Ekaterina Uglovskaia

The New Industrial Era

Industry 4.0 & Bobst company case study

Bachelor's Thesis

Degree Programme in International Business

January 2017

XAMK
South-Eastern Finland
University of Applied Sciences

Author	Degree	Time
Ekaterina Uglovskaia	Bachelor in International Business	January 2017

Author
Ekaterina Uglovskaia

Thesis Title
The New Industrial Era. Industry 4.0 & Bobst company case study

73 pages
7 pages of appendices

Supervisor
Dr. Ilkka Virolainen

Abstract

This thesis deals with the emerging concept of Industry 4.0, which refers to the fourth industrial revolution and means the major transformation of the manufacturing and the way processes and information flow are organized within companies.

The study was conducted based on the interest of the Bobst company with the purpose of estimating its potential within the changing industrial environment.

The thesis was divided into two parts – theoretical and practical, where secondary research and both qualitative and quantitative methods were used.

The theoretical part was devoted to collecting relevant and up-to-date information about the concept of Industry 4.0.

In the practical part, the survey in Bobst was conducted to obtain information about company’s interest, expectations and current actions within the concept. Based on the collected data and personal observations of the author, recommendations to the actions and potential development were given.

In conclusion, the primary research question was answered with the reference to obtained in the first and the second part knowledge. The results indicated that Bobst has already made some steps towards Industry 4.0 and company’s leading capabilities give it the ability to establish a data-driven organization of the future.

It is important to mention that although the study has reached its purpose, there were some limitations. First, due to the fact that the concept is quite new, there was a lack of different arguments about the topic, and also an overall number of available published and official materials was small. In addition, some aspects of the data about Bobst could not be presented in this study to protect company’s confidential information.

Keywords
Industry 4.0, fourth industrial revolution, data-driven, connected, transformation.

ACKNOWLEDGEMENT

Having finished my thesis, I wish to express my gratitude to everyone who supported me throughout the process of conducting this research project. I am genuinely thankful to them for sharing their ideas, truthful views and professional opinions on the topic related to my work.

I would like to thank all people at Bobst and South-Eastern Finland University of Applied Sciences for providing me with the facilities and resources required for this study.

I am deeply grateful to Valery Naula. This paper would have been incomplete without his constant assistance and dedicated involvement.

I certainly thank Manelik Sfez for the guidance at Bobst and advice on the subject of my thesis.

I also thank those who took time to participate in the survey, helping me to make the project of a better quality.

Furthermore, I would like to thank my research supervisor Dr. Ilkka Virolainen for the provided help.

Finally, I must express my gratitude to everyone involved in my personal life for listening and encouraging me throughout my studies and during the process of writing this project.

Thank you,

Ekaterina Uglovskaia.

CONTENTS

1 INTRODUCTION

Continuous development of technologies word-wide affect the way customers behave, think and perceive value. In fact, all the stages of change that manufacturing went through were stimulated by the human needs and growing customer demand. First three industrial revolutions were characterized by the transition to new manufacturing processes due to the invention of steam power, electricity and use of electronics (Figure 1).

Figure 1. Industrial revolutions (Bobst, 2016)

Industry 4.0 is the fourth industrial revolution that is taking place already nowadays. This era is characterized by modern trends on connectivity and collaboration, advanced services, materials and processing technology. My paper is dedicated to the fact that Industry 4.0 will transform dynamics of the market in the manufacturing industry, change individual company's structure and have a major influence on the competitive landscape.

Given the importance of such industrial implications and effect they will have worldwide, in this paper I would like to focus on the fourth industrial revolution, its development, importance and value that it adds to organizations and their customers within industrial manufacturing.

1.1 Objectives and research question

This study is conducted based on the interest of the Bobst company, which is a leading supplier of equipment and services to packaging and label manufacturers in the folding carton, corrugated board, and flexible materials industries. The company is founded in 1890 in Switzerland, employs close to 5 000 people around the world and is presented in more than 50 countries.

The purpose of the thesis is to estimate Bobst's potential within the concept of Industry 4.0 and to prove that the establishment of the new era will open new business opportunities, increase revenues and extend service and product offering by connecting and transforming company's internal processes.

The primary research question of my work is*: What is Bobst's potential within the concept of Industry 4.0?*

1.2 Methodology

This paper will be divided into two parts – theoretical and practical, where secondary and both quantitative and qualitative research methods will be used.

To present the relevant data by the end of the research, the thesis will comprise a comprehensive review of books, journals, scientific articles and various companies' reports published online. With the help of the secondary data analysis, I will research existing theoretical information in order to better understand the concept and be able to give recommendations on how to apply it in practice.

Briefly, quantitative research refers to the explanation of a concept by means of numerical data, graphs and charts, while qualitative is based on people's subjective thinking, their opinions and perceptions of certain issues.

Quantitative research “emphasizes objective measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques” (Babbie, 2010). It explains particular phenomena by collecting numerical data that are analyzed using mathematically based methods.

In this paper, the quantitative research method will be used, and data will be gathered through the survey, which seems to be the most suitable way for evaluating the knowledge of the company’s team about Industry 4.0 and obtaining information about Bobst’s current actions within the concept. A survey is a preferred data gathering tool for this thesis, as it can be distributed to a larger number of people, and when well designed and structured - might help the author to obtain all required information, excluding the need for additional interviews.

The survey will be made via the Internet tool called the “SurveyMonkey”. This online survey instrument allows to create a questioner, send it out via email and automatically analyze results and visualize collected data with the use of graphs and tables.

Qualitative research is “an effort to understand situations in their uniqueness as part of a particular context and the interactions there, with the researcher as the primary instrument for data collection and analysis” (Merriam, 2009). Qualitative research helps to understand how people interpret their experiences and what meaning they attribute to them.

The use of qualitative research method in the thesis will facilitate the collection of information through personal observations. “Involvement is a setting can lead to a free and open speaking with members and foster an in depth understanding of situation or concept” (Cohen, 2006). The practical part of the work will include author’s reflections, thanks to the knowledge obtained during the internship in the company and the ability to take part in daily processes.

1.3 Thesis structure

Therefore, the thesis is structured as follows. Chapter 2 of the paper gives the background information and definition of Industry 4.0 concept, mentioning its main features. It explains the term Digital Enterprise as it is a crucial element of the fourth industrial revolution. The chapter also introduces readers to the main trends that arise in the organizational structure as well as new business models, technologies, and factory types. It outlines the most recognized by companies' benefits and opportunities opened by the adoption of Industry 4.0 concept; in addition to risks and challenges faced by the businesses and ways to overcome them.

To conclude theoretical part, Chapter 3 emphasizes the data about the possible impacts that are expected with the beginning of the new industrial era and Chapter 4 discusses various initiatives taken by countries in order to adopt Industry 4.0 concept.

Finally, Chapter 5 represents a practical part of my work and includes information about competitors, survey results, and SWOT analysis, as well as Business Model Canvas, which allowed me to create a list of recommendations and draw a conclusion, answering the primary research question. Chapter 6 summarizes the results and gives a conclusion. The Industry 4.0 glossary is available in the Appendix 1.

2 INDUSTRY 4.0

2.1 Features

In general, development of Industry 4.0 means the appearance of "smart factories"[1], where machines are able to adapt to changes by reconfiguring and re-optimizing themselves, and where data from various resources is aligned with digitalized processes. For instance, once the production has

---

[1] "Smart Factory" - is a manufacturing solution, which is designed according to sustainable and service-oriented business practices that provides flexibility and adaptiveness to production processes in order to dynamically solve problems arising within processes (MacDougall, 2014).

begun in the old factory, it is challenging and time-consuming to make a change in the process. On the contrary, a smart factory has a chance to implement the sudden and real-time change in a request. By gaining automation, manufacturing moves from centralized to a distributed: cyber-physical production system[2], which allows businesses to increase the flexibility, incorporate last-minute changes and offer product variations for acceptable prices (Wanga, 2015).

In addition, Industry 4.0 is closely related to the "Internet of Things" movement, which in its turn refers to a flexible and service-oriented computing infrastructure (Lopez Research LLC, 2013). The "Internet of Things" mainly means – establishment of connections between physical assets through which data can transfer. These connections are based on general or dedicated (unique IP address) internet protocols.

The "Internet of Things" excludes the idea of analytics; however, its large scale facilitated the rise of cyber-physical production systems – mechanisms controlled or monitored by computer-based algorithms, which are also based on connectivity but involve complex analytics (Bacheri, 2015).

Cyber-physical systems in manufacturing have five levels of tasks. In short, these levels are: connection (data which is generated by connected physical assets is gathered), conversation (data is converted into information using algorithms), cyber (complex analytics and deep-learning algorithms are performed on this information), cognition (system uses specific prediction algorithms to foresee its potential), and configuration level (machine tracks its performance, can detect failures early on and send information to the operation level). Information collected on the last level serves as feedback to business management systems and is accessed using, for instance, applications, as cyber-physical systems store and maintain data via the cloud (Bacheri, 2015).

[2] "Cyber physical system" (CPS) - are smart embedded systems characterized by both hardware and software that operate both at virtual level and physical level, interacting with and controlling physical devices, sensing and changing the real world (Baheti, 2011).

Nowadays, very few companies across different industries use the full potential of the “Internet of Things” and cyber-physical systems. Most of the businesses limit their actions to embedding sensors in manufacturing equipment or tagging products with RFID[3] tags, which requires little analysis (Bacheri, 2015).

Apart from simply connecting assets and facilitating production by analyzing data, cyber-physical production systems create a smart network of machines (for example, robots), systems, products and individuals across the entire value chain and are able to design smart solutions or increase cooperation between people and machines (MacDougall, 2014). Generally saying, it is a technology system that establishes interaction between physical and virtual worlds.

Thus, to transform into the smart factory and gain competitive advantage by fulfilling increasingly individualized customer requirements, companies must go through the digital transformation, in other words, become a Digital Enterprise, where IT[4] (such as embedded sensors) and OT[5] (such as additive manufacturing) are used in internal and external operations.

To sum up, there are three main characteristics that define Industry 4.0: *digitalization*– network for managing and planning production, *automation systems* - for acquiring data, and finally, *automatic data interchange* – for connecting supply chain (Roblek, 2016).

[3] “RFID” - refers to an automated data collection technology that uses radio frequency waves to transfer data between a reader and a tag to identify, track and locate the tagged item (Gartner).
[4] ”Information technology” (IT) – a common term for the entire spectrum of technologies for information processing, including software, hardware, communications technologies and related services, which does not include embedded technologies that do not generate data for enterprise use (Gartner).
[5] ”Operational technology” (OT) - a hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise (Gatner).

2.2 Definition

Industry 4.0 is a strategic initiative used to describe the trend towards digitization and automation of the manufacturing environment that has been proposed and adopted by the German government as a part of the "High-Tech Strategy 2020 Action Plan", but got international recognition and is widely known across Europe (MacDougall, 2014).

