end-to-end encryption in the latest versions of our app. When end-to-end encrypted, your messages, photos, videos, voice messages, documents, and calls are secured from falling into the wrong hands…WhatsApp's end-to-end encryption ensures only you and the person you're communicating with can read what is sent, and nobody in between, not even WhatsApp…" (Whatsapp, 2016)*

The statement above shows how committed companies are to provide secure data transfer. They state privacy as their key value, indicating that they realize this is essential for consumers to use their services. It is very interesting to note that not even Whatsapp itself can access the data, a feature often criticized by governments as they rely on data in criminal cases and are not able to access it.

A second tool often used is data anonymization. Data anonymization aims to change data so that individuals cannot be identified out of the given data set, but information can still be gathered. In the EU, guidelines for data anonymization are very strict, stating that it must be absolutely impossible to reidentify any individual from the data, for it to be considered anonymous data. (Roth, 2016)

It is often a fine line between keeping the data useful for research or businesses and at the same time eliminating any risk of identification. The degree of data anonymization also often depends on who is looking at the data. For example hospitals can keep full sets of data, with doctors being able to access all information available, while some institutes in the same hospital can only extract part of the information. In these cases it is very important to keep the main data highly secured, as any attack could extract all data. For this reason, many companies prefer not to store the complete data set, but only the already anonymized, as they eliminate the risk of theft and privacy lawsuits, again having to trade of usefulness and protection. (Whimsley, 2011)

Popular procedure in anonymization techniques, when dealing with larger data sets, is aggregation. In aggregation, several individual data files which share common values are grouped together, keeping the relevant data intact, but eliminating data which could be used to identify individuals. Common with aggregation is also generalization of data, putting data in groups rather than keeping the exact values. Patient weight could for example be categorized in 80-85kg instead of keeping the exact value of 82kg. (WSGR, 2015)

4.2 Company management

Digitalization will inevitably change current management structures, simplifying many tasks but also creating challenges, as globalization is defining new rules in market competition. Companies are facing the challenge of dealing with competitors which they did not expect, car manufacturers for example are being threatened by technology companies such as Google or Apple. It will be the task of future managers to act across multiple industries, creating products which previously where not in their product line and enhance them with the companies know how. Managers must adapt quickly to current changes and strategic decisions will have much shorter impact.

A further challenge is the rapid increase in Innovation cycle, in the cell phone industry already under one year, which creates high pressure on companies and management to develop new products.

4.2.1 Development of Information and Data exchange

Managers use Information and Data as prime basis for their decisions. Data today is being gathered and analyzed much faster and in much larger dimensions. Big Data allowing seeming endless amount of data to be stored and process, all providing real time capture and access to the data. Virtual collaboration, a tool which connects people who are geographically separated and allows them to work on the same project, is creating completely new opportunities of outsourcing and project planning throughout different branches of companies. (IGI, 2016)

Technical solutions are being implemented to provide the same information status to all actors in between management, customers, suppliers and capital providers. Up

until now information was divided asymmetrically, as it had to be manually passed on in between actors, which was often neglected as it was time consuming or also to keep the information secret. The possession of information gave each actor an advantage over the others, which could now be diminished. Through digitalization and cloud storage, information is real time present for all participants. There will still be restrictions, such as controlled access to the data or contracts limiting its use, but the tendency shows that information will reach a much broader and faster access. (Brühl, 2015)The fast access of data is drastically changing the ordering and purchasing behavior of companies as they can react immediately to price fluctuations of their suppliers and consumer needs. Instead of making orders themselves, managers will specify rules to computer's which will handle orders based on these rules, relying on real time information.

4.2.2 Big companies approach (Google & Facebook)

As product cycles are rapidly changing, only companies which continuously redefine themselves can survive. Facebook and Google have both proven their capability in this field as they have shown constant growth over the past years. Facebook stock has seen a 240% and Google 160% stock growth over the last 3 years. (Google Stock, 2017) This growth can be traced back to strong presence in the market, with customer focused approach and strong core values.

> *"1. Focus on the user and all else will follow.*
>
> *Since the beginning, we've focused on providing the best user experience possible. Whether we're designing a new Internet browser or a new tweak to the look of the homepage, we take great care to ensure that they will ultimately serve you, rather than our own internal goal or bottom line. Our homepage interface is clear and simple, and pages load instantly. Placement in search results is never sold to anyone, and advertising is not only clearly marked as such, it offers relevant content and is not distracting. And when we build new tools and applications, we believe they should work so well you don't have to consider how they might have been designed differently." (Google, 2017)*

Shown above is Googles first core value, which gives a clear statement that the user is priority number one. Googles main purpose, despite offering a wide array of services, is still being a search engine, and they focus on keeping this use as efficient and user friendly as possible. As stated in their value, placement in search results is never sold, showing their integrity towards their users and giving the user trust in their product. The search engines main page is always clear of advertising, focusing solely on the customer's intention of searches. Facebooks first value states following:

> *"Focus on Impact*
>
> *If we want to have the biggest impact, the best way to do this is to make sure we always focus on solving the most important problems. It sounds simple, but we think most companies do this poorly and waste a lot of time. We expect everyone at Facebook to be good at finding the biggest problems to work on." (CBS, 2017)*

Similarly to Google, Facebook emphasizes focus on doing one thing, and doing it well. This principle is also enforced with the user as top priority in mind. This approach might seem obvious, but in fact many companies operate and invest a lot of time and money on activities which could be neglected.

4.3 Generation Millennials

The Millennials is the generation born between 1980 and 2000, who as defined by Goldman Sachs are:

"*A different world, a different worldview. Millennials have grown up in a time of rapid change, giving them a set of priorities and expectations sharply different from previous generations*." (Goldman Sachs, 2017)

This generation is making it difficult for companies and mangers to deal with, as their expectations and way of living is very different than what was customary up until now.

Top five characteristics of what Millennials expect

From their boss	From their company	Learning expectations
Will help me navigate my career path	Will develop my skills for the future	Technical skills in my area of expertise
Will give me straight feedback	Has strong values	Self-management and personal productivity
Will mentor and coach me	Offers customizable options in my benefits/rewards package	Leadership
Will sponsor me for formal development programs	Allows me to blend work with the rest of my life	Industry or functional knowledge
Is comfortable with flexible schedules	Offers a clear career path	Creativity and innovation strategies

Table 4:Top characteristics of what millennials expect (Harvard Business Review, 2017)

As seen in Table 4, expectation of millennials are much higher than those of previous employees. As millennials see their work place as integral part of their life, they set high standards to find a fulfilling place. Previously salary was the main concern for employees, but now many are willing to earn less, providing they receive more vacation or will refuse to work for a boss they feel uncomfortable with, no matter how much they get paid. This shift often puts current managers in a difficult position, as money was their primary negotiation tool.

This does not mean that millennials deny or resist leadership, in fact they need strong leadership and are very open, even rely on, constant feedback on their work. Millennials show a very positive outlook on work, and if managed adequately they can achieve great results, boosting the company. It will show in the future which companies manage to find the correct balance between the generations, giving them advantage over their competitors as they then can combine new technologies with experience and which companies will fail to do so, leaving them set behind. (Harvard Business Review, 2017)

5 Health Care 4.0

Among all influences of Industry 4.0 and the Internet of Things, smart health and in particular, remote monitoring is one of the most important to daily life of people. Life expectancy is constantly increasing and more people chose to stay at home rather than moving in elderly centers, due to financial but also personal reasons. Modern technologies are enabling this trend, helping elders live by themselves, while still being safe and taken care of.

