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# *Industry 4.0: Securing the Future for German Manufacturing Companies*

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Recently, it could be observed that German manufacturing industries are facing high competitive pressure from China and North American companies. Other market volatility such as fluctuating customer demand and resource scarcity tremendously affect the unique position of German manufacturers. The initialization or Industry 4.0 procedures might be one solution to overcome recent market volatility and to secure the future for German manufacturing industries. Therefore the major aim of the current thesis was to gather and investigate critical factors that have an influence on the implementation of Industry 4.0 processes. The concluding results provide evidence that two factors are positively correlated to the implementing process, namely: IT-infrastructure and Firm size. Than 4 factors are negatively correlated, which could be defined as: Lack of financial resources, Skills mismatches of employees, Reluctance to change, and Maturity stage.

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# 1. INDUSTRY 4.0: THE FUTURE FOR GERMAN MANUFACTURING FIRMS?

## 1.2. The Dilemma of market volatility and striving for new opportunities

Fundamental manufacturing technologies, sophisticated data exchange systems and efficient automation are radically changing and influencing the economic landscape. The higher the degree of digitalized and networked processes within industrial operations, the higher the desire for more interfaces in – development, production, and sales. For instance, digitalization of modern society and economy builds the foundation for merging the real world with the virtual world, which essentially has a large impact on industrial processes. Here lies the next productivity wave, by not only offering unexpected efficiency improvements but also a major competitive advantage. This transformation is known as the fourth industrial revolution, also called Industry 4.0, representing the link between industrial production and information technology. Germany is seen as a pioneer to build and establish the requirements for Industry 4.0 (Federal Ministry of Education and Research, 2016). Research and Development activities related to Industry 4.0 are supported with €200 million from government funding and the major entities involved in the process are - The German Ministry of Education and Research and the German Federal Ministry of Economic Affairs and Energy (Drath & Horch, 2014; Federal Ministry of Education and Research, 2016).

Especially, companies from Germany are facing increased competitive pressure from abroad such as China and South America. Companies located in these countries increase their productivity and innovative capabilities to push even faster goods and services through the innovation life cycle. Additionally, scarcer raw materials, rising energy prices and the increasing average age of the employees tremendously affect the German economy (Federal Ministry of Education and Research, 2016). Next to this, German manufacturing companies need to deal with specified customer needs and fluctuation in demand that require flexible production schedules. Brettel, Friederichsen, Keller & Rosenberg (2014) who largely share this viewpoint, reveal that "*The growing demand of customized products in combination with decreasing product lifecycles asks for further transformation towards organization structures, which cope with increased complexity*" (p.37). Predominately there is a desire for manufacturing companies in Germany to establish innovative concepts, to cope with complexity and to overcome the adverse effects of economic development.

Here, Industry 4.0 might be an answer to the challenges lying ahead. The forth and new digital industrial revolution describes the vision of tomorrows manufacturing: Smart factories, machines, raw materials, and products communicate with each other and cooperatively manage production processes (Siemens, 2016). In practice, raw materials are able to find their way independently to drive production processes, which offer many advantages in terms of: Increased flexibility (Siemens, 2016; Rüßmann et al., 2016; Davies, 2015; Deloitte, 2015), efficient mass customisation (Davies, 2015; Deloitte, 2015; Brettel et al., 2014), increased speed (Davies, 2015; Deloitte, 2015), better quality (Rüßmann et al., 2016; Deloitte, 2015; Brettel et al., 2014), and improved productivity (Davies, 2015; MacDougall, 2014; Brettel et al., 2014; Geissbauer et al., 2014). A number of benefits exist, however, there are still great technical and economic challenges German companies has to deal with if they decide to transform operations based on Industry 4.0 guidelines. Recent literature provides evidence that the following challenges are most frequently mentioned: Lack of financial resources (Rüßmann et al., 2016, Davies, 2015), skills mismatches of labour force (Davies, 2015), reluctance of German manufacturing companies to change towards data driven business models (Baums, 2015), legal questions of liability and intellectual property (Davies, 2015). After stating the benefits and challenges of implementing industry 4.0 it becomes apparent that past literature and studies reveal contradicting results in evaluating the future success of the new manufacturing and industrial technology.

While, one part of researchers and analyst state, that Industry 4.0, is Germanys key mechanism for future growth and productivity in manufacturing industries, the other part remains consistent with their theory arguing that the manufacturing companies cannot overcome significant obstacles. To bridge the theoretical gap the major aim of the following master thesis tend to investigate the potential impact of Industry 4.0 for German manufacturing companies, by examining crucial factors, which are positively or negatively correlated to the success of the digital transformation. While, the upcoming latest industrial revolution is a hot topic among researchers, it is similarly important for the management and companies who are interested in a transformation towards Industry 4.0. Especially, German manufacturing firms have the opportunity to gather profound information related to the feasibility of implementing Industry 4.0. Further, they could also compare if the firm specific requirements are existent, and if applicable, they could already prepare for the transition to digitalization. Through accessing the current thesis German companies have a recommendation on factors that have a strong impact on the transforming process. Simultaneously, it will identify significant opportunities and risks and propose solutions for successful implementation of the strategic initiative – Industry 4.0

## 1.2. Germany and their Unique Preconditions to Initialize Industry 4.0

Worldwide many companies are already preparing for the upcoming edge of digitalization. While many manufacturing firms from different nations have the technical capabilities to enter the process of digital manufacturing, German companies hold extraordinary conditions to ride the journey towards Industry 4.0. Relevant conditions include: high standards of production technologies and innovative suppliers, world's leading manufacturers in the field of the embedded systems and specialized business software, and globally significant industry for IT security technologies (Federal Ministry of Education and Research, 2013; Baums, 2015; Deloitte, 2015). Additionally, the German government supports research activities with publically and privately funding at the highest international level. This results in a rigorous knowledge of companies in "*the development and production of innovative manufacturing technologies and the management of complex industrial processes"* (Kagermann et al., 2013). Next to this Germany has a highly qualified workforce, with considerably expertise in embedded systems and automation engineering, which gives them a good starting point to develop strong position in the digital manufacturing industry (Kagermann et al., 2013). Thus, German manufacturing companies have a unique opportunity to establish a leadership position by entering the new industrial revolution – Industry 4.0.