The concept was first proposed in 2011 at the world's leading industrial fair - Hannover Messe, followed by the plans and reports in 2013, finally leading to the official adoption by the German government.

In English-speaking world, such terms as the "Internet of Things"[6], the "Internet of Everything" or the "Industrial Internet" are also commonly used, being synonyms to the concept of Industry 4.0.

What does the term "Industry 4.0" mean exactly?
To answer this question, comparison of definitions given by six different resource has been made.

Table 1. Industry 4.0. Definitions

Author	Definition	Key features
Koch, Kuge, Schrauf & Geissbauer (2014)	The term Industry 4.0 stands for the fourth industrial revolution and is best understood as a new level of organization and control over the entire value chain of the life cycle of products, it is geared towards increasingly individualized customer requirements.	• Fourth industrial revolution • Entire value chain organization and control • Individualized requirements
MacDougall (2014)	Industry 4.0 or Smart industry refers to the technological	• New technology age • Moving toward cyber-physical systems

[6] "Internet of things" a network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or thee external environment (Korsten, 2015).

	evolution from embedded systems to cyber-physical systems. It connects embedded system production technologies and smart production processes to pave the way to a new technological age which will radically transform industry and production value chains and business models.	• Embedded systems • Smart production • Connection • Transformation
McKinsey Digital (2015)	Industry 4.0 seen as a digitization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber physical systems, and analysis of all relevant data.	• Digitization • Embedded sensors • Cyber-physical systems • Relevant data
Deloitte AG (2015)	The term Industry 4.0 refers to a further development stage in the organization and management of the entire value chain process involved in manufacturing industry.	• Development • Entire value chain • Organization and management
Geissbauer, Vedso & Schrauf (2016)	Industry 4.0 - the fourth industrial revolution, focuses on the end-to-end digitization of all physical assets and integration into digital	• Fourth industrial revolution • End-to-end digitization of assets • Digital ecosystem within value chain

	ecosystems [7] with value chain partners.	
Pfohl, Yahs & Kurnaz (2015)	Industry 4.0 is the sum of all disruptive innovations derived and implemented in a value chain to address the trends of digitalization, automization, transparency, mobility, modularization, network-collaboration and socializing of products and processes.	• Disruptive innovations • Value chain • Digitalization • Automization • Transparency • Mobility • Modularization • Collaboration • Socializing

According to the Table 1, definitions of Industry 4.0 presented by various resources have major similarities. They mainly focus on Industry 4.0 being a new step in the industrial development due to embedded smart systems that enable connection between partners across entire value chain.

Therefore, the following definition can be composed:

“*Industry 4.0*” is the term that refers to the fourth industrial revolution, characterized by the use of disruptive digital technology, increasingly individualized customer requirements and connections between embedded systems and smart production processes, aimed to create digital ecosystem and dramatically transform industry, production value chins, and overall business models.

[7] ”Ecosystem” – a short-hand for “digital” or “connected” ecosystem, which is a distributed, adaptive, open socio-technical system with properties of self-organization, scalability and sustainability inspired from natural ecosystems. Digital ecosystem models are informed by knowledge of natural ecosystems, especially for aspects related to competition and collaboration among diverse entities (Korsten, 2015).

2.3 Digital Enterprise

Industry 4.0 opens opportunities for manufacturing companies - big enterprises, small and medium.

Digital transformation, which refers to a specific change in business, where IT plays a domain role, is a crucial element of the Industry 4.0 paradigm.

“The future of technology looks smart, mobile, cloudy, social, and big” (Gollenia, 2014). Generally, there are four areas of digital transformation that a company must take into consideration: customer experience, employee experience, partners and the offering. Therefore, digital companies that are capable of making the right strategic decision and create business value by applying the right instruments to monitor technological and socio-political trends are more likely to succeed in the future and stay competitive in a rapidly-changing market.

In order to transform into the Digital Enterprise and be able to deliver a fast and innovative response to changes, companies must have specific characteristics.

Thus, ideal Digital Enterprise has excellent transformation skills, stands out in innovation and is able to develop entirely new business models based on new technology (Gollenia, 2014).

Moreover, Digital Enterprise easily responds to technological trends and is able to react faster to customer needs, offering 24/7 availability. Such company reduces product life-cycles, provides transparency and increases customer satisfaction.

Company’s desire to experiment, ability to adapt and keep up with the development pace play a significant role regarding its success. In digitalization context, there are three different strategic approaches for companies to adopt (Figure 2). Firstly, businesses that prefer to take risks by implementing untested solutions but act quickly are taking *innovators* approach. The second approach is called *early majority* and is used by the companies who learn from other's experiences, which helps them to be aware of possible issues and avoid mistakes. Finally, companies that rely on already-tested solutions, wait for the proof of reliability and vast adoption of the concept are called *late majority*. However, using the third approach and being the last to implement digitalization, companies risk being left behind in the fast developing market.

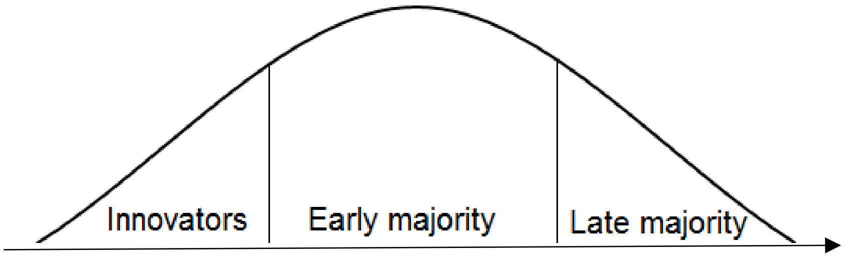

Figure 2. Strategic digital adaptation approaches

Stepping on the path of becoming a Digital Enterprise, companies go through specific development phases, represented by the maturity model. A digital maturity model describes the levels of the digitalization process of an organization and includes four steps (Koch, 2014):

1. Digital novice

This level represents the achievement of initial results in all departments, product and service portfolios, however, is characterized by uncoordinated activities within the organization and unsystematic risks control.

2. Vertical integrator

Second maturity level illustrates digitalization of operative and administrational processes, online internet-based connection between data from product development, production materials, and actual products, which becomes available for all systems of the company.

3. Horizontal collaborator

On the third maturity level integration of the company's external value chain is carried out. It is characterized by the connection of product and service portfolios with suppliers and customers, in order to create end-to-end solutions.

4. Digital champion

The last level of maturity represents a digital champion, who incorporated new methods of performance within the value chain; digitalized and globally optimized key processes according to cost and control criteria. Besides, existing product and service portfolios have been expanded by new, disruptive business models.

Generally, there are two ways for organizations to adapt to Industry 4.0 and become fully digital: they can either focus on transformation in terms of one major project; or gradually implement series of steps that will also lead to changes but not be titled under Industry 4.0 transition process.

To become digital champions companies must determine the path that is the most promising for them, by analyzing trends, benefits, and threats that they might be facing on the way to digitalization.

2.4 Main trends and technologies

This sub-chapter will give the overview of the main trends that are emerging together with Industry 4.0. It will briefly explain the basics of arising business models as well as new factory types that companies have to be aware of. The summary of the trends is presented in Figure 4, p.20.

Smart machinery, data sensors and connected systems are the basis of Industry 4.0. The concept is characterized by the outstanding technology and efficiency in all business processes. Manufacturing equipment of the new era is described by the use of wearables, highly automated machine tools and robots, which will establish collaboration, advanced human-machine interface and be able to flexibly adapt to changes.

Concerning the workforce, modern smart factories will require technically skilled and qualified employees. Due to the high processes automation, the trend will be to cut working places, while the rest of manufacturing jobs will include more short-term but hard-to-plan tasks. Workers qualifications will include proficient IT knowledge, data processing and analytics, statistical knowledge and organizational understanding, ability to adapt and interact using modern human-machine interfaces (Gehrke, 2015).

Moreover, as a result of new digital business models and high organizational complexity decision making will move towards decentralized instead of a centralized system. This shift will allow faster respond to changes, ensures that fewer mistakes are made and open the way for innovation. Besides, a trend in artificial intelligence[8] will define new ways in decision making, fraud detecting and data analyzing. It will also determine efficient consumption of energy and resources optimizing production in order to increase performance and achieve manufacturing sustainability (Deloitte AG, 2015). Two examples of an artificial intelligence that have outperformed humans are: the chess battle between the IBM computer Deep Blue and a chess master Garry Kasparov in 1977, when the program has analyzed every possible move as quickly as possible and won the game (Murphy, 2015); and the AlphaGo – Google's machine that in 2016 has defeated Korean grandmaster Lee Sedol with one loss out of five rounds in the "Go" – a complex board game that requires intuition, creative and strategic thinking (Wong, 2016).

Intelligent evaluation of data across different processes and machines will lead to the possibility to adopt predictive maintenance[9] techniques. Predictive maintenance (PdM) means identifying machine faults early enough to predict the ideal point in time when maintenance should be performed. It differs from the commonly used reactive (post-failure) and preventive (scheduled) maintenance techniques as it is based on the use of Big Data and advanced analytics. Even though no equipment lasts

[8] "Artificial intelligence" the theory in computer science that refers to development of computer systems and building smart software and machines that are able to perform such tasks as visual perception, speech recognition, decision-making, and translation between languages

[9] " Predictive maintenance" - techniques that are designed to help determine the condition of in-service equipment in order to predict when maintenance should be performed resulting in cost savings over routine or time-based preventive maintenance (Wikipedia, 2016)

forever, the technique of predictive maintenance can extend machine lifecycle and prevent its breakdown. Figure 3 – the P-f (potential and functional failure) curve outlines the time and costs interdependence and illustrates how PdM technique works. The main idea is – the faster the problems are identified, the lower the costs to repair. For instance, “early signals” are the points of focus for the company to keep machines running at full capacity. Therefore, carrying out PdM technique results in minimizing downtime, increasing productivity and cutting costs.