5.1 Smart Hospitals

Smart hospitals are a phenomenon that has developed in the past years. The ultimate goal is to introduce “smartness” in a hospital environment, which means taking advantage of everything ICT has to offer and implementing it in a productive way to ensure optimal patient care. Developments are slowly reaching hospitals today, with many functions available, but still lacking complete integration.

One of the greatest challenges is that smart hospitals need to be connected to all linked systems, such as doctors’ offices, so that fully smart hospitals can only be achieved when all linked systems have upgraded as well. As patients receive medical care in many institutions, most have been to several hospitals and have specialized doctors all located elsewhere, it is easy to see that the boundaries of smart hospitals lie very broad.

A clear definition of smart hospitals is as follows:

“*A smart hospital is a hospital that relies on optimised and automated processes built on an ICT environment of interconnected assets, particularly based on Internet of things (IoT), to improve existing patient care procedures and introduce new capabilities.”* (Security and Resilience for Smart Health Service and, 2016)

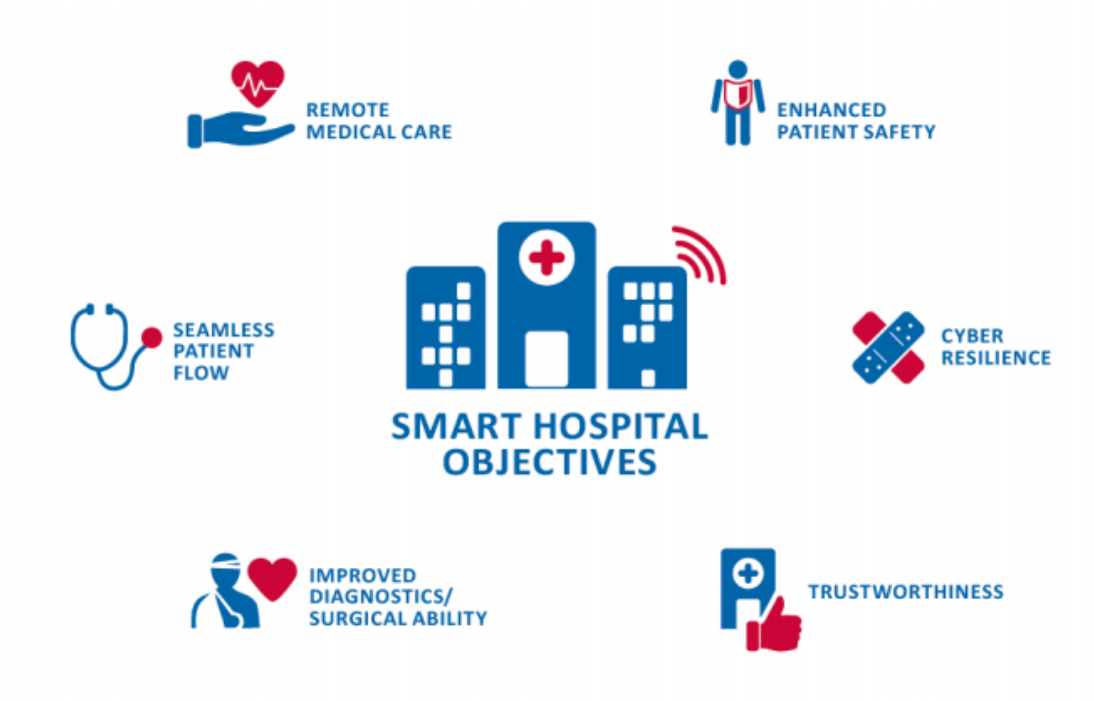


Figure 8: Objectives of a smart hospital (Security and Resilience for Smart Health Service and, 2016)

Overall smartness in hospitals offers many opportunities as well as challenges to current health care systems. One objective falls into the surgical sector, as robots may soon be able to perform micro-surgery, which means that new treatment methods could be implemented. Despite of this, old methods can also be improved by sophisticated software solutions and modernized administration processes.

Seamless patient flow is also a great advantage of using ICT in hospitals, as automatic systems can identify and resolve problems before they effect patients and create waiting times and errors. The constant availability of patient information is essential to optimize all current systems. One of the most important advantages of smart hospitals is remote health care, achieved through remote monitoring, which is covered in the next chapter. The idea is to extend hospital borders and relocate vital functions to patient's homes.

Smart hospitals are striving to enhance patient safety, by monitoring patients more closely and technologies sending warnings in early stages so that doctors or machines have sufficient time to react.

Cyber resilience refers to hospitals competence to ensure their services in communication and technology are always available and secure. As smart hospitals rely on working communication networks, it is essential for those to be constantly working as otherwise the entire system collapses. As hospitals are dealing with very sensitive data and functioning hospital equipment is often vital for people's lives, security is put at highest level to prevent any threats or sudden disruptions.

In line with security, hospitals trustworthiness must be established, as patient's trust plays a huge role in their choice of hospitals. Trustworthiness is essential in every step of a patient's treatment, especially when dealing with storage of data and prescription of pharmaceuticals.

5.2 Remote Monitoring

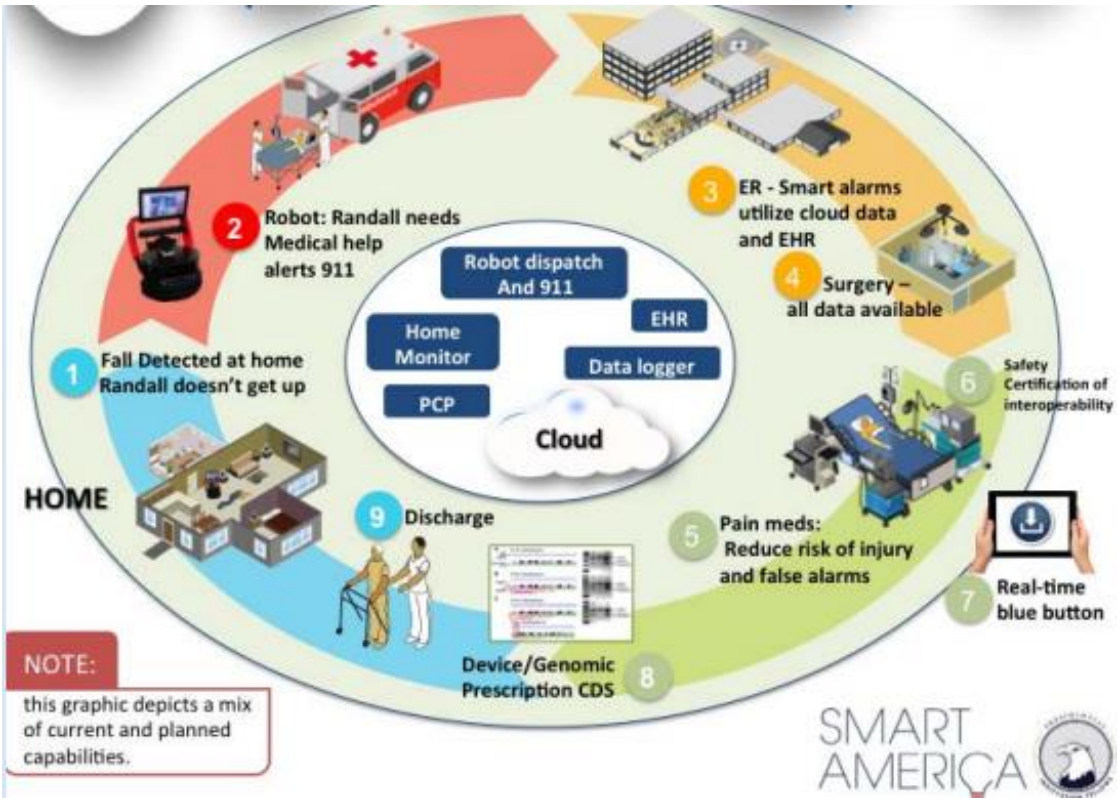


Figure 9 Smart Healthcare (Conhit, 2016)

Doctors and patients can soon greatly benefit from home monitoring techniques as soon it will be possible for patients to monitor all vital health stats in advance of a doctor's appointment, or even daily when required. Sensors and equipment are becoming more affordable, especially those for routine measurements and so when patients enter the doctor's office, the doctor can evaluate all presented data and make much more accurate decisions than a single measurement in his office would allow.