### 1.3. What Factors have an Affect on the Process of Implementing Industry 4.0 procedures?

Showing that German manufacturing companies (GMC) are well placed to enter the next wave of manufacturing, the purpose of the current thesis is to gather and evaluate information on significant factors, influencing the success of the strategic initiative Industry 4.0 and to propose on how to manage these challenges effectively. In order to investigate the core concept the following research question need to be answered:

*"What are the critical factors that have an influence on the implementation of the strategic initiative Industry 4.0?"*

The first section starts with the methodology, introducing how the information for the research is gathered and investigated. The next section starts with the main part of the paper by revealing the theoretical framework, beginning with describing the way of the industrial revolution. To get a better understanding of Industry 4.0 processes the third chapter describes the key characteristics and propose a specific definition. The following section reveals the opportunities for the German manufacturing companies based on the theoretical contribution of Deloitte (2015). Subsequently, the Section 3.4. and 3.5. propose the critical factors, which have an influence on the digital transition. The final chapter describes the main findings of the thesis, followed a discussion part.

## 2. METHODOLGY

The research approach for the current thesis is selected on the basis of previous analysis from different studies and scholars. Key scholars rely on a quantitative approach rather than a qualitative one to analyse the success of digital transformation (Deloitte, 2015; Blanchet, 2014; Geissbauer et al., 2013). Further quantitative research methods are especially used for objective measurement including statistical or numerical analysis of polls, such as surveys or questionnaires (Babbie, 2010).

The difficulty in this case is that Industry 4.0 implementation is a recent topic, which is not discussed excessively. Therefore companies are struggling with finding the right path to weigh the advantages against the disadvantages. Next to this a large amount of organizations are considering digitalization as important, but beyond this, the steps are not established for the process of implementation. If a quantitative approach is performed only a small amount of organizations could be surveyed, since the implementation in most of the cases is not accomplished. Companies who consider the transformation towards digitalization could only provide forecasts and estimations of the critical factors relevant for the digital transformation. However, these are only estimates and not considerably show that they significantly have an influence on the transformation. Therefore the current thesis makes use of a qualitative approach, which is based on a literature review and survey results from different research and consulting companies. The literature is primarily sourced from Google Scholar, Elsevier and Sciencedirect. The current thesis makes use of both German and English literature. This was basically done; because Germany enjoys a pioneering status related to research and development activities of Industry 4.0 procedures. And additionally the thesis investigates primarily German manufacturing companies therefore it an appropriate practise in this case. To increase the generalizability, manufacturing companies from different operational fields were used within the current thesis: Manufacturing, engineering, automotive, food industry, and information and communication industry. The survey covers both – large and medium-sized firms. Noteworthy in this context is that digitalization and Industry 4.0 are interchangeably used throughout the whole paper. The following section will start with the theoretical foundation of the thesis by introducing the way of industrial revolution.

## 3. THEORETICAL FRAMEWORK

### 3.1 The Way of Industrial Revolution Towards Industry 4.0

Essentially, the term Industry 4.0 is a result of several historical stages of industrial revolution. In the late 18th century a transition took place from predominately agrarian and rural societies in Europe towards an industrial society, which was initiated by the introduction of water and steam power as a source of mechanical energy production. Predominately the result was that manufacturing industries implemented a shift to "*powered, special-purpose machinery factory and mass-production* (Rifkin, 2016). This transition was especially beneficial for the iron and textile industry, supported by the development of steam engines, which played a significant role in the industrial revolution (Rifkin, 2016). But also other systems of industries were positively affected by the development of steam engines, such as transportation, communication and banking. As an example, rail transports with the support of steam engines heated by coal enabled efficient handling of logistics. During this period, industrialization helped to increase scale and scope of manufactured goods.

The second industrial revolution started at the beginning of the 20th century with the introduction of electronic energy, which replaced oil and coal as primary source of energy, resulting in the development of mass production (assembly-line) (Wolter et al., 2015). Production processes of tailoring become relatively easy, triggering a boost in mass productivity that resulted in an establishment of the social middle class with economic welfare. The third industrial revolution, also known as the digital revolution started in the early 1970s and has continued till the present day (Kagermann, et al., 2013; Wolter et al., 2015). Computers played a major role within the transition from an industrial nation towards an information society. For instance, the adoption of electronic systems and information technologies enabled the automation of industrial production processes, such as the control and coordination of work in progress, and global supply management. Additionally, Microelectronics and biotechnology supported the development of new production methods, which tend to have a positive affect on new products and services (Wolter et al., 2015). The Figure 1 below illustrates the way of the industrial revolution.