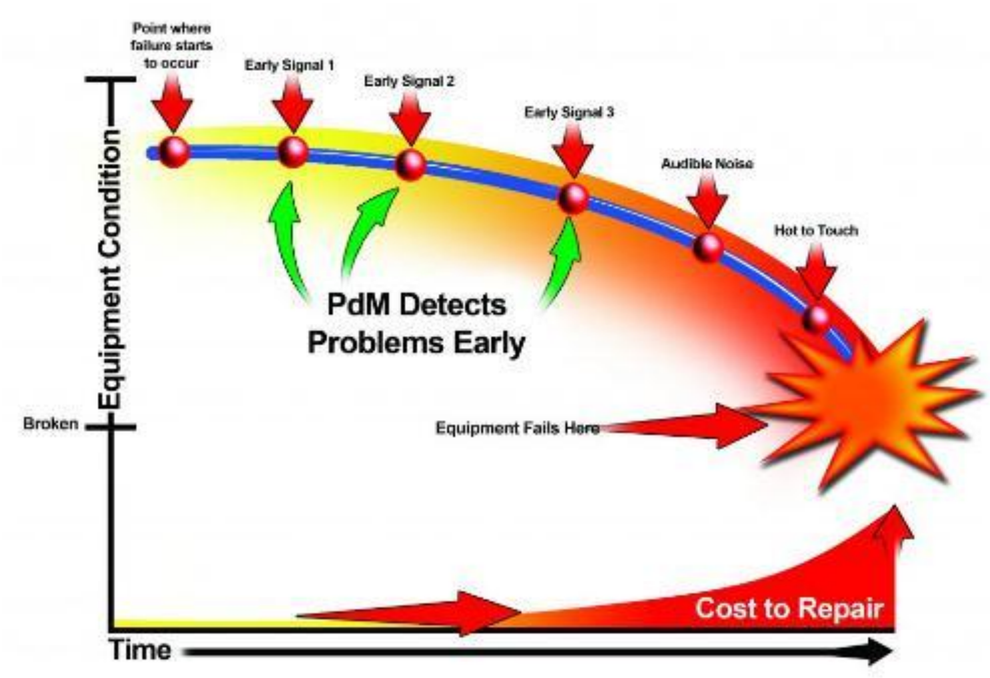

Figure 3. P-f curve (Google.com images)

Another Industry 4.0 trend is characterized by the highly individualized products, manufactured in small batch sizes that will allow penetrating the market with specific purchasing patterns. Big Data [10] collection will facilitate customer profiling that allows to define customer needs and wants more effectively. Companies will have to give their customers the

[10] ”Big Data” - the term which is often used to describe massive, complex, and real-time streaming data that require sophisticated management, analytical, and processing techniques to extract insights (Gupta, 2016).

feeling that the product was made specifically for them. The new level of customer satisfaction will demand functionality and connectivity, rather than a simple benefit of ownership (Newman, 2016).

In addition, technical resources will allow companies to establish high quality, efficient and flexible production processes resulting in a complex and wide choice of designs and geometrics. Use of additive technologies, for example, 3D printing [11] and rapid prototyping [12], will allow to manufacture on a high scale and larger quantities. Machines will work directly from computer models, so clients can request unique shapes without existing manufacturing limitations (SPA Lasers, 2015).

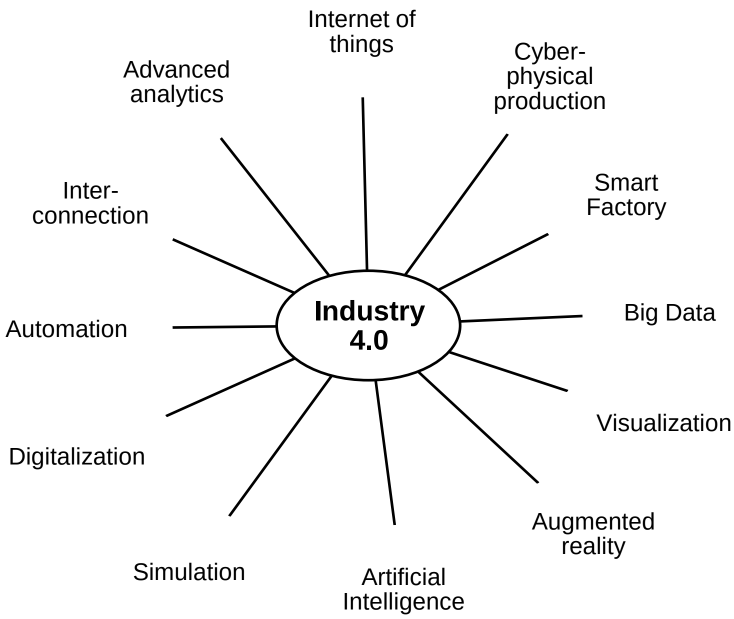

Figure 4. Industry 4.0 Trends

[11] "3D printing" is a technology that produces solid objects from digital designs by building up multiple layers of plastic, resin, or other materials in a precisely determined shape (Bono, 2016).
[12] "Rapid prototyping" is a group of techniques used to quickly create a model of a physical part or assembly using three-dimensional computer aided design data.

2.4.1 LoRa technology

Due to the fact that *automotive data interchange* is one of Industry 4.0 main characteristics, this sub-chapter presents information about the new trend in this field – the use of LoRa technology, which revolutionizes the way connections are made within the fourth industrial revolution. Even though in this paper the author will specifically talk about LoRa, it is important to mention that there are other equivalent technologies developed by various companies.

Most of current connective solutions are expensive, high in energy consumption and small in range.

LoRa (Long Range) is a modern technology initialed by the industry leaders to enable the Internet of Things concept and drive the connected world to the full potential (Figure 5).

Figure 5. LoRa logo (LoRa Alliance, 2016)

LoRa is the physical layer or the wireless modulation which creates the significantly increased long range communication link (LoRa Alliance, 2016). Although similar technologies have been used in military and space communication for many years, it is the first low-cost implementation for commercial usage.

LoRaWAN which defines the communication protocol and system architecture, represents one open global standard (LoRa Alliance, 2016).

In general, LoRa is characterized by the low power (battery lifetime), low cost, long range (over to 15 km) and high data rate. LoRa is flexible and easy to adopt, it is scalable to deal with growing demand and has security and encryption to protect data. Its use possibilities are almost endless, which is facilitated by the sensors and devices that can send and receive information even if located indoor or underground.

Its significant benefits are network capacity and security as well as possibility to enable the connectivity of any kind of device or solutions.

2.4.2 Blockchain technology

Making transactions, current supply chains have to rely on intermediaries every step of the way – from government and lawyers to dealers and banks, which adds costs. Nowadays, Industry 4.0 brings the trend towards decentralized technologies that can be used collaboratively opening more opportunities for Blockchain technology.

Blockchain is a more efficient way to store and record transactions which was created in 2008 in order to manage digital currency – Bitcoin and secure its activities. Blockchain represents transactions put in blocks that are cryptographically linked to each other. Blockchain offers all parties involved in the business network secure and synchronized chain, recording every sequence of information from the beginning to an end (Technology Trends, 2016).

With Blockchain - the data is transparent, stored publically and cannot be edited by a single owner, which eliminates a risk of fraud. The technology also has mechanisms that resist falsification ad duplication (Huckle, 2016). If someone makes an unauthorized change in the transaction, everyone in the chain has to approve it.

Blockchain is a faster, cheaper and more secure management of data. Besides, it is a complex and irreversible chain that is difficult to hack. To sum up, Blockchain is a distributed database that provides security and allows to speed transaction processes (Huckle, 2016).

The same technology has to be used within the concept of Industry 4.0 in order to provide goods and services more efficiently with the potential to lower costs on all levels. Besides, it should not be limited only to transactions management. Technology should establish trust and allow to track and trace all types of shared data that occurs at any period of time in relationships between a company, its customers, and suppliers.

2.4.3 Emerging factory types

The modern business environment is dominated by change and uncertainty. Within Industry 4.0 concept, companies are forced to identify and develop unique manufacturing capabilities, be innovative in producing and delivering products. High flexibility, low volumes and short delivery times are required to meet the demand.

There are three emerging factory types that differ depending on which demand segment and needs companies address (McKinsey Digital, 2015):

Smart automated factory is the first new type that is characterized by full automation and mass production at low cost. These plants are digitized, highly cost efficient and produce large volumes.

Customer-centric factory will be based on data-driven demand prediction and characterized by the production of highly customized goods and affordable costs. Machines will be extremely flexible and able to adapt to changes in demand in terms of volumes, specifications, and other parameters quickly. After customers place their online orders, the models will be sent directly to the most suitable factory. Despite machines' need to adapt, factories will still be able to provide high productivity due to processes automation. Moreover, the use of additive technologies and 3D printers will influence the range of products that the line can make, opening up an extensive catalog of options without increasing inventories.

E-factory in a box is an agile, small-scale, mobile and prefabricated facility addressed to niche and remote markets. The concept will represent standardized modules that can be installed in containers and easily transported. The factory will be quick to set up, lightly automated and able to produce a limited range of products at a new location. In addition, customers will be able to stop by and design their own products on-site, choose structures and materials and draw on simulation tools with the help of specialists. 3D printing, robotics[13] and end-to-end information flow will enable highly-skilled central teams to support the e-plant in a box and facilitate operators' work.

Therefore, the e-factory in a box does not need to be located in an industrial area and will be highly adaptable to local trends and fully integrated into its ecosystem

Even though, the impact of the new development differs between industries and companies, the planning and transformation processes follow a common model. It is important for businesses to remember that adoption of Industry 4.0 concept is not only about the latest technology, it must start with the roots, which includes the people, the culture, the strategy and the processes. Besides, careful investigation of possibilities, benefits and risks must be carried out.

2.4.4 New business models

Industry 4.0 facilitates the rise of new business models that recognize data as a valuable asset and are driven by opportunities to collect, use and share information. Business models outline companies' strategic goals, sources of profit and products and service portfolio. Within the concept of Industry 4.0, business models transformation is crucial for maintaining competitive edge.

New business models focus on the value creation for the company and more importantly for all stakeholders. They lead to increase in

[13] "Robotics" - a branch of the artificial intelligence and field of computer science and engineering concerned with creating robots – machines capable of carrying out a complex series of actions automatically; devices that can move and react to sensory input (Webopedia).

individualized and innovative products and service offerings and integrated solutions based on the Big Data.

New technology solutions change employees' roles from operators to problem solvers and facilitate collaboration of entire value chain, resulting in an increasing customer integration into product and service engineering and design (Arnold, 2016).

There are five emerging business models:

1. Platform or ecosystem business model

Business ecosystem represents the shift from a random gathering of participants to a structured community.

The first new type of business model has emerged around so-called platforms[14] that can act as a marketplace linking supply and demand. Platforms connect value chain members and exchange information about products, services and various process by the communication stream. Companies can either develop their own advanced products and applications or use service providers.

2. Pay-per-use business model

A completely new way for selling products in the manufacturing industry is to use the pay-per-use business model. In this case, payment is based not on the fact of simply equipment ownership and a fixed price, but on the fact of usage. This business model introduces opportunities for a supplier in the way of customer relations and data collection. The model enables a try-before-buy approach and allows to increase revenue per subscriber.

3. Subscription-based model

Another emerging business model is characterized by increasing flexibility and quick adaptability. Subscription-based model means that a customer pays a subscription price to have access to the specific product. It gives

---

[14] ”Platforms” - short-hand for “technology” or “software” platform, which is the digital layer that allows business partners to connect and interact from any applications or devices (Korsten, 2015).

the possibility for selling the idle time while locating a machine on the factory of one manufacturer. It facilitates predictable cost over the term of the plan and the ability to spread the cost of the subscription over time.