Remote monitoring and its effects on patient care can be seen in a cycle on Figure 9. The cycle consists of nine stages, each interlinked by core IoT technologies, most importantly the cloud, which enables information transfer between all stages and its interactors. The setting of the cycle is an elderly patient living alone in his home, who has an accident and then receives treatment in a modern hospital. Living by himself the patient was remotely monitored. The scenario is futuristic, as most technologies are not ready today, but depicts a realistic picture for the near future.

1. In Stage 1 the patient falls and is unable to get up by himself. The fall is detected by the remote monitoring technologies in his home, in this case a care robot. Care robots are being developed today, but are not yet used for home monitoring. Devices used today include mostly camera based observations and wristbands with monitoring abilities. (Robotics, 2016)

2. The robot detects that the patient is unwell and "calls 911". In remote monitoring houses, trend is to first connect the patient with emergency contacts over in house speaker systems and when this is unsuccessful an ambulance is called.

3. Patient is delivered to the ER. As his data, including all previous hospital and doctor visits and his stats over the last days is stored in the cloud, doctors can react immediately on his conditions.

4. In surgery, the same data is available, in modern hospitals a robot could be performing the surgery.

5. After completing surgery, the patient is given medication, which is administered precisely according to his medical history, ensuring highest

benefits such as reduced pain, eased and fast recovery and prevention from future accidents.

6. Stage 6 depicts an overall requirement for smart health to comply with safety certifications of interoperability, which certifies patient care in the following criteria:"

    a. Functionality—the ability to create and manage electronic records for all of a physician practice's patients, as well as automate the flow of work in the office.

    b. Interoperability—the ability to receive and send electronic data between an EHR and outside sources of information such as labs, pharmacies, and other EHRs in physician offices and hospitals.

    c. Security—the ability to keep patient information safe and private." (Harvard Med, 2009)

7. The Real-Time blue button is a symbol for patients to access all their personal medical data in real time on the web.

8. Before being released the patient is prescribed medication for future intake or equipment necessary for his home

9. Patient is released. In modern hospitals, patients can be released much earlier as before, as patients care can continue at their house, aided by proper medical equipment, monitoring and robots.

5.2.1 System architecture of remote monitoring systems

Most systems are built on of three layer architecture, a Wireless Body Area Network (WBAN), which includes wearable sensors as data acquisition devices, a data transmission device and a processing unit. A common application would be a wearable thermometer which transmits data via Bluetooth to a gateway server, which processes the data and stores in on an online cloud server, accessible by doctors.

Critical to remote monitoring devices is not only data acquisition, transfer and cloud services but also data analysis. Data is not only reviewed by doctors at checkups, but has to be constantly analyzed, as in many cases alarms have to be triggered at certain

values detected by the system. Given the large amounts of data involved over long periods of time and the fact that values corresponding to different patients give different results, this can be a tedious implementation. (NXP, 2016)

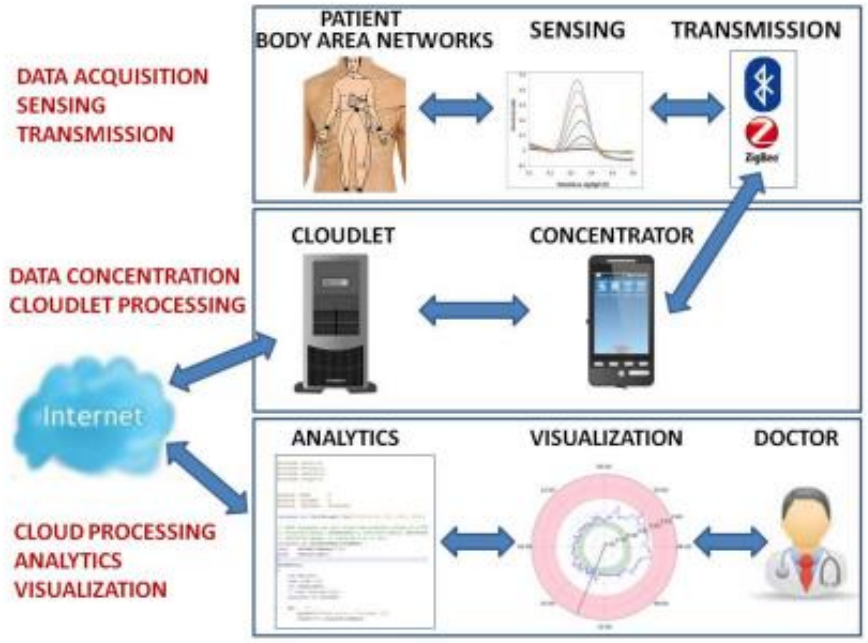


Figure 10 Components of a remote patient monitoring system (ECE, 2015)

Figure 10 shows the system architecture for a remote monitoring device, divided in data acquisition, concentration and analytics.

Data acquisition is achieved by permanently attached or useable sensors which measure biological data such as temperature, blood sugar, sleep patterns or activity. The sensors are usually connected wirelessly to a data processor which can be a smart phone or external device located in the home or carried by the patient.

Data transmission is usually performed in close to real time to cloud services, which are accessed by health organizations and personal doctors. The data is first transferred to a data concentrator in the home using Bluetooth or Zigbee. The data concentrator is then connected to the internet via Wi-Fi or using cellphone signals.

5.3 Biometrical Identification

Biometrical identification uses a person's unique characteristics to define and verify his identity. The most common form of biometric identification is the fingerprint, but many distinct features can be used for identification such as vein patterns, facial recognition, iris scanners or DNA Profiling. Which form of identification is used mostly depends upon time, location and accuracy level. DNA profiling for instance is a very accurate form of identification, but takes time and requires direct contact to the person, facial recognition on the other hand can be used to spot a single person out of a crowd, although accuracy not always very high and identification can easily be avoided. (Iritch Inc, 2015)

Biometrical systems usually consist of three modules:

1. Sensor and extraction module - Extracts information from people and selects focal points and points of interest

2. Local feature extraction module – Processes regions around points of interest into representations which then can be compared disregarding size or orientation

3. Matching Module – Compares the searched query with an existing database to find matches (Bakshi, 2014)

Previously the matching module retrieved data from a local storage, but as identification modules tend to get more mobile, real-time information becomes more relevant and data amounts are rapidly increasing, cloud storage is used instead. Using cloud platforms gives the advantage of receiving relevant information at real time and matching modules can access various platforms, given they have the authority, depending on their queries. Many countries have linked their databases with others, enabling horizontal integration with cloud platforms can facilitate this process and keep all partners on real-time status.

Not only biometrical data is used to identify people, data privacy concerns are among the strictest in health care. The HIPAA (Health Insurance Portability and

Accountability Act) safe harbor lists the following components all relevant in data protection in health care.