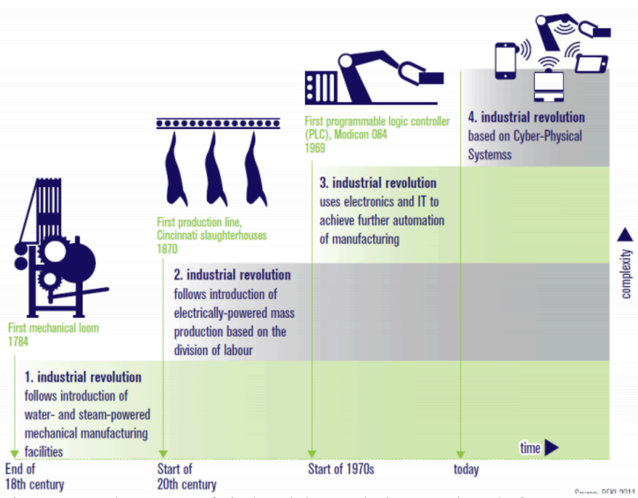


Figure 1: The way of industrial revolution retrieved from German Research Center for Intelligence (2014)

### 3.2. The Definition of Industry 4.0 and its Key Characteristics

Past and recent scholars clearly reveal that there is neither a distinct definition of Industry 4.0 nor a consistent view of interpretation (DBR, 2014). The Federal Ministry of Education and Research (2016) defines Industry 4.0 as "*Industrie 4.0 combines production methods with state-of-the-art information and communication technology. The driving force behind this development is the rapidly increasing digitisation of the economy and society. The technological foundation is provided by intelligent, digitally networked systems that will make largely self-managing production processes possible*". Similarly, "*Industry 4.0 focuses on the establishment of intelligent products and production processes*" (Brettel et al., 2014, p.38). Other authors argue that Industry 4.0 is the process of evolution rather than solely the development of a revolution and define the term as: "*Essentially, Industry 4.0 is the technical integration of CPS*[1] *in production and logistics as well as the application of the Internet and its services for industrial processes. The resulting consequences have also an affect on the value chain, the business models, the downstream services and the work in progress*" (Wolter et al., 2015). This viewpoint is also reinforced by Drath and Horch (2014) arguing that Industry 4.0 is *"(…) often understood as the application of the generic concept of cyber physical systems*[1] *(CPS)"* (p.56).

A recent study of the audit and advisory company Deloitte (2015) reveals that Industry 4.0 could be defined as merging the real and virtual world, which essentially reflects the interpretation of CPS. The private American worldwide consulting firm McKinsey & Company defines the term as "*the next phase in the digitization of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing*" (Baums, 2015). Next to this the German Trade & Invest association states that "I*ndustry 4.0 connects embedded system production technologies and smart production processes to pave the way to a new technological age*" (MacDougall, 2014). A general definition should include the function of CPS and it tends to merge the real and virtual world. Therefore the author of the following thesis uses the following definition as general guideline to interpret Industry 4.0:

Industry 4.0 could be defined as a smart way of combining the real and virtual world by implementing CPS within production and industrial processes to establish a self-managing network between human, machine, products and objects.

The term self-managing network is especially important to mention when Industry 4.0 is defined. One of the major futures of Industry 4.0 is the self-management and self-control of data exchange between machines (Brettel et al., 2014; Federal Ministry of Education and Research, 2013; Wolter et al., 2015). This is especially important to consider in terms of increased flexibility and productivity for the German manufacturers. To get a better overview the following chapter will describe, based on recent literature, how the future look like under Industry 4.0.

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[1] CPS – Cyber Physical Systems – refers to the bonding of the physical and virtual world. The aim is to create a network between human, machine,

### 3.3. Creating Value Opportunities for German Manufacturers: The theory of Deloitte (2015)

#### *3.3.1. Increase competiveness through digitalization*

According to Deloitte`s (2015) research, Industry 4.0 generates different future impacts affecting the German manufacturing companies. These might affect positively or negatively the outcome of implementing the strategic initiative Industry 4.0. These impacts will be described in the current section.

(1) Increase competitiveness: The increase in global competition on product quality and production costs had forced the German manufacturing industry to shift their production facilities towards low wage countries, in order to bridge and manage the gap between productivity and quality issues (Brettel et al., 2014). Similarly, matured manufacturing companies acknowledged that buyers are reluctant to pay high price premiums for small improvements on quality (Brettel et al., 2014). As a consequence, companies try continuously, to exploit the advantages of sophisticated production strategies, such as lean manufacturing and mass customization. Virtualization and digitalization of operational processes will be the next step to increase competiveness. Industry 4.0 is seen as beneficial in supporting processes of supply chain management, such as enabling real time access to certain product and production information for all internal entities (Brettel et al., 2014). The boundaries between internal entities will diminish, "as *autonomous systems exchange data, gained by embedded systems throughout the entire value chain*" (Brettel et al., 2014, p. 37). The digital transformation for German manufacturing companies to Industry 4.0, tend to have an impact on both- local and global value chains (Deloitte, 2015). Through the transformation, cost of manufacturing can be reduced and companies are able to deliver customized products/services with more efficiency. Moreover, digitalization allows companies to optimize not only individual production steps, but also the entire value chain. Through digitalization companies are able to enhance both – sustainable competitive advantage and build capable organizations (Rüßmann et al., 2015). This is also correlated to the stronger connection between machines and products, which increases efficiency in industrial operations and supports companies to build a competitive footprint. The possibility of gathering and analysing data across centralized machines, tend to enable, much faster, more flexible, and highly efficient processes to develop quality products at reduced costs, which tend to increase *productivity*, economies of scale and scope, trigger industrial growth to - establish a competitive advantage (Rüßmann et al., 2015). A successful transformation comes along with several benefits for Germany, such as contributing more than 25% to GDP and generating over 7 million additional jobs (Brettel, et al. 2014).

#### *3.3.2. Increase flexibility through digitalization*

The next impact of implementing Industry 4.0 is (2) Increased flexibility. The term flexibility could be defined as *"the capacity to adapt" across four dimensions; temporal, range, intention and focus* (Golden et al., 2000). According to Baums (2014), German manufactures need to rethink the design of traditional production processes to capture the full potential of Industry 4.0 implementation. This includes "employing *dynamically programmable production technology in combination with increased flexibility of the machine itself (e.g., flexible grip hooks) has multiple benefits, among them are individualized customization, more dynamic allocation of resources/capacity, shorter changeover times, and reduced production complexity with fewer constraints"* (Baums, 2014, p. 29). While, digitalization decreases the complexity of production processes it also increases flexibility by categorizing small value orientated units, sharing only relevant information related to specific process steps (Brettel et al., 2014). Moreover, digitalization enables product flexibility through rapid manufacturing (RM) techniques, where products are assembled on the basis of 3D models (Brettel et al., 2014). This is especially beneficial in the case of customized products, which are tremendously requested from specific customers.