4. Intellectual property -based business model

Companies that are involved in technology-intensive domains and have the ability to create, own and sell intellectual property, will adopt IP-based business model (Ferriani, 2015).

Even though currently manufacturing companies lack the knowledge and experience to generate value from intellectual proprietary data that they own, the new business model could be based on the subscription of software, maintenance, and support. To monetized knowledge and deep expertise on their products, for example, companies could offer add-on service such as training courses.

5. Data-driven business model

Gradually, Big Data is proving to be a crucial element of economic growth. Having access to and combining large datasets opens up opportunities that were not previously possible (Bulger, 2014). This model is built around skill in analytics and software intelligence.

There are various direct and indirect methods for monetization of data.

Generating data through primary product and crowdsourcing can be examples of a direct approach. Crowdsourcing of data means that companies receive contributions from a large online based community, rather than from their employees or suppliers. It gives businesses the opportunity to improve their data-driven offerings with external knowledge at an affordable cost.

Indirect monetization, on the other hand, means the use of internal data. For instance, using the information gathered from machinery utilized by a specific customer can generate value-added services (McKinsey Digital, 2015).

Thus, the main transformation of business models is characterized by a shift from physical product revenues towards more service-based revenues, platforms, and developer ecosystems. The choice of a business model depends on company' specialization, knowledge, data, and assets.

No matter which assets the company builds – physical, intangible or organizational, the development has to be connected with the digital strategy of the company.

2.5 Opportunities and benefits for manufacturing industry

According to the survey conducted in 2014 by the market research institution: digitization will have a temporary influence on both our living and working environments. Industry 4.0 offers various opportunities for the industrial sector to develop its leading global position. This sub-chapter will introduce various opportunities and benefits obtained by the manufacturing companies after applying the concept of Industry 4.0 to their businesses.

Core principles of the fourth industrial revolution are connection of people, things, and machines. It is of great significance to remember that to ensure smooth industrial digitalization companies must cooperate and connect through their entire value chain.

The following sub-chapter of my thesis is based on the survey results conducted by various market research institutions. My goal is to collect relevant information and explain opportunities that Industry 4.0 arises for manufacturing industries.

According to the survey report of TNS Emnid, conducted among 235 German industrial companies, most of the surveyed businesses have already implemented the Internet of Things concept in their divisions. Like that 1/3 of the respondents are already actively working on digitalization, while 1/4 classifies their degree of digitalization as high and have already experienced above average growth in recent years (Koch, 2014).

So, what are the opportunities underlying the new concept?

The major goals of the Industry 4.0 are to increase customer satisfaction, achieve high flexibility and efficiency, as well as low energy consumption and costs. To do so, companies must implement a specific strategy to the entire business process and make digitalization a crucial part of the CEO agenda.

The potential of the smart factory goes far beyond the optimization of production technologies. Starting with digitalization and automation of vertical and horizontal value chains, companies must create intelligent and connected solutions for their products and services portfolio. Thus, new connecting technology leads to the establishment of the digital business model, which means increasing customer benefits, performance relations and innovative product portfolio (Koch, 2014).

Being digital, companies optimize and secure the flow of goods and information through the value chain. Besides, optimal connections of manufacturing systems allow to prevent failures, increase quality and reduce cost (Lopez Research LLC, 2013).

According to the TNS Emnid research, a noticeable quantitative advantage resulting in efficiency increase of 3,3% per year is anticipated by companies who invest in digitalization. They also expect 2,6% reduction in production costs; however, this might only be achieved if there is an equivalent change in the entire supply chain (Koch, 2014).

Furthermore, the impact of production on the environment in terms of pollution, resource consumption and global warming is severe. Industry 4.0 facilitates the creation of energy and resource efficiency by intelligent analysis of information. It allows to increase production by the growth in transparency throughout all manufacturing processes; improve quality of the product by integrated use of data; make processes more flexible and focus on core areas of specific value chain (Koch, 2014).

Another benefit of the concept includes the ability to acquire and organize Big Data in order to maximize profitability and improve decision-making. Digitalization increases understanding by making huge amounts of data accessible and ready to use (Brynjolfsson, 2014).

The cyber-physical production systems are capable and responsible not only for automation of organizational processes but also for maintenance management. Systems' use will enable rapid reaction to changes in demand, stock level or errors, which will lead to the overall waste reduction.

In addition to benefits of predictive maintenance mentioned in the previous chapter (minimizing downtime, increasing productivity and cutting costs), it is important to mention that the use of the technique will allow companies to manufacture part on demand, which will lead to a decrease in stock.

In B2C and to some extend in B2B, Industry 4.0 customers will not have to select products from a fixed range set by the manufacturer, on the contrary, they will individually combine required functions and components. Such range of variety will become profitable for companies, consequently increasing the size of the market and turnover.

In addition, it will not be enough to just have a good technical product anymore; the new product must be presented by superior sensor[15] technologies, connectivity, and generation of data (Koch, 2014). Emerging and exponential technologies, which take a significant part in the transformation to Industry 4.0, will influence products customization, boost customer focus and save costs, thus, open new opportunities and affect companies' competitiveness (Deloitte AG, 2015).

[15] "Sensors" - device that responds to a physical stimulus (as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control).

Even though it might seem that with the establishment of smart factories there will be fewer jobs for people in the manufacturing sector, this is not exactly true. Industry 4.0 will require skilled workers for the places that cannot be automated. Knowledge-based experts and decision-makers, people with digital and analytics skills, for example, system planners, engineers or coordinators will be of great demand (Korsten, 2015).

Cyber-physical production based companies will succeed in meeting the growing demand for the work-life balance for their employees by means of smart systems that can organize work more efficiently and deliver a new standard of flexibility (Kagermann, 2013).

Beside, disruptive technologies (for example, wearables and connected sensors) can facilitate safer conditions for workers, increasing labor productivity and effectiveness (Sniderman, 2016). Manufacturing sites are dangerous because of the heavy equipment used, materials involved and the physical nature of work. Plant managers will be able to fully monitor the status, identify the exact location and check safety of all operators on the manufacturing site, and, in case of emergency, employees will just need to press a button and call for help from a control center (Korsten, 2015).

Decreased production costs and reduced importance of labor costs could also contribute to the repatriation of manufacturing to Europe.

Here is a summary of Industry 4.0 benefits for companies:

- Advanced planning and controlling with relevant, real-time data
- Rapid reaction to changes in demand, stock level, errors
- Sustainable manufacturing/ resources efficiency (materials, energy, people)
- Higher quality, flexible production
- Increased productivity
- Ad-hoc reaction to market changes
- Personalization of products
- New level of customer satisfaction

- Increase in competitive advantage by the successful digital business model implementation and technology creation
- Costs and wastes reduction
- Safer work conditions
- New work places
- Work-life balance
- Increase in revenue
- Innovative company's image

When companies will benefit from the concept implementation, what will be the advantages for the customers and end-users?

Industry 4.0 is believed to reach the customers of the future. Smarter and safer products and services; personalized, unique designs; easier ordering process and faster delivery; access to data and ability to track orders starting the engineering step –these are some of the customer's benefits. In the future, customers' buying and behavior patterns will change, allowing them to purchase and control anything they desire using the Internet. With Industry 4.0 their needs will be easily perceived, met, and exceeded.

Stepping aside from the manufacturing industry and B2B market, a great example of the entirely new customer experience is presented by the real-estate market. With the use of virtual and augmented realities, the way that potential homes buyers are engaged in the whole process is different. For instance, using the virtual reality applications clients can walk through the house not actually being on site. Moreover, augmented reality technology allows to design 3D, life-like, interactive home models in order to make a precise demonstration of renovation or construction plans in a way that older techniques (for example, photos) could never compete (Augment, 2016).

Nowadays, industrial companies of all sizes come to an understanding that they can meet increasing customer needs and remain competitive only with significant investments in digitalization. The ability to generate additional value from available data will allow to maximize customer benefits and boost profits.

Industry 4.0 opens great perspectives in data and in the efficient use of gained opportunities.

The concept of smart factories is based on sustainable and service oriented business practices (MacDougall, 2014). Due to increased connectivity and advanced use of information in all processes, newly established business models will become more data-based, organized and customer-focused.

Thus, according to the TNS Emnid marketing research, by 2020, European industrial companies will invest €140 billion annually in industrial internet applications (Koch, 2014).

2.6 Challenges and risks for manufacturing industry (PESTEL)

Industry 4.0 is a complex concept, which represents not just replacing old facilities with new ones, but changing the organizational culture and overcoming managerial challenges created by the disruptive technologies along three different dimensions: the next prospect of operational effectiveness, new business models and foundations for the digital transformation of the company (McKinsey Digital, 2015).

In the following sub-chapter, various challenges caused by the Industry 4.0 will be analyzed using the PESTEL framework. It includes political, economic, social, technical, environmental, and legal factors.

Besides, the “Risk matrix”, which estimates the amount of harm that companies can expect under specific circumstances, will allow to emphasize the most relevant to modern situation risks. The likelihood of the harm to occur and its impact are characterized as High, Medium and Low.

Technical and environmental challenges:

Connected systems embedded in all business processes along the horizontal and the vertical value chains lead to a massive and continuous data flow. The ability to organize, analyze and efficiently use such data volumes is very important for success of companies that strive to gain digitalization. Companies must avoid information leakages – spots where information gets lost, because they cause inefficiency, as the lost data could have been valuable for a stakeholder somewhere else in the value chain (McKinsey Digital, 2015). Thus, a major challenge set by Industry 4.0 will be managing the large quantities of data. Figure 6 shows that likelihood of difficulties caused by the new technology and data management are high which might lead to unpleasant consequences. Being aware of high risks, it is critical for companies to take actions before the problem occurs.

		Impact		
Likelihood		Low	Medium	High
	High		X	
	Medium			
	Low			

Figure 6. Risk matrix for technical challenges

Another point that businesses have to deal with is the ongoing climate change and natural resources scarcity, leading to the need for automated sustainable solutions (Hecklaua, 2016).

In addition, next challenge includes resources issue. Many companies find it difficult to support transformation because it requires significant investments. However, other simply do not want to modify and deal with complexity in their grown structure. The choice of the technical provider is also of major importance, as company's future and success depend on the technology it will implement (Lopez Research LLC, 2013). Companies providing digitalization products and services, on the other hand, will have to find ways to capture value and be ahead of quickly evolving technology, otherwise there offering risks commoditization.