1. Names
2. Zip codes (except first three)
3. All elements of dates (except year)
4. Telephone numbers
5. Fax numbers
6. Electronic mail addresses
7. Social security numbers
8. Medical record numbers
9. Health plan beneficiary numbers
10. Account numbers
11. Certificate or license Numbers
12. Vehicle identifiers and serial numbers, including license plate numbers
13. Device identifiers and serial numbers
14. Web Universal Resource Locators (URLs)
15. Internet Protocol (IP) address numbers
16. Biometric identifiers, including finger and voice prints
17. Full face photographic images and any comparable images
18. Any other unique identifying number, characteristic or code (SAS, 2015)

All elements must be removed or anonymized for a person to be considered unidentifiable.

5.4 Patient Platform Medical Apps

Smartphones have revolutionized the way we live our life; being constantly turned on and connected to the internet, these devices have great impact on our daily routines. Each smartphone is personal, adapted to its owner, storing his data and information. This revolution has brought great advances in health care, with more than 216,000 (Sept. 2015) medical apps on the android and apple app store, twice as many as in

2013. (Medscape, 2015) It is important to note than just 36 of these apps make up 50% of all downloads, relativizing the huge number of total apps, but the trend is clear, health is apps are becoming increasingly popular and used.

Increasingly common are overall tracking medical apps, such as the “health” app integrated in the Apple iPhone. These are open to anybody and track daily medical information such as activities, vital data, sleep and nutrition. As the smartphone is usually constantly carried by the user, it is able to record data such as steps or heartbeat, providing the user is also carrying extra equipment. Other data is entered by the users themselves. (Apple, 2016)

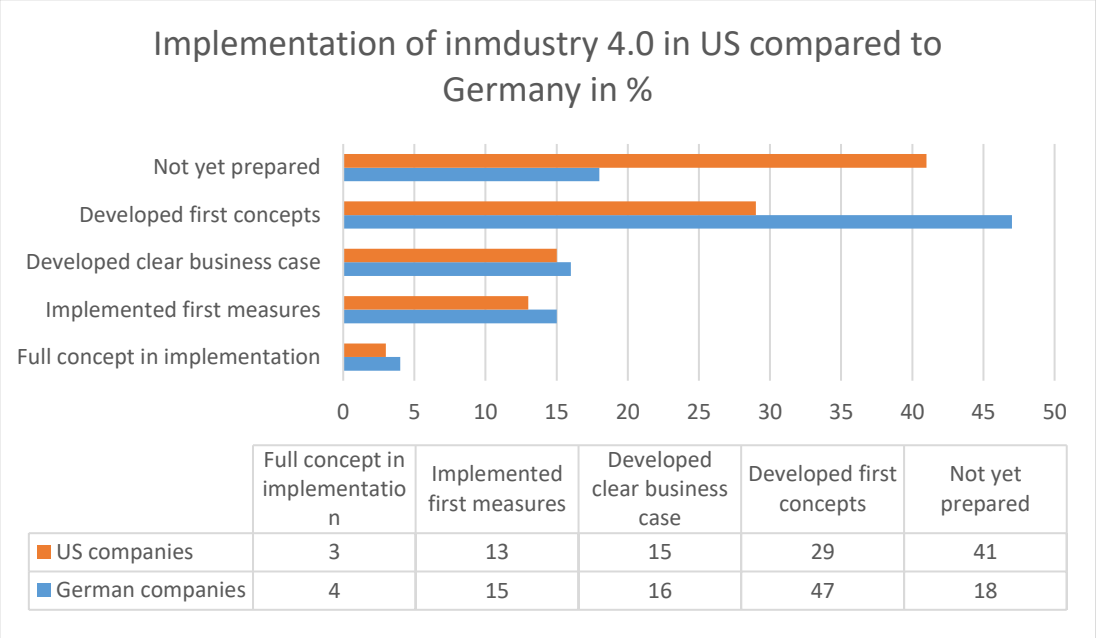
Professional use of medical apps is also increasing, as more and more doctors, laboratories or hospitals offer or use apps and cloud services. The use of apps enables doctors to easily track patient’s health and communicate with them or other doctors. They can access patient data in real time and read notes from other doctors which otherwise might have been disclosed. Specialized apps are often used for medical image viewing, giving doctors the opportunity to work away from Imaging machines or PCs as images can be accessed over the cloud. (NCBI, 2014)

While there is a general approval for the use of apps in hospitals, there are many doctors disagreeing with their implementation, as they are worried about their patients care. Concerns regarding apps are often found in distrust in cloud services, arguing that data is not safe, which is especially critical in medical data, where the strongest data protection requirements apply. Further doctors are worried that apps might damage the doctor-patient relationship, with patients trusting their apps more than their doctors and doctors losing any personal contact to patients. As patients are often using measuring devices with their apps, for example a wristwatch to measure their heartbeat, there are concerns as these measuring devices often do not have the necessary calibration or accuracy needed. Patients still rely on the outcome of these measurements and often falsely regard them as correct. (NCBI, 2014)

6 Discussion

6.1 Current state of implementation

Most companies are seeing the importance and impact of industry 4.0 and are beginning, if they do not have already, to implement key components. It is essential for the future of industry 4.0 that all actors use complying technologies, as technologies used rely on and communicate with each other.



	Full concept in implementation	Implemented first measures	Developed clear business case	Developed first concepts	Not yet prepared
US companies	3	13	15	29	41
German companies	4	15	16	47	18

Figure 11 : Study on implementation of industry 4.0 technologies throughout US and German companies (BCG, 2016)

Companies in both countries, which are seen as leading developers of industry 4.0, are showing similar trends in the development of industry 4.0 standards, although Germany is clearly taking a lead. About the same percentage of companies 3 US and 4 German show full concept in implementation, the difference in development becomes much clearer comparing companies who are not prepared, where twice as many US companies (41%) are listed compared to German (18%).

The implementation of industry 4.0 will rise at high rate as companies are relying on each other to implement functioning standards for their technologies to work. Currently employees who are not familiar with or do not have the necessary education

to work industry 4.0 are limiting the implementation. This will change when millennials become the largest working generation and accelerate implementation of new enabling technologies.

Many technologies existing today have not reached full potential and companies are often waiting for these technologies to develop further, as investment costs are high. Same principal applies to data handling, where data laws and security are key factors and companies are not sure how to work with them.

6.2 Millennials in the workplace

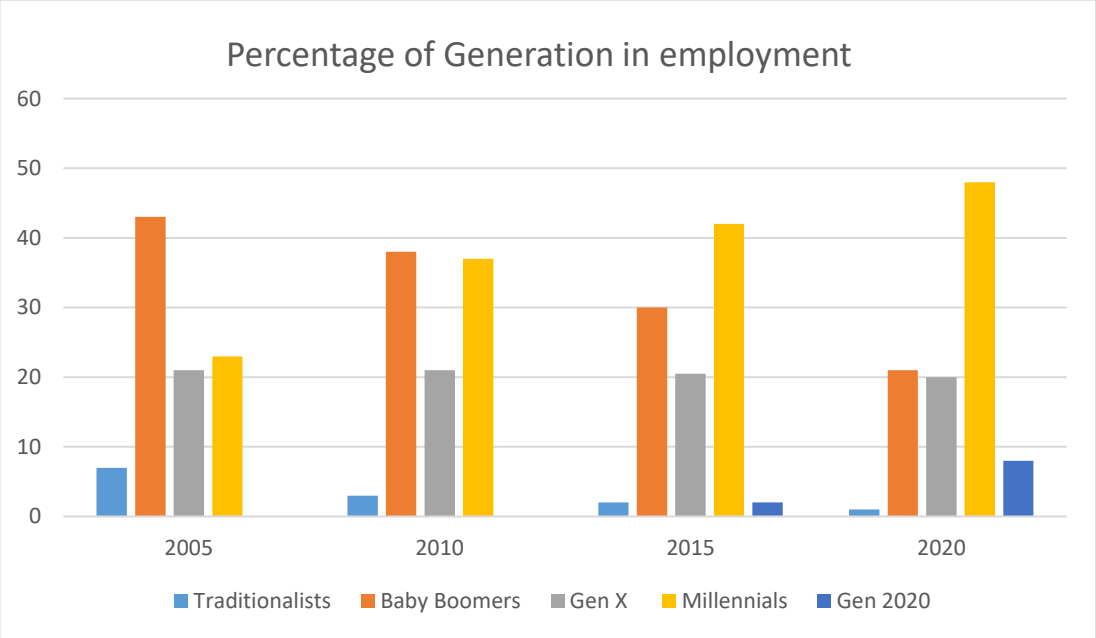


Figure 12: Percentages of each generation in employment (Gigaom, 2016)