One of the core futures of Industry 4.0 is the high degree of automation, which is considerably embedded within smart factories. Through sophisticated flexible networks of CPS, the production process becomes more efficient, since the systems are able to monitor the operations automatically. While, these systems allow flexible production, which tend to respond in real-time if for example raw materials are needed or failures are detected, they are also able to considerably optimize the production process (MacDougall, 2014). According to MacDougall (2014) "*Production advantages are not limited solely to one-off production conditions, but can also be optimized according to a global network of adaptive and self-organizing production units belonging to more than one operator*"(p.10). These production advantages might be enabled through the so-called system CyPro [2] (Cyber-Physical Production Systems), initiated and developed by Wittenstein AG, it is able to generate a significant increase in productivity and flexibility of German manufacturers and to build a strong footprint as a provider of CyPro systems (MacDougall, 2014).

#### *3.3.3. Higher quality and efficiency through digitalization*

The third impact realized through the adaption of digitalization is (3) Higher quality and efficiency of the production process. For instance Deloitte (2015) argues predominately that digitalization will ensure the efficient use of energy resources and a reduction might be obtained,

[2] Representative spectrum of cyber-physical system modules for production and logistics systems for industrial use.

through reduced lead times and new forms of marketing and distribution channels, with a large focus on the business of e-commerce. The autonomous communication between the machines supports company's operational analysts in tracking relevant data sets to reduce errors and optimize production processes. Industry 4.0 transforms random machines into sophisticated smart machines, which share continuously information on, *errors and faults, current stock levels, and changes in orders or demand levels* (Deloitte, 2015, p. 4). The autonomous exchange of information between the smart machines allows for better coordination and communication of work in progress and deadlines, resulting in higher efficiency and *optimising throughput times, capacity utilisation and quality in development, production, marketing and purchasing* (Deloitte, 2015, p. 4). Whereas, scholars provide evidence that the initialization of Industry 4.0 shows significant improvements in product quality with limited errors and faults. As an example the Siemens electronics plant in Germany manufacturers Programmable Logic Controls (PLCs) by using digitalization processes within a smart factory. This made it possible to reduce the defects from 500 per million in 1989 to 12 defects per million in 2015, with a reliability rate of 99% (Davies, 2015). Ultimately, quality plays a crucial role within the whole process of cost reduction, as long as the defects could be reduced and savings realized it will boost also long term competiveness of German manufacturers. This aspect is also reinforced by the author Davies (2015), who reveals that the top 100 European manufactures could cut down costs by €160 billion if they are able to reduce all defects down to zero.

### *3.3.4. Cost reduction through digitalization*

Cost reduction might also be realized through the (4) efficient use of resources, which is the fourth impact and will be described in the current section. Resource efficiency considers not only the responsible usage of natural resources without harming the environment, but also the efficient utilization of human capital and raw materials. One characteristic of digitalization are smart networks, priory used to exchange data between resources, raw materials and products. An advantage of these networks is that all raw materials and products could be traced and located anywhere with regard to time and place (Deloitte, 2015). All production processes and steps of work in progress of products are registered automatically and could be monitored if needed. Moreover, changes in orders or demand, the quality of products, failure of machines will be demonstrated by the autonomous machines in real time. This is especially beneficial for the manufactures, since problems and failures are eliminated directly after occurrence. This will result in an easy way of monitoring the production process and the efficient use of resources with major focus on waste reduction (Deloitte, 2015).

Particularly resource efficiency under Industry 4.0 is characterized by the efficient use of raw materials, energy consumption and human capital. In case customers tend to demand sustainable products and services, which tend to force manufacturers to reduce their environmental footprint. Similarly, there is a need that German manufacturers need to increase quantity to satisfy the demand of products and services. Manufacturers face the dilemma of maximizing quantities by using only few resources (Geissbauer et al., 2014). Digitalization is one of the solutions that have the ability to solve this dilemma. Under Industry 4.0 additive manufacturing has more relevance and also specific technologies such as advanced robotics, which are proven to be more cost-effective options in storing and harvesting energy (Geissbauer et al., 2014). Advanced robotics belongs to the group of smart machines that are able to communicate autonomously, enabling the previous mentioned benefits. Apart from the high costs of implementing Industry 4.0 techniques advantages occur to reduce the large amounts of energy consumption and the usage of raw materials. However there is a need for German manufacturers to calculate the trade-offs between the input of further resources and additional investments on smart factories to realize the whole benefits of savings (Geissbauer et al., 2014). The initialization of Industry 4.0 will not only affect positively the competitive position of German manufacturers but also provides solutions for global challenges such as the efficient use of energy consumption. The implementation of Industry 4.0 procedures do not only have positive impacts but also negative ones. Therefore the following sections will describe the negative impacts of implementing Industry 4.0 procedures.