Economic challenges:

Due to the fact that concepts of Industry 4.0, Internet of Things and Digital Enterprise are quite new to the industry, it is difficult to estimate outcomes of actions and decisions taken by companies. That is why some companies are not yet convinced about starting the process of digitalization. Since they do not clearly see economic benefits and there is lack of uniform standards and regulations for the information and data exchange, organizations are scared to make high investments. Besides, depending on company's size the impact of the Industry 4.0 varies. As a result, some companies do not feel any need to digitalize yet.

The probability of risks caused by economic challenges is estimated to be medium with the low impact, as currently no dramatic consequence is expected if companies fail to invest or struggle in implementing the concept (Figure 7).

		Impact		
		Low	Medium	High
Likelihood	High			
	Medium			
	Low		X	

Figure 7. Risk matrix for economic challenges

Social challenges:

In order to stay competitive in the process of continuous globalization, companies are pushed to reduced time-to-market, deal with shorter product lifecycles and the need to cut costs. Growing customer needs and wants in the area of digitalization and connection, lead to collaboration of entire value chain within a company, which results in highly complex organization of processes (Hecklaua, 2016).

Another challenge for companies to digitalize is a lack of qualified employees. Transformed processes and business models require new technical skills and qualifications from the workers. Therefore, implementing the concept of the industrial internet, where all systems are connected and process-dependent, making use of technology may occur to be a major obstacle for personnel. An important problem to mention is a talent gap in manufacturing due to retiring workforce (EY, 2016).

Moreover, with the emergence of highly automated factories, where machines are able to carry out the task in a more efficient way than humans, there is a risk that a number of less-demanding, low-skilled occupations, where workers perform repetitive tasks will become unnecessary and disappear. Machines have obvious advantages over human workers - they can work non-stop every day without needing a break; they also won't demand healthcare or the salary increase from their employer, besides, their "arms" are capable of operating independently and making two unrelated tasks at once (Brynjolfsson, 2014).

Even though social risks that are described above are highly important and have to be taken into consideration, they are not extremely relevant at the current level of Industry 4.0 development. For instance, since the concept is quite new and not widely implemented, it is doubtful that in the nearest future machines will substitute people. However, if technology leads to more efficient use of labor, then does this automatically lead to reduced demand for labor? (Brynjolfsson, 2014). The answer is "yes" and there is proof among the manufacturing companies already nowadays (Figure 8).

	Impact			
Likelihood		Low	Medium	High
	High			
	Medium		X	
	Low			

Figure 8. Risk matrix for social challenges

Political and legal challenges:

Standards are crucial to enable the exchange of data between machines, systems, and software within a network. Rules and regulations, standardized terms and definitions create a secure basis for development, protecting environment and equipment (Prof. Dr. Adolph, 2016). In case communication regulations are only recognized nationally, competition and trade may be encumbered and costs can rise (EPRS, 2015).

Political environment is probably one of the most unpredictable factor in business. When it comes to the concept of Industry 4.0, data protection is very important, as it is computed in the "cloud" and is highly exposed to the damage, but countries might have different data protection and IP laws. Political instability issue is of great significance too, let's take China as an example. Interconnection of the value chain is one of the key elements of Industry 4.0 and is entirely based on the use of Internet. "Chinese government has long had restrictive policies on what people can and cannot do online", thus, any sudden changes and new regulations might disrupt operations of Industry 4.0 dedicated companies doing business with or in China (McCarthy, 2016).

Data security is another big challenge faced by the companies. There are various risks related to Internet of Things devices. For instance, digitalization creates the risk of cyber-attacks, unauthorized access, and misuse of information, control over devices or their damage. Since machines and industrial systems are rarely offline for security updates, above mentioned risks are very high. Besides, there is another risk facilitated by the massive flow and rapidly growing data that is being generated by smart objects (Weber, 2016). Due to the fact that old systems were not designed to be connected, retrofitting old systems in accordance with Industry 4.0 applications may also increase security risks (Sniderman, 2016).

Moving towards increased automation, manufacturing companies face unique security issues, among which are – loss of data, production control and system's availability, financial loss, or maybe even injuries on production.

Furthermore, basing all business processes on technology is recognized as a big risk too, as sudden system's failure or deadlocks might lead to severe consequences, damaging company's reputation and brand image (Wanga, 2015).

Summarizing all above mentioned risks, Figure 9 outlines the critical need for companies to manage political, legal and security challenges while implementing the concept of Industry 4.0.

		Impact		
		Low	Medium	High
Likelihood	High			X
	Medium			
	Low			

Figure 9. Risk matrix for political and legal challenges

2.7 Risks mitigation

The given sub-chapter represents possible solutions to some of the risks and challenges described is the previous part of the work. Information is combined and based on various resources.

1. Big data management

Cloud-based manufacturing will contribute significantly to the success of Industry 4.0. The use of cloud[16] based applications makes it easy to gather, monitor, distribute and analyze data, it provides flexibility and unlimited access to all key information. Besides, it saves costs by eliminating the need for heavy local installations of applications. Thus, cloud-based solutions facilitate efficient use of Big Data flow, not only between factories but also across the entire value chain (Gollenia, 2014).

Another enabler of big data projects is a Master Data Management[17] (MDM). Master data typically includes the core entities of the enterprise including customers, prospects, citizens, suppliers, sites, hierarchies and chart of accounts (Gartner). Nowadays, Master data is already useful, but within Industry 4.0 concept it will become a uniform, fully automated and interconnected file for business data of the organization, creating deeper insight and enabling efficient decision making. MDM will help to structure and harmonize big data and make it actionable with a clearer view on information (Bahrenhurg, 2016).

2. Talent

Industry 4.0 requires skilled and digitally sophisticated workforce. Therefore, new competencies must be developed both on individual employee level and within the organization as a whole. The solution can be a creation of certified training courses adapted to the requirements of the digital world that would help workers with changing the content of the job and provide them with knowledge for dealing with short-term and unexpected activities (MacDougall, 2014).

[16] ”Cloud-computing” is an Internet-based technology that offers an elastic services with shared resources and data, which provides on-demand access to a shared pool of configurable computing resources (Thamesa, 2016).

[17] Master Data Management – (all data in one file) a technology-enabled discipline in which business and IT work together to ensure the uniformity, accuracy, semantic consistency and accountability of the enterprise’s official shared master data assets (Gartner).

Additionally, industry 4.0 calls for employees with a foundation in mathematics, data science and information technology. Governmental policies can officially create the basis for the education and help with increasing demand for well-trained people - starting in school (Koch, 2014). Besides, in order to recruit next generation workforce - new roles, benefits and career paths must be created and emphasized (EY, 2016).

There already exists an initiative called the “Academy Cube” that was founded in Germany and supported by international industrial enterprises and public institutions. The initiative is aimed at unemployed graduates in ICT and engineering and underlines the need for the training formats within the concept of Industry 4.0. Since 2013 it has been offering workers’ the opportunity to get a qualification and connect them with industrial enterprises (Kagermann, 2013).

3. IT resources and infrastructure investments

High technological investments should not prevent businesses from building their Digital Enterprise, due to the fact that new technology adoption will be followed by increasing cost reduction potentials (Arnold, 2016).

Industry 4.0 accepts two ways of company’s digitalization. The first one is the adaption of existing system, while the other one requires installation of entirely new infrastructure (Deloitte AG, 2015). To identify the most logical approach, companies should analyze their current situation and make the right choice, which will secure a long-term market advantage.

When making a decision, costs and expenses are crucial factors for most manufacturing companies. That is why it is important to carry out a thorough analysis and identify if existing systems and networks can be modified and used.

4. Lack of standards

Many challenges cannot be defeated by companies alone and demand joint efforts of industrial associations, trade unions, and employer’s associations. Official governmental policies can support development of Industry 4.0 and facilitate companies in implementing the concept. With clearly defined uniform industrial standards and regulations at the European or international level companies would have support and, therefore, be more enthusiastic to invest in industrial internet (Koch, 2014). In 2014, for instance, the European Commission in the discussion for the ”European Industrial Renaissance” officially stated the importance of digital technology in order to increase European productivity; and later the same year a “Strategic Policy Forum on Digital Entrepreneurship” was created to focus on the digital transformation of European industry and enterprises (EPRS, 2015).

Therefore, commonly agreed on international standards and communication protocols can encourage interoperability across various sectors and countries, ensuring open markets worldwide for European manufacturers and products.

5. Data security

Policy-makers and industrial associations must define international uniform standards and competitive data protection laws in the area of IT security.

To minimize the risk of cyber-attacks companies must apply tailored risk management and suitable security strategy across its value chain (Deloitte AG, 2015). For instance, manufacturers could use such practice as tracing and tracking with built-in unique identifiers, which would reduce the risk of misplacement of materials, as well as, tamper theft and counterfeit possibilities (Goldenberg, 2016).

In addition, companies themselves must also develop skills to meet threats of the digital world and be prepared not only to prevent cyber-attacks, but also deal with them (Deloitte AG, 2015). All employees have to be involved and properly trained to be able to mitigate the risk of compromised security (McKinsey Digital, 2015). Encryption algorithm plays an important role as a valuable and fundamental tool for the protection of data (Stergiou, 2016).

Furthermore, cyber security[18] is not a concern of a single company, on the contrary, the vast number of stakeholders involved in the value chain play significant role in understanding risks. That is why manufacturers should conduct stakeholders' analysis and educate them about the importance of cybersecurity, emphasize the risks and awareness (Goldenberg, 2016).

System's failure and deadlock risks can be reduced by a dedicated investigation, elimination of possible problems and creation of prevention strategies (Wanga, 2015). For instance, cloud-based services are not only used for managing assets and monitoring conditioning but can also help in detecting anomalies and predicting maintenance.

Smart choice of IoT platform vendor with high-tech built-in safeguard solutions is of high importance as well. Evaluation of provider's financial performance, industry knowledge, partners, and range of offering is necessary (Lopez Research LLC, 2013).

3 IMPACT OF INDUSTRY 4.0

Through the time, Industry 4.0 is expected to have a big impact on global economies. According to the European Parliament report, the concept can deliver estimated annual efficiency gains in manufacturing of between 6% and 8% (EPRS, 2015).

Digitalization has dramatically disrupted the industry and left manufacturers no choice but to adapt, redefine and integrate. The chapter will discuss six major areas influenced by the concept of Industry 4.0:

[18] " Cyber security" is the protection of computer systems from the theft or damage to the hardware, software or the information on them, as well as from disruption or misdirection of the services they provide (Goldenberg, 2016).

manufacturing process, technology and sector, competition, product/service, warehousing and relationships within the value chain.

3.1 On process

According to the McKinsey Industry 4.0 Global Expert Survey 2015, manufacturing companies identify several improvement potentials enabled by Industry 4.0. The largest expected improvements include labor, quality, and resource/process.