As seen in Figure 12 the number of millennials employed is steadily rising, projected to reach the highest percentage over all generations by 2020. This rapid onset and change in workforce will create a strong need for companies to adapt in time, for them to reach out to the new generation and can hire capable people. While millennials will be the most employed by 2020, they still won't be in charge, meaning upper level management positions for coming years, as these positions are traditionally held by more experience workers from previous generations.

Startups too are seeing a strong increase, where a large proportion is founded by millennials, resulting in very young companies, led by young, innovative people. Many startups today develop brilliant ideas, but eventually fail as a result of lack of management, which can often be contributed to lack of experience in workforce and lack of money. As most startups are built on investors, they often cannot hold up expectations or deliver their product on market in time to reach success.

6.3 Challenges for today's supply chain management

Supply chains are changing in companies and they must adapt appropriately in order to keep up with the current market. Efficient supply chains are essential for companies to deliver their products punctually, but also for keeping up with the emerging need of fabricating personalized products.

Many businesses today have not adapted to modern technologies, mostly due to lack of money for investment and are being hindered at competing with others. As companies are growing it is necessary to develop the logistics appropriately to meet the company's new demands, otherwise it is easy for companies to lose overview. Companies are relying on their supply chains to keep visibility in their current system, which allows them to produce cost efficiently and produce according to their customer's demand.

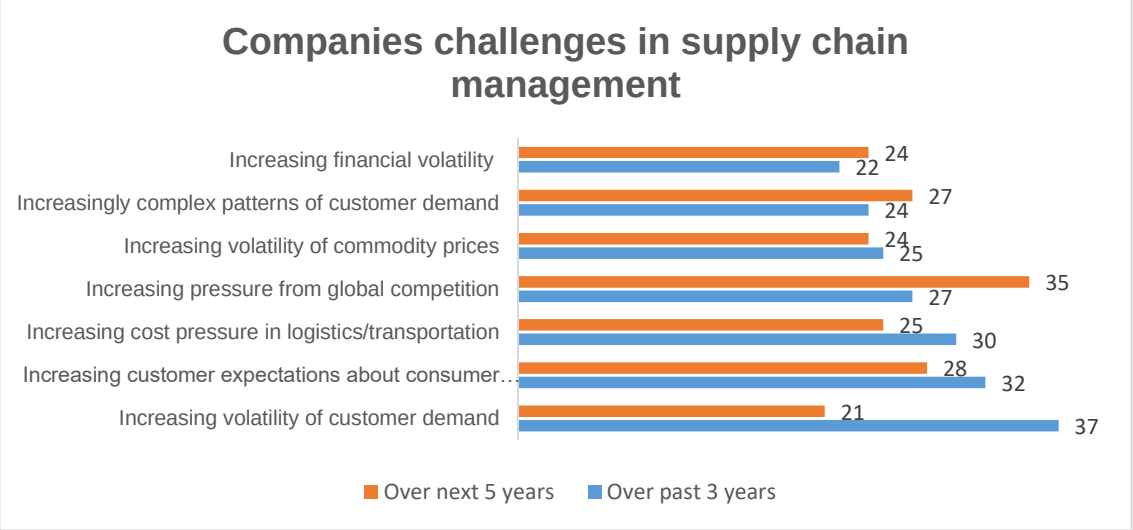


Figure 13: Company challenges in supply chain management found in a McKinsey study with 639 respondents (McKinsey, 2008)

Figure 13 shows part of the result of a McKinsey study which was conducted in 2008, outlining the mayor challenges companies where expected to face regarding supply chain management in the next five years, compared to the previous three. The trends shown in the study are still valid today, companies are less worried about consumer service/ product quality or increasing volatility of customer demand. Companies here have adapted and can fulfill these requirements for their customer. Quality issues for example are declining as machines are becoming much more reliable and efficient.

On the other had companies expected, and still do today, increase in problems concerning more complex patterns in customer demands and increasing financial volatility. The largest change is in pressure concerning global companies. This challenge arises as globalization is taking place at a rapid evolving pace and new competitors can come from anywhere in the world. (McKinsey, 2008)

Correctly implemented and modernized supply chains can help overcome these greatest challenges as they enable companies to adapt to complex pattern in demands, by increasing their flexibility and making them able to compete globally.

6.4 Data security

Data security is a topic which has constantly been under debate and will likely impose ongoing discussions as big data and data interchange through industry 4.0 enabled technologies continuous to rise. Following today's trends, it is very likely that laws concerning private and personal data will become stricter. Data anonymization is a key concept, with more techniques evolving, keeping the principal that an individual must be impossible to identify out of a given data set which is considered private. This concept benefits both companies and users, as companies can obtain valuable data they need, keeping the customer protected. (WSGR, 2015)

On the other hand, the private use of the internet as we know it is decreasing, as mapping of IP addresses or geo locations is increasing. Governments are storing user relevant data for homeland security purposes and tracking of illegal activities.

6.5 Challenges of remote monitoring devices

Biological data is recorded by wearable devices, often carried for 24 hour periods by patients, which need to store, process and transmit the data in secure and efficient manner. As these devices need to be wearable, this greatly limits their design specification, as they need to be light and small and should not interfere with patients daily movement or activity. One of the greatest challenges in designing these devices is energy efficiency. Most devices run on rechargeable batteries, which need to last for at least a 24h period and need safety energy implementations in order to prevent any loss of data.

7 Summary & Outlook

Industry 4.0 will influence how business and manufacturing is conducted in the future and will also affect private lives of people. While it is sure to bring many benefits, as productivity and efficiency for manufacturers can be greatly increased and everyday life for people can be improved, threats to security and jobs exist. The following table shows a SWOT Analysis of Industry 4.0, conducted by the European Parliament.

Strengths	**Weakness**
Increased productivity, efficiency, competitiveness, revenue Growth in high-skilled and well paid jobs Improved customer satisfaction – new markets: increased product customization and product variety Production flexibility and control	High dependence on resilience of technology and networks: small disruptions can have major impacts Dependence on a range of success factors including standards, coherent framework, labor supply with appropriate skills, investment and R&D Costs of development and implementation Potential loss of control over enterprise Semi-skilled unemployment Need to import skilled labor
Opportunities	**Threats**
Strengthen Europe's position as a global leader in manufacturing (and other industries) Develop new lead markets for products and services Lower entry barriers for some SMEs to participate in new markets, links to new supply chains	Cybersecurity, intellectual property, data privacy Workers, SMEs, industries, and national economies lacking the awareness and/or means to adapt to Industry 4.0 and who will consequently fall behind Vulnerability to and volatility of global value chains Adoption of Industry 4.0 by foreign competitors neutralizing EU initiatives

Table 5: SWOT Analysis of Industry 4.0 by European Parliament (European Parliament, 2016)

The strengths of industry 4.0 are clearly in improving manufacturing, as efficiency and productivity can both be improved, while reducing labor costs and errors. Job requirements in industry 4.0 will change, reducing physical labor, but increasing the need for highly skilled and trained professionals, with higher pay. Advantages for

customers include highly customable and variable production capabilities, which allow people to design products exactly to their expectations, while maintaining reasonable prices and delivery times.