### *3.3.5. Increased cyber risk through digitalization*

The following sections will describe the negative impacts of implementing Industry 4.0. The fifth negative impact is (5) cyber risk, which could be defined as (...) „*a multitude of different sources of risk affecting the information and technology assets of a firm*" (Biener et al., 2015). This cyber risk is also triggered through online networks, Internet traffic, and storing personal information. Whereas, specific sources of risks could be categorized as hacker attacks, virus transmission, data breach, and cyber extortion. Industry 4.0 initialization is highly characterized by digital networked systems and data is shared and communicated via the support of internet applications. Here lies the risk for German manufacturers, since they are exploited to the risk of cyber attacks. In case many companies believe that the implementation of digital processes tend to increase the already existing cyber risk for industrial nations. As an example, Playstation Network and Sony Online Entertainment faced a cyber attack in 2011, where 77 millions of credit and debit card information of users had been stolen by cyber hackers. The profound losses peaked by \$2 billion dollars (Balkhi, 2013). This evidentially shows that there is a need for companies to develop contingency plans to mitigate exposure of cyber risk. One of the solutions after the successful digital transformation is to employ big data analyst and cyber-security experts (Davies, 2015).

Additionally, machines and the IT-infrastructure should be up-to-date, and if they are out-dated, they need to be exchanged quickly. Especially, in the case of the IT-infrastructure, since out-dated software increase the risk of cyber attacks. For instance, hackers have the ability to infiltrate a malware in to the systems of German manufacturers, changing for example the specifications of products. Companies will loose control over the production process and the worst scenario is when more than 1000 of products are manufactured caused by data manipulation of cyber attacks. The survey of the Fraunhofer (2015) institution in Germany provide evidence that most of the manufacturing companies planning to implement digital processes have the opinion that IT-security will be of the biggest challenges. This aspect is also reinforced by Baums (2014) who states that cyber-security is of major importance and needs to be addressed at top-management level. Further the author proposes 4 key practices to manage cyber-risk effectively (Baums, 2014): First, prioritize protection around key assets. As a starting point companies should access information on their primary production assets and evaluate their individual cyber-risk based on attractiveness and damage potential. Than they should rank order the assets from the highest risk level to the lowest and protect them accordingly. Second, Integrate cyber security into core processes, is defined as the integration of cyber resilience systems into company wide risk management operations. Additionally, manufacturers need to secure core production processes with the support of implementing cyber defence programs.

Regular training and routine simulations of cyber attacks will facilitate short-term reactions. The third key practice is to foster the integration of management and employees. There is a certain need that employees understand the negative impact of cyber attacks and the associated effect on cyber security. Companies should assign employees to special training and workshop events, which particularly focus on secure data exchange and storage. Considerably management activities are to serve as a leading authority within in the whole process and to enhance the learning process. The fourth and final key practice comprises the safeguard of technologies, which is characterized as the crucial "*integration of security into the technology for all connected technologies*" (Baums, 2014, p. 47). Next to this enterprises need to automate defence processes, in order to allow cyber security employees to secure the technology against cyber attacks. According to Baums (2014), there is a relevance that all previously mentioned practices should be integrated in the organizational processes. In the past, many organizations believed that cyber security falls under the responsibility of IT-experts, but digital transformation requires that every single department of the networked organization needs to be involved to reduce the risk of cyber attacks (Baums, 2014).

#### *3.3.6. Digitalization requires efficient safety and security systems*

The last impact is (6) Safety and security is seen as a crucial factor to the success of digital transformation. For manufacturing companies it is a prerequisite that production process and the products itself do not cause any damage to either people or the environment (Davies, 2015). Simultaneously the coordination and communication between the system and products contain confidential information, that should be protected against misuse (Davies, 2015). Companies need to ensure that safety and security systems are integrated to identify in advance if misuse is suspected. Unique identifiers combined with specified training procedures for company interns will support the successful identification of misuse (Davies, 2015). Security breaches might have significant implications for manufacturing companies' reputation. There is the possibility that confidential information are retrieved by unknown users who could share the data without permission on online platforms. Based on these information customers might loose trust on the operations of the company.

In the previous example of Sony Online Entertainment and Playstation Network, the accounts of 77 million users were hacked. This shows clearly that disappointment among customers could occur, and companies run the risk that unsatisfied customers switch to competitive products or services. Another aspect of security breaches are that they could cause technological failures during production process if they are misused through unauthorized access. All machines and robots are connected by the digital network and an unauthorized access provides the opportunity to change and modify the data and content of the production process. This is especially harmful for companies since hackers are able to shut down the whole production, so no products are assembled, and machines and systems need to be restarted or reconfigured. This tends to result in huge financial losses and also damage companies reputation. But there is also the possibility that software errors or failure of humans could affect the security standards of the company. When companies ensure that consistency plans exists based on safety and security breaches they are in a good position to mitigate the risk of misuse and unauthorized access.

## 3.4. Factors that are Positively Correlated to the Success of Digital Manufacturing

#### *3.4.1.Established IT-infrastructure to drive digitalization processes*

To give a profound answer to the core concept there is a need to investigate the positive factors that have an influence on the success of implementing the strategic initiative Industry 4.0. Therefore this section will gather detailed information on crucial factors supporting the process of transformation.

Academia reveals that two major factors have a positive influence, namely: (1) IT –Infrastructure and (2) Firm size (Kagermann et al., 2013; Geissbauer et al., 2014; Deloitte, 2015). The existing capabilities of German Manufacturers related to the IT-Infrastructure plays a key role within the process of digitalization. Like, previously stated Germany has a significant level of IT competences and by systematically combining their prevailing communication and information technology with traditional strategies they are able to succeed in digitalization. Germany is continuously extending their IT-infrastructure and service based on smart networks, such as cloud computing (Kagermann et al., 2013). These smart networks build the foundation for the CPS systems and tend to be integrated in the so-called "smart factories" combining the real with the virtual world. According to Davies (2015) the digital infrastructure and its connectivity with the Internet is one of the core values under Industry 4.0. Considerably this will require the extension of certain network infrastructure, in order to enable the digital transformation. Additionally, specification of the network service quality needs to be arranged with legal agreements (Kagermann, et al., 2013). This will support the need of "*high band- widths for data-intensive applications and for service providers to guarantee run times for time-critical applications*" (Kagermann, et al., 2013, p. 22). Similarly, the implementation of CPS systems tends to increase the demand for manufacturers on relevant IT- infrastructure related to „ *space, technical quality and reliability* " (Kagermann, et al., 2013, p. 26).