1. Labor is mentioned as an important improvement due to the fact that it is a major cost driver in most industries. Thus, digitalization affects labor productivity by reducing manual processing and waiting time or increasing the speed of operations.
2. Industry 4.0 includes advanced process control and digital performance management to eliminate quality issues, as possible defects or failures to meet quality requirements lead to extra costs.
3. Digitalization improves a process and drives value in terms of material consumption and speed (McKinsey Digital, 2015).

Although, above mentioned points are recognized as the most important, the area of improvements might depend on the company and industry. Thus, among the other expected improvements are *asset utilization* that allows making the best use of company's machinery*; control of inventories and supply/demand match* due to the fact that smart factories can predict demand and control supply in stock; *time to market* and *sales/after sales services*.

3.2 On technology and sector

Apart from the processes improvements facilitated by the installation of new infrastructure, the fourth industrial revolution will also affect machines themselves. Digital Enterprises will be equipped with intelligent, autonomous and mobile technologies that are increasingly sensitive and easy to operate. “A set of disruptive digital technologies will transform the manufacturing sector by 2025” (McKinsey Digital, 2015).

Therefore, digitalization of the manufacturing sector is driven by a number of disruptive technologies. Firstly, Big Data, Internet of Things and Cloud technologies allow companies to enable powerful storage, transmission, and processing of information.

Moreover, advanced analytics, digitization and automation are supported by increase in available data, innovations in artificial intelligence and machine learning[19] in addition to improved statistical techniques and equipment services.

In addition, another driver is characterized by the use of touch interface, as well as virtual[20] and augmented realities[21] in order to shorten the period of time required to conduct tasks (McKinsey Digital, 2015). For example, augmented-reality-based systems enable virtual training or coaching, facilitate the ability to choose required parts in a warehouse or send instructions over mobile devices (Rüßmann, 2015).

Finally, additive manufacturing (for example, 3D printing), advanced robotics and energy storage are drivers enabling cost reduction, range of materials expenditure and increase in quality – benefits associated with digitalization. Disruptive technology of Industry 4.0 concept improves the way companies organize their activities. The ability to perform simulations is critical to facilitate rapid and precise decision making. Simulation also

[19] ”Machine learning” - A type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed (TechTarget).

[20] ”Virtual reality” - provides a computer-generated 3D environment that surrounds a user and responds to that individual’s actions in a natural way, usually through immersive head-mounted displays and head tracking (Gartner).

[21] ”Augmented Reality” - is the real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects (Gartner).

allows operators to test and optimize machine settings for the next product in line, decreasing setup times (Rüßmann, 2015).

3.3 On competition

Nowadays, considerable amount of the disruptive technologies is presented by small, innovative companies as they are more responsive to change and are able to implement new business models more easily than larger companies. Thus, they are considered to have a competitive advantage within the transforming environment.

The rapidly changing competitive landscape is stimulated by disruptive technologies that give a chance to the small and new players to enter the market and capture emerging value pools. Therefore, the estimated influence of the Industry 4.0 on the market shows that there is a possibility of highly specialized players emergence and entry of organizations from outside the traditional manufacturing field, which will lead to increase in an overall number of players and drive complexity (McKinsey Digital, 2015).

Consequently, traditional value chains are going through the major transformation - a higher degree of collaboration and specialization is likely to occur, which might be especially beneficial to companies with a high level of complexity and great investment needs for production facilities.

In addition, the quality of production has a great impact on the competitiveness. It is estimated that the top 100 European manufacturers could save €160 billion if they eliminated defects, scrap, and reworking, which will become possible with the adoption of Industry 4.0 concept (EPRS, 2015).

3.4 On product

Industry 4.0 will influence the entire product lifecycle - from design and production to the consumption phase and end-of-life. With the use of additive manufacturing and other advanced IT technologies, product improvements are inevitable. Industry 4.0 allows to modify existing products and make them safer and smarter by adding sensors and enabling connectivity, or developing entirely new products and services to boost user experience.

Besides, digitalization facilitates production - makes it possible to carry out proactive sensing and quality control for detecting defects and improving the product by allowing customers to test and provide feedback on the early design stage via prototypes and virtual simulation.

3.5 On logistics

The important element of the supply chain infrastructure is a distribution center of the company, which is within the concept of Industry 4.0 considered to be a strategic resource of competitive advantage.

Industry 4.0 can influence the way finished goods are moved, warehoused, and distributed, because automated systems adapt to their environment and handle tasks more efficiently. Therefore, key impacts of the fourth industrial revolution on the distribution centers are characterized by the well-organized asset utilization, reduction of delays, response time improvements and downtime minimization – resulting in overall inventory optimization (Taliaferro, 2016).

Besides, the new industrial era makes it possible to simplify order process and resolve problems online, improve shipment status information and enable real-time tracking and tracing as well as fast trucks (un)loading. Overall improvements in the process of logistics yield internal company’s efficiency, increase revenue and improve customer satisfaction (Küng, 2016).

3.6 On relationships with customers and suppliers

Digitalization and connectivity will bring organization's relationships with its customers and suppliers to the new level. Within the concept of Industry 4.0 collected data can be intelligently used to meet and perceive customers' needs, plan demand, act proactively and even involve them in the company's operations.

"We are working with many customers to establish a new strategic digital core competency to create completely new and enhanced product and service offerings" - Bernd Leukert, Member of the Executive Board, Products & Innovation at SAP SE (McKinsey Digital, 2015).

By the use of technologies that collect large amounts of data, Industry 4.0 makes it visible and available in real time to the up- and downstream supply chain. Exchange of information, improved data flow and connectivity can help supply chain stakeholders to allocate resources to critical tasks, maximizing the efficiency of a supply chain, enhance operations planning and guide future improvements. Additionally, data generated through Industry 4.0 technologies can be used for pricing optimization, accounting, and billing (Taliaferro, 2016). Therefore, connection and interaction within the entire supply chain will facilitate elimination of organizational borders (Pfohl, 2015).

With the increase of investments and joint forces of companies, associations, trade unions and policy-makers, competitiveness of European businesses and industrial locations can be strengthened, which will greatly impact the economy.

Therefore, according to the 2016 Global Industry 4.0 Survey, companies across various sectors expect significant growth opportunities and benefits over the next five years after implementing Industry 4.0 concept. On average, surveyed predict to reduce operational costs by 3.6% each year (Geissbauer, 2016).

4 COUNTRIES' ACTIONS

"The industrial sector is important to the EU economy and remains a driver of growth and employment" (EPRS, 2015). That is why, due to decreasing manufacturing performance, EU Commission has established a target of increasing sector's share from 16% in 2012 to 20% by the year 2020. However, some people argue that the goal cannot be achieved in the foreseeable future, others are convinced that it sends out the correct idea of the need to transform and is possible to reach by means of Industry 4.0 (Heymann, 2013).

Therefore, on behalf of the Digital Single Market Strategy, the European Commission initiates industrial sectors to exploit new technologies and helps them to manage a transition from old to new systems.

Industry 4.0 is supported and largely invested in by a number of countries that represent the largest industrial sectors by added value in the EU. These countries include Germany, Italy, the UK and France (ERPS, 2015).

Germany.

To encourage the development of smart factories Germany has invested 200 million euros starting 2010 on behalf of the High Tech Strategy 2020 Action Plan. This encourages the application of the digital technologies to the industrial sector by both public and private sectors as well as government (ERPS, 2015).

Italy.

”Fabbrica del Futuro” - Italian project that took place in the year 2013 was designed to enhance quality, flexibility, and customization in the manufacturing sector. It was responsible for research activities in areas of customization, sustainability, ICT, material recovery, control systems, factory reconfiguration, quality control and human-machine interaction (ERPS, 2015).

The UK.

In its turn, the UK has also introduced some policies in order to influence manufacturing responsiveness, sustainability, openness to the new markets and dependence on skilled workers (ERPS, 2015). Like that, the high-value manufacturing centers were opened and received more than £200 million of government funding since 2011 with the purpose to facilitate companies’ research and expertise in areas of, for instance, advanced technologies and process innovation (ERPS, 2015).

France.

France has created the framework called “Industry of the Future” that unifies several projects aimed to increase companies’ awareness of the need to transform and their desire to develop new technical base and invest. For instance, the factory of the future project was launched in 2015 to create demonstration centers to showcase new products and services dealing with robots, Internet of Things and Big Data. Important to mention, that France has provided 1 billion euros available in loans for the SMEs that to develop robotics, digitalization or energy-efficiency projects (ERPS, 2015).

Switzerland.

Switzerland is not yet a leader in digitalization and, according to “Business and Innovation Forum Slovakia – Switzerland” report, falls behind the European Union. In 2015 initiative called “Industry 2025” has been launched and supported by various industry associations with the aim to signal the need for transformation, outline new opportunities and change established in the sector mindset (Kaiserswerth, 2016).

The United States of America.

Apart from European countries, Industry 4.0 has also boosted interest in the USA, where manufacturing sector has always been a significant part of the economy. The USA as well as Germany has put considerable affords for transforming manufacturing sector. Several key areas have been addressed in order to facilitate country's development within the concept of Industry 4.0. First, *enabling innovation,* which is responsible for new concepts and ideas of changing the organizational and production processes, resulting in a unique and flexible offering. Second, *securing the talent* - is focusing on improving the workforce and educating the next generation, so that it is ready for the work in the rapidly changing environment of new technologies. Thirdly, *improving the business climate* - refers to creating a comfortable environment that would encourage businesses to invest, for example, tax reform, streamlining regulatory policy, improving trade policies, and updating energy policies (Kurfuss, 2014).

US's "Advanced Manufacturing Partnership" (AMP) was formed in 2011 uniting the effort of the industry, the government and universities to invest in the emerging technologies that will create high-quality manufacturing jobs and enhance global competitiveness (Kurfuss, 2014). The "Smart Manufacturing Innovation Institute" supported by the AMP in the year 2016 will bring together over $140 million in public-private investment and will help to improve energy efficiency and productivity (Energy.gov, 2016).

Besides, President Obama has suggested building the "National Network for Manufacturing Innovation" – regional centers facilitating development and adoption of technologies. Like that, "America Makes: National Additive Manufacturing Innovation Institute" responsible for additive manufacturing, "Digital Manufacturing & Design Innovation Institute" designing IT tools, sensors, etc., "Next Generation Power Electronics

Manufacturing Innovation Institute" aimed at enabling the next generation of high-power, energy-efficient electronic chips, and some other institutions were founded (Kurfuss, 2014).

China and Japan.

Asian countries also investigate into the concept of Industry 4.0. Even though China has invested a lot in the third industrial revolution and is preoccupied with establishing sustainable business activities, it is moving towards the transformation with its "Made in China 2025" initiative and currently formed the "China 3D Printing Technology Industry Alliance" (Siepen, 2015). "Made in China 2025" is inspired by the German Industry 4.0, however, is a broader project as it focuses on the development advanced and as well as traditional industries; and has specific measures for innovation, identified benchmarks and established goals. It guides manufacturing to be innovation-driven, optimized and green with the goal of raising domestic content of core components and materials to 40% by 2020 and 70% by 2025" (Kennedy, 2015).