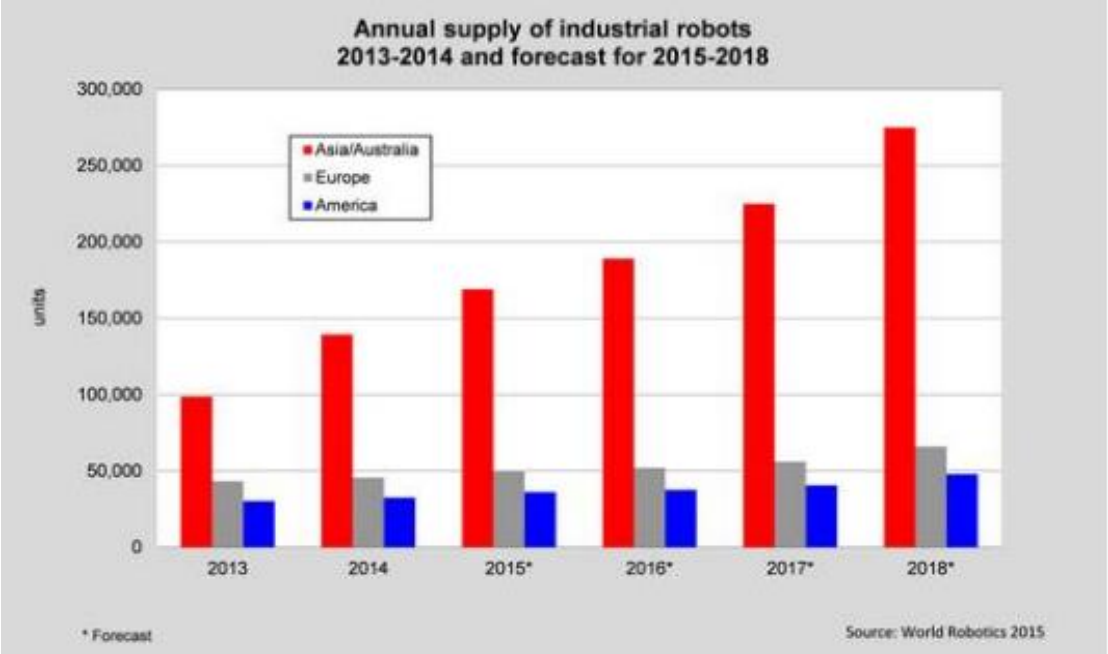


Figure 14: Forecast of annual supply of industrial robots (IFR, 2016)

Figure 14 shows the annual supply of industrial robots for the last years and a predicted forecast to 2018. Asia/Australia make up the biggest share in purchase of new robots, by 2018 about three times as much as Europe and America combined. This is due to the large amount of people living in Asia and the fact that many European and American companies have outsourced their production to Asia. The high rise of industrial robots worldwide, is a strong indication of companies ready to implement industry 4.0 standards in their factories.

While highly skilled jobs are expected to rise, a weakness of industry 4.0 will be the loss of unskilled labor. Less and less people are needed throughout factories for manual labor since the third industrial revolution and now the trend will rapidly increase even further as industry 4.0 will take jobs also from lower office positions. As less people are employed, dependence on machines and networks rises, a fully implemented industry 4.0 factory is completely dependent on network systems and technologies. (IFR, 2016)

Threats regarding the implementation of industry 4.0 can be seen mostly in privacy. As data is being constantly recorded and stored, it is very important to implement strict data laws to ensure proper handling and to securely store all data to protect it from unintended access. Data handling is not only an issue for companies and businesses, but also for private people, who are using more and more technologies which track personal data. This is of special concern in the medical sector, as medical data is especially vulnerable and needs to be protected at highest level.

At the moment, many companies are in the process of launching industry 4.0 related programs and implementing new standards in their companies. These programs will still need some time and full implementation is still a few years ahead. In many cases technologies are further developed than the people required to work with them. Most employees still need training in order to handle these new technologies and many of the next generation, which are receiving the necessary training, have still not completed their studies. Similarly, business models have to be adapted in accordance to industry 4.0 and for full implementation to be successful this implementation has to be completed in not only the business itself but also all its customers and suppliers.

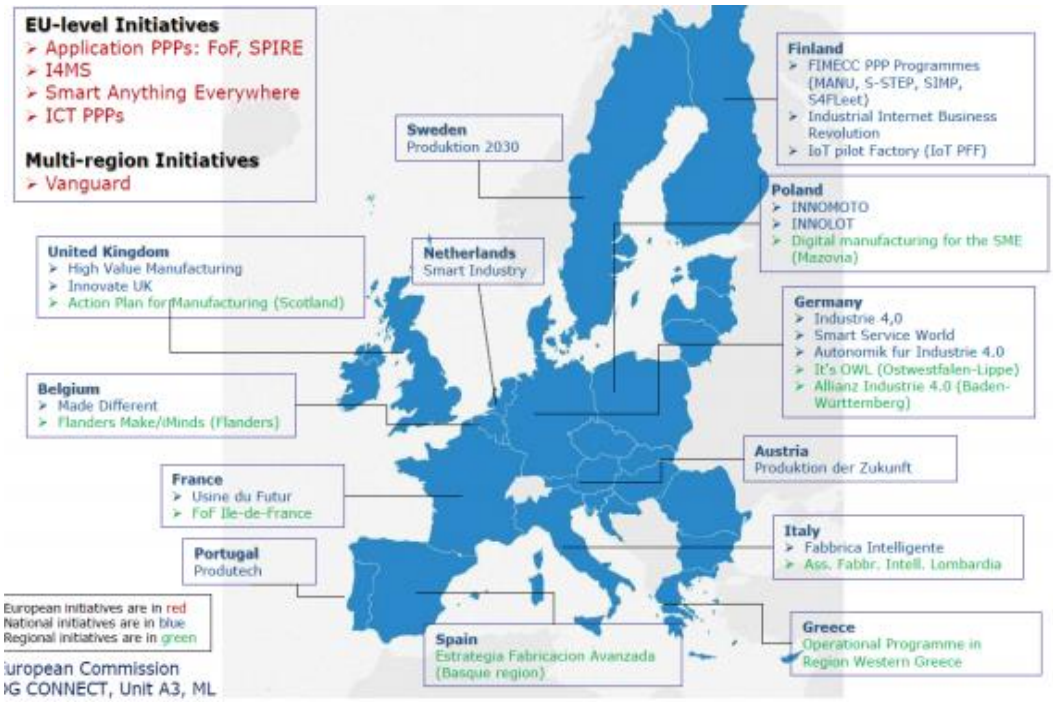


Figure 15: Implementation of Industry 4.0 across Europe (European Parliament, 2016)

Figure 15 shows development Initiatives across Europe which benefit the implementation of industry 4.0 for each country. These initiatives are mainly designed for manufacturing and do not include development of technologies in the private sector. Initiatives created by the EU such as I4MS or Smart Anything Everywhere are intended to create an equal foundation for technologies across the EU.

7.1 Keeping big data in check

I personally see big data as the key technology in the development of industry 4.0. Big data is already being used in many businesses and households today and brings enormous potential for business owners and customers, but needs to be handled with great care for the system not to spiral out of control in the next years.