For instance, the broadband infrastructure should be characterized by high-quality communication to ensure an efficient data exchange between the autonomous systems. Therefore Industry 4.0 implementation demands highly the expansion of broadband Internet infrastructure, not only within Germany, but also with its partner countries (Kagermann, et al., 2013). The government on both level, national and international, should support this intention by implementing relevant quality standards of IT-infrastructure. To access the relevance of IT-infrastructure the famous consulting company PricewaterhouseCoopers (PwC) surveyed 235 German manufacturing companies from 5 different industries. The results showed that 90% of companies believe that the IT-infrastructure and the ability to examine data exchange is a key indicator for the success of digital transformation (Geissbauer, et al, 2014). Further from all surveyed industries, especially the information and communication industry is the most advanced industry related to the establishment of digital processes. The key task to successful initialization of digital processes is to connect the different systems to build one single network, whereas the management of data exchange within the infrastructure is of major importance. German manufacturing companies need to provide relevant communications and IT infrastructure to realize connectivity and to exchange and analyse data, which should be if possible in real-time (Geissbauer, et al, 2014). Companies who develop these procedures are able to successfully manage big data systems that will result in defining key measures to optimize production processes (Geissbauer, et al, 2014). In a similar manner like the consulting company PwC, the enterprise Deloitte (2015) surveyed companies from several industries and the results revealed that more than half of the companies found that their IT-infrastructure is not fully suitable. The remaining organizations state that they lack required infrastructure for the digital transformation. Like already previously stated in the section, companies need to develop sophisticated IT-infrastructure, which serves as a key requirement for the implementation of Industry 4.0 procedures. Thus a well-developed IT-infrastructure creates a positive effect on digitalization. To be more precise:

*Proposition 1: The IT-Infrastructure of German manufacturing companies is positively correlated to the success of implementing the strategic initiative – Industry 4.0.*

### 3.4.2. Firm size as a positive denominator for implementing Industry 4.0 procedures

Subsequently, the second factor (2) Firm size has also a positive influence on digitalization. There is a widespread opinion on the measurement of firm size, mostly evaluated through: book value, number of employees, revenues, years of existence and degree of diversification (Moeller et al., 2004). Larger manufacturing firms tend to have better technical and financial capabilities, which considerably leaves them with better conditions to enter the new industrial revolution (Deloitte, 2015). They might not fear a transition, since they build on their experience and values taken from past years related to technical transition, which positively affect the implementation of Industry 4.0. However, recent scholars have different viewpoints on how firm size is positively or negatively correlated to the success of digital transformation. Deloitte (2015) argues that larger manufacturing firms recognize the topic as very important, in comparison to small and medium sized firms who largely suspect if the transformation to digital is advantages for them.

Noteworthy in this context is that several scholars predominately revealed that the transition is especially beneficial for small and medium sized firms (Deloitte, 2015; Federal Ministry of Education and Research, 2016; MacDougall, 2014). They have the ability to transform to digital more rapidly, since they need to build new IT-infrastructure from scratch, which is seen as an easy endeavour (Deloitte, 2105). Moreover scholars who analysed the correlation between firm size and the ability of digital transformation found that "*the relationship is stronger for new versus established firms and for smaller versus larger firms*" (BarNir et al., 2003). In contrast very large manufacturers have deep-rooted operational processes and it could become relatively complex for those organizations transforming to new procedures and task. Other viewpoints related to this controversy of firm size

include that "*many SMEs are not prepared for the structural changes that Industry 4.0 will entail, either because they lack the requisite specialist staff or because of a cautious or even sceptical attitude towards a technology strategy that they are still unfamiliar with* "(Kagermann, et al., 2013). In addition to this profound statement is that small and medium sized companies lack investments to participate in the digital transformation. A different viewpoint is considered by Geissbauer, et al., (2014) who argues that the level of product portfolio optimization is independent from firm size. And noteworthy, small and medium sized companies (SMEs) are already preparing for the wave of the digital edge.
Subsequently, one of the advantages for SMEs are if the transformation is successful they are able to compete with large manufacturers not only domestically but also on an international basis. International competition is fierce and especially from countries such as China and North America put a lot of pressure on SMEs. The transformation to digitalization could serve as a unique opportunity to build a competitive advantage. But this requires also the support and expertise of employees, who are willing participate in the transformation process. The number of employees also measures firm size, and larger firms could choose from a large scale of employees with specific knowledge and expertise. Larger companies might have a benefit in this case, since they could choose from a large pool of employees, finding suitable interns who could participate in the transformation process. If this is compared to SMEs, it becomes obvious that they are not able to choose from a large pool of interns. But this not directly influences the participation of SMEs in the transformation, because according to recent scholars and surveys they already initialize the first steps for the digital transformation (Deloitte, 2015; Federal Ministry of Education and Research, 2016; MacDougall, 2014). Therefore the following proposition is defined:

*Proposition 2: The firm size of German manufacturing companies is positively correlated to the success of implementing the strategic initiative – Industry 4.0.*

After describing the factors positively affecting the transition the next section will elaborate on the factors, which have a negative effect on implementing Industry 4.0 procedures.

## 3.5 Factors that are Negatively Correlated to the Success of Digital Manufacturing

### *3.5.1 Lack of financial resources as a primary source for declining the digital transformation*

Davies (2015) investigated with his Article "Industry 4.0 – Digitalization for productivity and growth" for the European Parliament factors that have a negative impact on the success of digitalization. Four different factors had been retrieved, namely: (1) Lack of financial resources (2) Reluctance to change (3) Skills mismatches of employees (4) Maturity stage.