In addition, Japan being probably the most advanced country in the field of robotics and automation has noticeable success in the field after launching "Robot Revolution Initiative". The country is constantly developing new disruptive technologies and is already using robots in many businesses, manufacturing and every-day practices (Siepen, 2015).

5 BOBST'S CASE

The following chapters form a practical part of the thesis and are based on the relevant data collected and the theoretical knowledge gained from the secondary (desk) research done in previous chapters.

To answer practical research question stated at the beginning of this thesis – *"What is Bobst's potential within the concept of Industry 4.0?*", decision to conduct a survey was taken as it was considered to be the most suitable way that will allow the author to better understand management team's awareness about the concept of Industry 4.0, evaluate their professional opinion about the company's position within the digitally transforming industrial environment.

After the survey results are collected and analyzed, the SWOT analysis and the Business Model Canvas will be made. Based on the Bobst's current situation within the concept and the questionnaire results, the author will try to develop a plan and a list of recommendations for the company's further actions.

Sub-chapter 5.1 will represent the overview of Bobst's competitors' and other companies' actions in Industry 4.0.

**Unfortunately, the following information is not available for public use as it represents company's confidential information.*

5.1 Competition and large companies' overview

5.2 Survey

5.3 Results

5.4 SWOT

5.5 BOBST's current situation

5.6 Recommendations

6 CONCLUSION

6.1 Summary of the main findings

To sum up, Industry 4.0 refers to the full automation and digitization of processes, and the use of electronics and information technologies within the entire value chain of the company. The connection of products, services, resources and value chain members require the transformation of processes, business models and company's portfolio.

Collected and analyzed throughout the thesis data gives the ability to answer the research question set at the beginning of the work – "What is Bobst's potential within the concept of Industry 4.0?"

Therefore, Bobst's current leading capabilities give it the ability to establish a data-driven organization of the future, where all internal and external activities and equipment are connected through platforms.

Companies like Bobst, who anticipate the market trends, have an innovative spirit and are prepared for the teamwork, have good prospects in Industry 4.0.

Bobst acts already now – shaping its business models, production systems, and product portfolios from a digital perspective. Short-term initiatives are launched, followed by preparation of long-term initiatives that aim at the entire organizational transformation.

As a digitalization of the whole value chain is significant for the success of Bobst – customers and suppliers will be influenced and integrated into information exchange throughout the entire product lifecycle.

In conclusion, thanks to the rapidly growing technologies within the concept of Industry 4.0, Bobst will have the opportunity to carry out larger projects and change the way products are manufactured and designed because of the available capacity. There is no doubt that the company will extend its products and services portfolio, introducing innovative ideas. Bobst will take advantage of what Industry 4.0 has to offer: wide opportunities for machine-to-human collaboration, interconnected products, and automated processes.

6.2 Reliability and validity

Reliability and validity of this study are based on the fact that the objective was clearly stated at the beginning of the project and successfully reached at the end. The outcome is aligned with the original research purpose, which shows the consistency of this study. The triangulation method which means the use of different resources to collect and interpret data about a single concept assures the credibility of findings.

Both theoretical and practical parts of the work were aimed at bringing value to the Bobst company by expanding its knowledge about the modern trend and answering the primary research question to evaluate directions for further steps. Therefore, collected theoretical data as well as practical part of the thesis can be used by the company for the further development within the concept.

6.3 Limitations and further research

It is important to mention that although the study has reached its purpose, there were some limitations. First, due to the fact that the concept is quite new, there was a lack of different arguments about the topic, and also an overall number of available published and official materials was small. In addition, some aspects of the data about Bobst could not be presented in this study to protect company's confidential information.

As this paper was made based on the interest of a particular company in the industrial sector, it has a specific focus and is not applicable to any business's case.

Therefore, ideas for further research can include development of Industry 4.0 in other sectors; in-depth study about the Industry 4.0 impact from customers' perspective or according to companies' sizes.

To conclude, being a constantly developing concept with a high impact on the business environment, Industry 4.0 is a significant topic for a deeper research.

REFERENCES

Arnold, C., Kiel, D. & Voigt, K. 2016. How Industry 4.0 changes business models in different manufacturing industries. Available at: https://www.researchgate.net/publication/304494710_How_Industry_40_changes_business_models_in_different_manufacturing_industries_rewarded_with_ISPIM_Best_Student_Paper_Award, [Accessed on 07 November 2016].

Augment. 2016. Architecture and construction. Available at: http://www.augment.com/blog/future-real-estate-vr-ar/, [Accessed on 10 January 2017].

Babbie, E.R. 2010. The Practice of Social Research. Belmont, CA: Wadsworth Cengage, 12th edition.

Bacheri, B. & Lee, J. 2015. Big future for cyber-physical manufacturing systems. NSF I/UCRC for Intelligent Maintenance Systems (IMS). Available at: http://www.designworldonline.com/big-future-for-cyber-physical-manufacturing-systems/#_, [Accessed on 12 January 2017].

Bahari, N., Maniak, R. & Fernandez, V. Ecosystem Business Model design. AIMS. Telecom ParisTech. Available at: http://www.strategie-aims.com/events/conferences/25-xxiveme-conference-de-l-aims/communications/3522-ecosystem-business-model-design/download, [Accessed on 08 November 2016].

Baheti, R. & Gill, H. 2011. “Cyber-Physical Systems.” In The Impact of Control Technology. Available at: http://www.ieeecss.org/sites/ieeecss.org/files/documents/IoCT-Part3-02CyberphysicalSystems.pdf, [Accessed on 24 November 2016].

Bahrenhurg, S. & Gortzen, M. 2016. Master Data Management. Bearingpoint. Available at: http://www.bearingpoint.com/ecomaXL/files/2016-02-26-BEARINGPOINT-accelerator-360_Master_Data_Management-interactiv_v2.pdf&download=0, [Accessed on 09 January 2017].

Bono, R. & Pillsbury, S. 2016. Industrial manufacturing trends. PWC. Strategy&. Available at: http://www.pwc.ch/en/publications/2016/benefits_management_en_web.pdf, [Accessed on 04 November 2016].

Brynjolfsson, E. & McAfee, A. 2014. The second machine age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. First Edition. W. W. Norton & Company, Inc.

Bulger, M., Taylor, G. & Schroeder, R. 2014. Data-Driven Business Models: Challenges and Opportunities of Big Data. Oxford Internet Institute. Available at: http://www.nemode.ac.uk/wp-content/uploads/2014/09/nemode_business_models_for_bigdata_2014_oxford.pdf, [Accessed on 07 November 2016].

Cohen, D. & Crabtree, B. 2006. Qualitative Research Guidelines Project. Available at: http://www.qualres.org/HomeObse-3594.html, [Accessed on 20 January 2017].

Deloitte AG. 2015. Industry 4.0. Challenges and solutions for the digital transformation and use of exponential technologies. Available at: http://www.industrie2025.ch/fileadmin/user_upload/ch-en-delloite-ndustry-4-0-24102014.pdf, [Accessed on 06 October 2016].

Energy.gov. 2016. Smart Manufacturing: Transforming American Manufacturing with Information Technology. Available at: http://energy.gov/eere/amo/articles/smart-manufacturing-transforming-american-manufacturing-information-technology, [Accessed on 24 November 2016].

EPRS. 2015. Industry 4.0 Digitalization for productivity and growth. Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568337/EPRS_BRI(2015)568337_EN.pdf, [Accessed on 16 November 2016].

EY. 2016. Digitalization in industrial products. Harnessing the power of digital. Available at: http://www.ey.com/Publication/vwLUAssets/Digital_Industrial_Products/$FILE/Digital%20Industrial%20Products-Brochure%20Single%20pages-Web.pdf, [Accessed on 31 October 2016].

Ferriani, S., Garnsey, E., Lorenzoni, G. & Massa, L. 2015. The intellectual property business model (IP-BM). Available at: http://www.ifm.eng.cam.ac.uk/uploads/Research/CTM/working_paper/2015-02-Ferriani-Garnsey-Lorenzoni-Massa.pdf, [Accessed on 08 November 2016].

Gartner. IT Glossary. Available at: http://www.gartner.com/it-glossary/ , [Accessed on 23 November 2016].

Gehrke, L., Rule, D., Bellmann, C., Dawood, D &others. 2015. A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective. VDI. Available at: http://www.vdi.eu/fileadmin/vdi_de/redakteur/karriere_bilder/VDI-ASME__2015__White_Paper_final.pdf, [Accessed on 28 November 2016].

Geissbauer, R., Vedso, J. & Schrauf, S. 2016. Industry 4.0: Building the digital enterprise. Global Industry 4.0 Survey. PWC. Available at: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf, [Accessed on 07 October 2016].

Goldenberg, S., Brown, J., Haid, J. & Ezzard, J. 2016. 3D opportunity and cyber risk management. Additive manufacturing secures the thread. Deloitte University. Available at: http://dupress.deloitte.com/dup-us-en/focus/3d-opportunity/3d-printing-cyber-risk-management.html, [Accessed on 27 October 2016].

Gollenia, A., Gollenia, U. & Lars, A. 2014. Digital Enterprise Transformation: A Business-Driven Approach to Leveraging Innovative IT. Farnham, GB: Routledge.

Gupta, M. & George, J. 2016. Toward the development of a big data analytics capability. Information & Management. Volume 53, 1049 – 1064.

Hecklaua, F., Galeitzkea, M., Flachsa, S. & Kohl, H. 2016. Holistic Approach for Human Resource Management in Industry 4.0. Procedia CIRP. Volume 54, 1-6.

Heymann, E. & Vetter, S. 2013. Europe's re-industrialisation. Deutsche Bank AG. Available at: http://www.dbresearch.de/PROD/DBR_INTERNET_EN-PROD/PROD0000000000323902.pdf, [Accessed on 24 November 2016].

Huckle, S., Bhattacharya, R., White, M. & Beloff, N. 2016. Internet of Things, Blockchain and Shared Economy Applications. Procedia Computer Science. Volume 98, 461-466.

Kagermann, H., Wahlster, W. & Helbig, J. 2013. Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Acatech national academy of science and engineering. Available at: http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report__Industrie_4.0_accessible.pdf, [Accessed on 28 November 2016].

Kaiserswerth, M. 2016. Smart Industry 4.0 in Switzerland. Business and Innovation Forum Slovakia – Switzerland. Available at: http://www.digitaleschweiz.ch/wp-content/uploads/2016/07/SmartIndustry4.pdf, [Accessed on 24 November 2016].

Kennedy, S., 2015. Made in China 2025. CSIS. Available at: https://www.csis.org/analysis/made-china-2025, [Accessed on 24 November 2016].