While companies, for the most part, benefit from big data, I believe people need to be very vigilant on how much of their data is being recorded and which companies are handing their data. One of the drawbacks of a fully connected world is that it becomes very hard to keep track of who is in possession of your data and to always be alert when your data is being recorded. I myself often struggle to find all relevant settings on my phone or computer to fully understand which data is being tracked and am often surprised at how much information is being recorded. It is very easy to agree to any form filled out on the internet, when signing up for a new application, but consequences can be sever.

In my opinion, companies should be limited in the amount of data they store and analyze about single individuals, as otherwise new technologies make it too easy for companies to manipulate people, leaving them vulnerable. Image a future world, where every advertisement is custom made to each person and then not only shown during movie breaks, but exactly when a person is feeling sad or hungry or any emotion relevant to the product. This could easily be achieved, by few companies working together, one keeping track and handling medical data and others keeping track of his shopping habits. This scenario is not in place now and probably not in ten years, but who knows what happens in twenty?

Big data brings us many advantages, not only for companies to produce and calculate more efficiently, but also in our households and in our medical care. We will receive products or treatment personalized to our exact needs and our radio will know which song to play, when we come home from work depending on our mood. Nonetheless it is very important to keep the power of data in mind and make sure that our data does not fall in the wrong hands. I believe that by putting pressure on companies, we can achieve change in data handling. It is in the interest of all to develop our world further and give way to new technologies, but the price for it should always be kept in mind, especially when consequences are not in the immediate future, but have to be predicted for the long run.

7.2 Doctor 4.0

Smart hospitals and remote monitoring devices all rely on new technologies, which greatly improve flow and processing of information. They are all built to aid doctors in making their diagnoses, secure patients health and facilitate recovery. Integral through most visions of future hospitals is that machines aid, but never replace doctors. I believe that as with other jobs, it still requires time, but machines have the potential to be doctors. Doctors will still be necessary for supervision, difficult cases and maintenance and updates for the machines, but machines can take over routine doctor tasks.

Surgery is the field in which I see greatest potential for robots and in which in some hospitals prototypes are already being developed, as machines can act much faster and precise than humans. Doctors are also developing small robots which can be swallowed and then perform Nano surgeries inside the body, something unthinkable to do by hand. These Nano-robots are expected to show great results in dentistry, neurosurgery and oncology. Promising results in the treatment of cancer has been the elimination of waste and other toxins which comes with chemotherapies used today. By deploying Nano-robots, cancer cells could be detected much earlier and treated more precise.

I think that machine doctors will not only be restricted to operational tasks, but can take over diagnosing as well. Sick people today often google their symptoms, which rarely gives proper result and can often lead to harmful misdiagnoses. When

interacting with a “robot doctor” of the future, I can image different results. Future robot doctors would not only be able to ask further questions based on the patient, they will be equipped with tools and able to measure patient health stats. Diagnoses could be made using endless statistics and information about the patient history, analyzed in matter of seconds.

7.3 The job of the future

I believe that after completion of the fourth industrial revolution, when industry 4.0 is implemented thoroughly in all factories and households, despite many people predicting complete takeover by machines, people will still have jobs. Every industrial revolution has put people in fear that machines will take over, leaving all of us out of work, but so far this has never been the case. I think that there will be a strong shift in how we work, but people will need to work and the system will require us to work nonetheless.

In the future typical working hours, meaning a 40 hour week or standard labor shifts, will be very rare, but instead people will have very flexible schedules, adapting to workloads and their own requirements. I believe people will need these flexible workdays, as their jobs will require them to be creative and involve a lot of mental labor, something than can only be achieved in a free and inspiring environment. Creativity is a key feature for future work, as it sets us apart from computers and machines.

Not everyone will be able to cope with the new system and I think that there will be a transition period in which many will find themselves unemployed, as they need to educated themselves further for them to be accepted by any company and as people need to shift their attitude and behavior towards their jobs, by taking more responsibilities and spending more effort. Simply sitting at a desk or standing in a factory completing routine tasks which involve little independent thinking will soon not be good enough anymore. Machines can take those roles and will require us to work at a higher level, giving us room to explore our own potentials, but also forcing us to work hard and use our brains.

As stated under the generation millennials, young people, who are just graduating their university, will have little trouble adapting to the new system as they are the generation forming the new workplace. Older generations will face more difficulties, as they need to adapt and keep up with not only new technologies but a completely new life and workstyle to find jobs. With the trend of new companies to focus entirely on the needs of millennials and completely redesigning company structures, I believe it is important to include existing managers from different generations in the process, as their experiences and achievements are what brought us to where we are today and much techniques and implementations used today, based on years of experience which should not be dismissed lightly.

When looking at opportunities for young people of my generation to create businesses and achieve the so called “American dream”, I see both potentials but also disadvantages in the future. We are living in a time when big companies are becoming more and more powerful, developing and patenting key technologies and in many cases buying up all their competition to create monopolies. It is very difficult to work your way up in these companies as there are strong hierarchies in place and only few make it to the top.

On the other hand, the internet has enabled the creation of star-ups, in my opinion the new approach for young people to achieve their American dream, to be successful and independent. Start-ups give young people the opportunity to be creative and develop their ideas, which through the help of industry 4.0 technologies can be realized. New factories and 3-d printing allow start-ups to manufacture their products, without needing to buy a whole factory or producing millions of products at a time, specialized products can be manufactured in small batches, with costs low enough for profit to be made.

Industry 4.0 will certainly change how we are living, it will change our workplace and our household, making life easier for people, giving them better treatment and allowing them to receive individualized products and care. It certainly has its drawbacks and until fully implemented still has a long way to go, which people living today need to be ready for and adapt to when the time has come.

8 Bibliography

Apple. (2016). Retrieved 02 11, 2017, from http://www.apple.com/ios/health/

Automation. (2016, 11 23). Retrieved from EAS: http://www.eas-schaltanlagen.com/main/index.php?webcode=integration&language=english

Automatisierungspyramide. (2016, 11 23). Retrieved from Kunbus: https://www.kunbus.de/automatisierungspyramide.html

Bakshi, S. (2014). Large Scale Cloud for Biometric Identification. In *Advanced Computing, Networking and Informatics* (p. 434). Springer.

BCG. (2016, 02 09). Retrieved from https://www.bcgperspectives.com/content/articles/lean-manufacturing-operations-time-accelerate-race-toward-industry-4/#chapter1

BDC. (2016). Retrieved 02 09, 2017, from https://www.bdcnetwork.com/workplace-design-trends-make-way-millennials

BDI. (2015). Retrieved 02 03, 2017, from https://www.noerr.com/~/media/Noerr/PressAndPublications/Brochures/studien/Rechtliche-Herausforderungen-Digitalisierung-Industrie-40.pdf

Bowers, N. (2016, 11 23). *http://www.electronicspecifier.com/design-automation/the-perfect-pyramid-of-automation*. Retrieved from Electronic Specifier: http://www.electronicspecifier.com/design-automation/the-perfect-pyramid-of-automation

Brühl, V. (2015). Wirtschaft des 21. Jahrhunderts . Springer-Gabler.