The first factor (1) Lack of financial resources describes the difficulty of German manufacturing companies to finance the initialization of Industry 4.0. Large amounts of funds and investment need to be raised to drive the process of digitalization. According to Davis (2015) the projected amount in Germany is €40 billion annually until 2020. Conversion at zero cost is rarely possible, and especially in the case of implementing the initiative Industry 4.0. A large part of SMEs fear the risk of transition to digital, because they are not able to access the future value of the investment (Davies, 2015). On the contrary multinational corporation (MNC) or large firms might take high-risk project, even knowing that the chance of payback is marginal, since they are diversified and losses will be balanced by the income from other division, products or services. Provided that both, SME`s and MNC`s, have enough liquidity to finance the investment decision on Industry 4.0. A large amount is needed to implement the IT-infrastructure and for instance Davies (2015) argues that only one out of five companies uses recently interconnected IT-systems to manage its production processes.
Recently, negative aspects of digitalization arises through news and scholars such as that the network systems are too "*expensive, unreliable and oversized*" (Davies, 2015, p. 5). Besides these issues literature argues that the network systems and machines are excessively emphasized by producers of equipment's and not really demanded by customer itself (Davies, 2015). The amount of initial investment also heavily relies on the type of businesses and the products the German manufacturer develop. For instance industries with high production volumes also agree on a larger initial investment to implement Industry 4.0 processes (Deloitte, 2015). Increasing the volumes to justify the large initial investment is not a solution for German manufacturers if there is no demand for the products. This issue is also reinforced by Deloitte (2015), who argue that additive manufacturing is very costly, even if the costs of the tools are lower in the long run. But in comparison to traditional manufacturing the payback of the initial investment will incur even faster. However, the initial investment need to be raised and SMEs face in this case difficulties to overcome this burden. Funds may be raised through bank loans or private credits, but this requires that the enterprise have securities in order to show that liabilities could be paid. Experts believe that the investment on industrial Internet in Germany will start from $20 billion in 2012 to approximately peak at $500 billion in 2020, whereas the added value through this investment will grow from $23 billion in 2012 to $1.3 trillion in 2020 (Davies, 2015). Of course this is an estimation, but if the added value could be reached in 2020 it would be an enormous payback for German manufacturing companies. Similarly the consulting company PwC argues that the investment in digital transformation tend to reach approximately around 5% of annual revenues per annum. The beneficial aspect in this case is that the estimated

return will already be generated within two years. According to the words of PwC " *the payoff will potentially be enormous, as competitive landscapes get redefined* (PwC, 2015). Similar viewpoints are revealed by Buhr (2015) who argues that the positive forecasts and expectation of digitalization will payoff the high initial investment. If Germany is able to build on their expertise and know-how related to industrial competencies, they need to invest more than €1.35 billion per year within in the next 15 Years. Whereas, large investments are realized by the extension of broadband communication (Buhr, 2015). After revealing all the key figures it becomes obvious that the estimation of the initial investment related to the digital transformation, deviates if the different sources are compared. However, in any case of operational transformation conversion at zero costs is not possible. Since it is a forecast, SMEs are still sceptical if they could rely on these estimates. This is also reinforced by Baums (2014) stating that there are "*long investment cycles, companies tend to be conservative in their decision making when it comes to fundamental disruption* (p. 7)" such as the transformation to Industry 4.0 processes. Noteworthy in this context is that manufacturers also need to pay attention to the increased cost of energy and the complexity of intra-logistics, which is a significant expense. Transformation to digital processes might be one solution to overcome this problem, which could generate profitable results in the long term not only for SMEs but also for large organizations. Essentially, the Federal Ministry of Education and Research (2016), argues that the digital transformation is especially beneficial for SMEs, but large initial investments in order to reap the rewards of Industry 4.0. And it is still unclear if SMEs could raise the funds for the transformation. Therefore the following proposition is applied:

*Proposition 3: The lack of company's financial resources is negatively correlated to the success of implementing the strategic initiative - Industry 4.0.*

### 3.5.2. Reluctant to change as a major factor to deny digitalization

Traditional business models had to be changed in order to succeed in transforming. Manufacturing companies need to build complex value networks for the production and distribution of products and it may require that business leaders need to switch or merge with other firms (Davies, 2016). These could be suppliers or distributers, but majorly specific telecoms and Internet service providers are selected or even competitors e.g. *in the establishment and use of standards that allow the transmission and exploitation of large quantities of data* (Davies, 2016). Some manufacturers are reluctant to change their traditional business models or to collaborate with new partners or even competitors. They are used to old pattern and an implementation of change is not always easy, when there is high level of uncertainty. Change implementation not only requires the support from employees but also from top-level management. The whole organization needs to be involved in the process of digital transformation. Whereas management has a specified task, to serve as a role model within all steps and processes.

The change towards digitalization is seen, as a complex task, and the complexity tend to increase if German manufacturers do not realize the importance of the change. This consideration is also revealed by Piderit (2000) who states "*Adapting to changing goals and demands has been a timeless challenge for organizations, but the task seems to have become even more crucial in the past decade*" (p. 783). Recent scholars rarely discuss the challenge of change management related to digital transformation. There might be several reasons for the reluctance to change. For instance, employees lack relevant know-how and expertise, which might hinder German manufacturers to consider the digital transformation as beneficial. Another viewpoint is that they hold a sceptical position, because they are not familiar with the new technology strategy and therefore refuse the change (Kagermann, 2013).