Koch, V., Kuge, S., Schrauf, S. & Geissbauer, R. 2014. Opportunities and challenges of the industrial internet. Strategy&. Available at: http://www.strategyand.pwc.com/media/file/Industry-4-0.pdf, [Accessed on 06 October 2016].

Korsten, M., Poweli, B., Kalyani, A., Amos, K. & othes. 2015. Industrial Internet of Things: Unleashing the Potential of Connected Products and Services. World Economic Forum. Available at: http://www3.weforum.org/docs/WEFUSA_IndustrialInternet_Report2015.pdf, [Accessed on 24 November 2016].

Küng, D. & Müller, R. 2016. Whitepaper – Opportunities for the Swiss Export Industry. Industry 4.0. Switzerland Global Enterprise. Available at: http://www.s-ge.com/sites/default/files/S-GE_Whitepaper_Industry40_2016_final.pdf, [Accessed on 29 November 2016].

Kurfuss T. 2014. Industry 4.0: Manufacturing in the United States. OSTA. Available at: http://ostaustria.org/bridges-magazine/item/8310-industry-4-0, [Accessed on 24 November 2016].

Lopez Research LLC. 2013. An Introduction to the Internet of Things (IoT). Available at: http://www.cisco.com/c/dam/en_us/solutions/trends/iot/introduction_to_IoT_november.pdf, [Accessed on 17 October 2016].

LoRa Alliance. 2016. A technical overview of LoRa® and LoRaWAN™. Available at: http://www.semtech.com/wireless-rf/iot/LoRaWAN101_final.pdf, [Accessed on 05 December 2016].

MacDougall W. 2014. Industry 4.0 Smart manufacturing for the future. Germany Trade and Invest. Available at: https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf, [Accessed on 17 October 2016].

McCarthy, K. 2016. China's new rules may break the internet warns US government. Available at: http://www.theregister.co.uk/2016/05/16/chinas_new_rules_may_break_the_internet_warns_us_government/, [Accessed on 24 November 2016].

McKinsey Digital. 2015. Industry 4.0 How to navigate digitization of the manufacturing sector. Available at: https://www.mckinsey.de/files/mck_industry_40_report.pdf, [Accessed on 24 October 2016].

Merriam, S. B. 2009. Qualitative Research: A Guide to Design and Implementation. Somerset, US: Jossey-Bass, 13-15.

Murphy, M. 2015. An AI computer learned how to beat almost anyone at chess in 72 hours. Quartz. Available at: http://qz.com/502325/an-ai-computer-learned-how-to-beat-almost-anyone-at-chess-in-72-hours/, [Accessed on 06 December 2016].

Newman, D. 2016. Top 10 Trends For Digital Transformation In 2017. Forbes. Available at:

http://www.forbes.com/sites/danielnewman/2016/08/30/top-10-trends-for-digital-transformation-in-2017/#7d3de6e16567, [Accessed on 10 November 2016].

Osterwalder, A., Pigneur, Y. & Bernarda, G. 2014. Value Proposition Design: How to Create Products and Services Customers Wants. Somerset, US: Wiley.

Pfohl, H., Yahsi, B. & Kurnaz, T. 2015. The Impact of Industry 4.0 on the Supply Chain. epubli GmbH. Available at: https://hicl.org/publications/2015/20/31.pdf, [Accessed on 24 October 2016].

Prof. Dr. Adolph, L., Anlahr, T., Dr. Bedenbender, H. & Bentkus, A. & others. 2016. German standardization roadmap: Industry 4.0. Available at: http://www.din.de/blob/65354/f5252239daa596d8c4d1f24b40e4486d/roadmap-i4-0-e-data.pdf, [Accessed on 17 November 2016].

Roblek, V., Meško, M. & Krapež, A. 2016. A Complex View of Industry 4.0. Sage Publications. Available at: http://sgo.sagepub.com/content/6/2/2158244016653987, [Accessed on 17 October 2016].

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. & Harnisch, M. 2015. Industry 4.0: The future of productivity and growth in manufacturing sector. BCG Perspectives. Available at: https://www.bcgperspectives.com/content/articles/engineered_products_project_business_industry_40_future_productivity_growth_manufacturing_industries/?chapter=2#chapter2_section3, [Accessed on 17 November 2016].

Schwieters, N. 2015. Ten digital trust challenges. RWC. Available at: http://www.pwc.com/gx/en/issues/trust/ten-digital-trust-challenges.html, [Accessed on 03 November 2016].

Siepen, S., Grassmann, O., Rinn, T. & Blanchet, M. 2015. INDUSTRY 4.0 The role of Switzerland within a European manufacturing revolution. Roland Berger strategy consultants GMBH. Available at: https://www.rolandberger.com/publications/publication_pdf/roland_berger_tab_industry_4_0_switzerland_20150526.pdf, [Accessed on 24 November 2016].

Sniderman, B., Mahto, M., Cotteleer, M. 2016. Industry 4.0 and manufacturing ecosystems. Exploring the world of connected enterprises. Deloitte university press. Available at: http://dupress.deloitte.com/dup-us-en/focus/industry-4-0/manufacturing-ecosystems-exploring-world-connected-enterprises.html, [Accessed on 27 October 2016].

SPA Lasers. Additive Manufacturing. 2015. Available on: http://www.spilasers.com/application-additive-manufacturing/additive-manufacturing-a-definition/, [Accessed on 08 November 2016].

Stergiou, C., Psannis, K.E., Kim B. & Gupta B. 2016. Secure integration of IoT and Cloud Computing. Future generation computer systems.

Taliaferro, A., Guenette, C., Agarwal, A. & Pochon, M. 2016. Industry 4.0 and distribution centers. Transforming distribution operations through innovation. Deloitte university press. Available at: http://dupress.deloitte.com/dup-us-en/focus/industry-4-0/warehousing-distributed-center-operations.html, [Accessed on 28 October 2016].

Technology Trends. 2016. Blockchain technology explained. Available at: http://www.blockchaintechnologies.com/blockchain-definition, [Accessed on 06 December 2016].

TechTarget. Definition. Available at: http://whatis.techtarget.com/definition/, [Accessed on 05 December 2016].

Thamesa, L. & Schaefer, D. 2016. Software-defined Cloud Manufacturing for Industry 4.0. Procedia CIRP. Volume 52, 12-17.

Wanga, S., Wana, J., Zhangb, D., Lia, D. & Zhanga, C. 2015. Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination. Computer networks. Volume 101, 158-168.

Weber, R. & Studer, E. 2016. Cybersecurity in the Internet of Things: Legal aspects. Computer law &security review. Volume 32, Issue 5, 715-728.

Webopedia. Terms. Available at: http://www.webopedia.com/TERM/, [Accessed on 29 November 2016].

Whelan, J. & Meaden, G. 2012. Business Architecture: A Practical Guide. Farnham, GB: Routledge.

Wikipedia. 2016. Predictive maintenance. Available at: https://en.wikipedia.org/wiki/Predictive_maintenance, [Accessed on 23 November 2016].

Wong, J. & Sonnad, N. 2016. Google's AI won the game Go by defying millennia of basic human instinct. Quartz. Available at: http://qz.com/639952/googles-ai-won-the-game-go-by-defying-millennia-of-basic-human-instinct/, [Accessed on 06 December 2016].

APPENDICES

Appendix 1

Glossary

3D printing	A technology that produces solid objects from digital designs by building up multiple layers of plastic, resin, or other materials in a precisely determined shape (Bono, 2016).
Artificial intelligence	The theory in computer science that refers to development of computer systems and building smart software and machines that are able to perform such tasks as visual perception, speech recognition, decision-making, and translation between languages.
Augmented Reality	The real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects. It is this “real world” element that differentiates AR from virtual reality. AR integrates and adds value to the user’s interaction with the real world, versus a simulation (Gartner).
Big Data	The term is often used to describe massive, complex, and real-time streaming data that require sophisticated management, analytical, and processing techniques to extract insights (Gupta, 2016).
Cloud computing	An Internet-based technology that offers an elastic services with shared resources and data, which provides on-demand access to a shared pool of configurable computing resources (Thamesa, 2016).
Cyber physical systems	Smart embedded systems characterized by both hardware and software that operate both at virtual level and physical level, interacting with and controlling physical devices, sensing and changing the real world (Baheti, 2011).

Cyber security	The protection of computer systems from the theft or damage to the hardware, software or the information on them, as well as from disruption or misdirection of the services they provide (Goldenberg, 2016).
Ecosystem	A short-hand for "digital" or "connected" ecosystem, which is a distributed, adaptive, open socio-technical system with properties of self-organization, scalability and sustainability inspired from natural ecosystems. Digital ecosystem models are informed by knowledge of natural ecosystems, especially for aspects related to competition and collaboration among diverse entities (Korsten, 2015).
Information technology (IT)	Common term for the entire spectrum of technologies for information processing, including software, hardware, communications technologies and related services, which does not include embedded technologies that do not generate data for enterprise use (Gartner).
Internet of Things	A network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or thee external environment (Korsten, 2015).
Machine learning	A type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed (TechTarget).
Master data management	A technology-enabled discipline in which business and IT work together to ensure the uniformity, accuracy, semantic consistency and accountability of the enterprise's official shared master data assets (all data in one file). Master data is the consistent and uniform set of identifiers and extended attributes that describes the core entities of the enterprise including customers, prospects, citizens, suppliers, sites, hierarchies and chart of accounts (Gartner).
Operational technology (OT)	A hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise (Gatner).

Platforms	A short-hand for “technology” or “software” platform, which is the digital layer that allows business partners to connect and interact from any applications or devices (Korsten, 2015).
Predictive maintenance	Techniques that are designed to help determine the condition of in-service equipment in order to predict when maintenance should be performed resulting in cost savings over routine or time-based preventive maintenance (Wikipedia, 2016).
Radio-Frequency Identification (RFID)	Refers to an automated data collection technology that uses radio frequency waves to transfer data between a reader and a tag to identify, track and locate the tagged item (Gartner).
Rapid prototyping	A group of techniques used to quickly create a model of a physical part or assembly using three-dimensional computer aided design data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.
Robotics	A branch of the artificial intelligence and field of computer science and engineering concerned with creating robots – machines capable of carrying out a complex series of actions automatically; devices that can move and react to sensory input (Webopedia).
Sensor	Device that responds to a physical stimulus (as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control).
Smart Factory	A manufacturing solution, which is designed according to sustainable and service-oriented business practices that provides flexibility and adaptiveness to production processes in order to dynamically solve problems arising within processes (MacDougall, 2014).
Virtual reality	Provides a computer-generated 3D environment that surrounds a user and responds to that individual’s actions in a natural way, usually through immersive head-mounted displays and head tracking (Gartner).

Appendix 2

The Survey

**Unfortunately, the following information is not available for public use as it represents company's confidential information.*