Capgemini. (2014). Retrieved 02 11, 2017, from https://www.de.capgemini-consulting.com/resource-file-access/resource/pdf/capgemini-consulting-industrie-4.0_0.pdf

CBS. (2017, 02 01). Retrieved from http://www.cbsnews.com/news/ceo-zuckerberg-facebooks-5-core-values/

Conhit. (2016). Retrieved 02 27, 2017, from Conhit: http://www.conhit.de/media/cit/cit_dl_vortraege/archiv_vortraege_2016/Ziegler_Bernhard_-_Industrie_4_0_als_Grundlage_fuer_das_Smart_Hospital_Praesentation_2016.pdf

DIS AG. (2016). Retrieved 02 08, 2017, from https://www.thinksimple.de/fileadmin/pdf/kundenstudien/dis_studie_futurejobs_2014.pdf

ECE. (2015). Retrieved 03 20, 2017, from ECE: http://www.ece.rochester.edu/~gsharma/papers/Moeen_HealthMonitor_SCC2015.pdf

EDE. (2017, 01 15). Retrieved from https://www.ece.ncsu.edu/research/cas/ecs

European Parliament. (2016). Retrieved 04 10, 2017, from http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

EY. (2016). Retrieved 02 09, 2017, from http://www.ey.com/Publication/vwLUAssets/EY-global-generations-a-global-study-on-work-life-challenges-across-generations/$FILE/EY-global-generations-a-global-study-on-work-life-challenges-across-generations.pdf

Forbes. (2015). Retrieved 09 02, 2017

Gigaom. (2016). Retrieved 04 06, 2017, from https://gigaom.com/2013/03/19/what-impact-will-millennials-have-on-the-workplace/

Goldman Sachs. (2017, 01 13). Retrieved from http://www.goldmansachs.com/our-thinking/pages/millennials/

Google. (2017, 01 02). Retrieved from https://www.google.at/intl/en/about/company/philosophy/

Google Stock. (2017, 31 01). Retrieved 31 01, 2017, from https://www.google.com/finance?q=NASDAQ%3AFB%2Cgoog&ei=UYSQWLntDcWCswHOr4No

Harvard Business Review. (2017, 02 01). Retrieved from https://hbr.org/2010/05/mentoring-millennials

Harvard Med. (2009). Retrieved 16 03, 2017, from Harvard Med: http://mycourses.med.harvard.edu/ec_res/nt/930820C0-27CB-4D8D-92CA-C5C152738BD9/cchit.pdf

Hirsch-Kreinsen, H. (2015). Digitalisierung industrieller Arbeit . Nomos.

Hortonworks. (2017). Retrieved 02 03, 2017, from http://hortonworks.com/apache/hadoop/

IAB. (2016). Retrieved 04 12, 2017, from IAB: http://doku.iab.de/forschungsbericht/2015/fb0815_en.pdf

IFR. (2016). Retrieved 04 10, 2017, from https://ifr.org/img/uploads/Executive_Summary_WR_Industrial_Robots_2016 1.pdf

IGI. (2016, 12 12). Retrieved from http://www.igi-global.com/dictionary/virtual-collaboration/31629

Iritch Inc. (2015). Retrieved 02 01, 2017, from Iritch Inc: http://www.iritech.com/blog/biometric-cloud-based/

Joapen. (2016). Retrieved 04 09, 2017, from Joapen: http://joapen.com/blog/wp-content/uploads/2013/10/Industry-4.0.jpg

Kunz, K. (2016, 11 23). *Vertikale Integration der IT-Landschaft*. Retrieved from ETZ: http://www.eas-schaltanlagen.com/main/index.php?webcode=integration&language=english

Lichtblau, D. K. (2016, 11 21). *Dienstleistungspotenziale im Rahmen*. Retrieved from VBW Bayern: https://vbw-agenda.de/downloads/pdf-neu/02/3/dienstleistungspotenziale-industrie-4.0-mar-2014.pdf

Manufacturing Execution System. (2016, 11 23). Retrieved from Siemens: http://w3.siemens.com/mcms/automation/de/manufacturing-execution-system-mes/seiten/default.aspx

Marcy, A. (2016, 11 23). *Intelligent automation series part 1: Introducing the intelligent automation pyramid*. Retrieved from Control Engineering: http://www.controleng.com/single-article/intelligent-automation-series-part-1-introducing-the-intelligent-automation-pyramid/109d090cec56a8e0b858cf1f7d866b3a.html

McKinsey. (2008). Retrieved 02 11, 2017, from http://www.mckinsey.com/business-functions/operations/our-insights/the-challenges-ahead-for-supply-chains-mckinsey-global-survey-results

McKinsey. (2013). Retrieved 04 12, 2017, from https://www.google.at/url?sa=t&rct=j&q=&esrc=s&source=web&cd=7&cad=rja&uact=8&ved=0ahUKEwjNg52b4pzTAhXKD8AKHQaGB2sQFghXMAY&url=http%3A%2F%2Fwww.mckinsey.com%2F~%2Fmedia%2Fmckinsey%2Fdo

tcom%2Fclient_service%2Fbto%2Fpdf%2Fmobt32_02-09_masscustom_r4.ashx&usg

McKinsey. (2017). Retrieved 02 07, 2017, from http://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Open%20data%20Unlocking%20innovation%20and%20performance%20with%20liquid%20information/MGI_Open_data_Executive_summary_Oct_2013.ashx

Medscape. (2015, September). Retrieved 02 11, 2017, from http://www.medscape.com/viewarticle/851226

NCBI. (2014). Retrieved 02 11, 2017, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4029126/

NIKE. (2017). Retrieved 04 12, 2017, from NIKE: http://www.nike.com/at/de_de/c/nikeid?ref=https%253A%252F%252Fwww.google.at%252F

NXP. (2016). Retrieved 20 03, 2017, from https://cache.freescale.com/files/corporate/doc/white_paper/IOTREVHEALCARWP.pdf

Oracle. (2017). Retrieved 02 03, 2017, from https://www.oracle.com/big-data/index.html

PWC. (2016). Retrieved 02 09, 2017, from https://i4-0-self-assessment.pwc.nl/i40/study.pdf

Robotics. (2016). Retrieved 15 03, 2017, from Robotics: http://www.robotics.org/content-detail.cfm/Industrial-Robotics-Industry-Insights/Robots-and-Healthcare-Saving-Lives-Together/content_id/5819

Roth, A. (2016). *Einführung und Umsetzung von Industrie 4.0.* Berlin: SpringerGabler.

SAS. (2015). Retrieved 02 07, 2017, from https://support.sas.com/resources/papers/proceedings15/1884-2015.pdf

Security and Resilience for Smart Health Service and. (2016). *ENISA*.

Shapeways. (2017). Retrieved 04 12, 2017, from Shapeways: https://www.shapeways.com/blog/archives/653-Amazing-3D-Printed-Glass.html

Siemens. (2014). *NASSCOM Engineering Summit 2014.*

Siepmann, D. (2016). Industrie 4.0-Fünf Zentrale Paradigmen. In A. Roth, *Einführung und Umsetzung von Industrie 4.0* (p. 37). Berlin: SpringerGabler.

Whatsapp. (2016). Retrieved 01 10, 2017, from https://www.whatsapp.com/faq/en/general/28030015

Whimsley. (2011). Retrieved 02 08, 2017, from http://whimsley.typepad.com/whimsley/2011/09/data-anonymization-and-re-identification-some-basics-of-data-privacy.html

WLW. (2016). Retrieved 02 11, 2017, from WLW: https://www.wlw.de/de/inside-business/einkauf/industrie-4-0-herausforderungen-scm

WSGR. (2015). Retrieved 08 02, 2017, from http://www.wsgrdataadvisor.com/2015/09/personal-data-anonymization-and-pseudonymization-in-the-eu/

Yakoob, N. (Ed.). (2017). *automationworld.com*. Retrieved 31 01, 2017, from https://www.automationworld.com/industrial-internet-things/decentralized-control-and-internet-things

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