The vast majority of companies are hold reluctant position towards a disruptive change that involves new and unknown technologies; therefore they tend to find it risky to implement the change (Baums, 2014). Additionally, the core function behind the digital processes is the technology (e.g. digital networks, data exchange systems, etc.), which has a huge influence of the significant steps related to the value chains (Baums, 2014). German manufacturers already realized that the production costs per day are high if downtime, of work in progress exists, so they tend to outweigh the benefits and risks of entering the digital transformation (Baums, 2014). The reluctance to change could be categorized in two different forms: reluctance of employees to change and lack of top-management support. The persistent working task of employees might change to worst ones if the transition is executed. While a part of the employees tend to see the transition as a personal challenge other might fear the risk of loosing their safe workplace if the transition is not successful in the long run. Employees are largely sceptical in terms of required task specification and even if there expertise is sufficient to fulfil the new tasks after digital transition. Important to note here is that top-management should support the whole process of the transformation and considerably be a role model for the company staff. Setting clear goals and milestones is a prerequisite to succeed in digital transition. Whether the transformation is effective or not depends also largely on the degree of willingness to change by the organization. Therefore the following statement will be defined:

*Proposition 4: The reluctance to change is negatively correlated to the success of implementing the strategic initiative - Industry 4.0.*

### 3.5.3. Industry 4.0 procedures require skilled staff

Basic requirements for preparing the shift towards digitalization include also the need for skilled workers with crucial expertise on information and communication technology (ITC). There will be tremendous change from traditional manufacturing work with largely manual labours towards coding and controlling sophisticated machines (Davies, 2015). Thus, Industry 4.0 requires a labour force with high skill levels and if this is not the case manufacturers need to find a way to replace or retrain them. According to Davies (2015), there will be a shortage of 825 000 ICT professionals in the labour market by the end of 2020. Through the transformation it is extremely important to employ staff, which has the right qualification to manage the digitized process. This aspect is also reinforced by Geissbauer et al., (2014) who state that the companies surveyed "*also consider the required qualification of employees at increasingly digitized companies to be a major obstacle"* (p. 7).

The initialization of digitization will radically change the role and tasks of employees. Whereas the major tasks include: "*real-time oriented control will transform work content, work processes and the working environment*" (Kagermann, 2013, p. 6). Next, the implementation of Industry 4.0 processes enables a socio-technical approach with the benefit that employees have the possibility to get more responsibility and stimulate their personal development (Kagermann, 2013). In order to enable this process it is necessary to develop and establish training and workshops for the employees, with the focus on new core tasks such as how to manage and control digitized systems. Noteworthy in this context is that the biggest burden for German manufacturers is the expertise of employees in the area of process and control know-how related to digitalization (Baums, 2014). Therefore training and continues professional development of employees is of major importance to succeed in early stages of the transition towards digitalization (Kagermann, 2013). The transformation will considerably require specific competencies of employees and especially in the IT-field. German manufacturers considering the transition towards Industry 4.0 procedures need to investigate if they meet the requirements to drive the change process. One of the tasks is to verify if employees have the right skills to be integrated into digital processes. Significant skills of consideration are ICT-expertise, big data management, data analysts, network management, mathematics and information technology. Companies who do not employ staff with these specific skills need to replace or retrain them or gather additional workers with the predefined skills. Important to note is here the shortage of 825 000 ICT professionals at the end of the year 2020 (Davies, 2015). Those employees who are able to transit to digital processes could find greater autonomy and more challenging work (Davies, 2015). However the challenge for organizations is to match employee competencies with Industry 4.0 requirements. Head-hunters and job agencies might be one way to find qualified professionals. But according to Davies (2015) a large part of young professionals do not see their career in a digitalized company. Moreover based on a survey the author argues that only 13% of young professionals could imagine to choose a workplace, which core operations are digitalized. The next option is to retrain the existing employees for the integration within the digital process, which requires a massive transformation of job specifications and competencies. This is also reinforced by the survey of PwC (2015), who conclude that 30% of respondents have the viewpoint that insufficient qualification of employees is of major concern. And 26% of respondents found that they mostly lack of agreed standards to develop the transition. Therefore it is important to establish relevant workshops and to enhance "*work in a way that fosters learning, enabling lifelong learning and workplace-based cyber-physical development* " (Kagermann et al., 2013, pp.6-7). Typical programs to foster learning may include simulations digitalized production process to generate an understanding of Industry 4.0 procedures. Other practices proposed by literature is digital learning techniques (Kagermann, 2013).

Whether the enterprise chooses to retrain employees or search for new professionals, depends highly on internal capabilities of the organization. While it is beneficial for companies to build on the expertise from existing employees, it might also make sense to source new professionals who are eligible for the transformation. A large part of SMEs might choose the option to search for professionals outside the organization, if the competencies of interns are not sufficient. Whereas, companies from communication and information sector have already IT-professionals who could drive the transformation towards digitalization. As long as the skills of employees is of major importance for Industry 4.0 transition it follows:

*Proposition 5: Skills mismatches of employees are negatively correlated to the success of implementing the strategic initiative - Industry 4.0.*

### 3.5.4. Organisational maturity stage as a factor influencing negatively the implementation of digital processes

The last factor that has an influence on the success of implementing Industry 4.0 processes is (6) Maturity stage, which is defined as "*the maturity stage entails capability maintenance. This involves exercising the capability, which refreshes the organizational memory. If exercised regularly, the capability becomes more deeply embedded in the memory structure of the organization"* (Helfat, 2003, p. 1003). The factor maturity stage in relation to the implementation of Industry 4.0 procedures for German manufacturers is rarely investigated by recent literature. The maturity stage of German manufacturers tends to play also a role on the decision to implement digital processes. Companies who could be assigned to this stage have already passed the introduction and growth phase related to the product life cycle. The core aim of the companies within this phase is to maintain their market share. New projects and major changes of operational strategies are rarely implemented, since the risk is too high to suffer losses. The market is already saturated and the sales volume reached already the peek. Next to this organizations are struggling with declining profits. In this situation organizations fear to implement Industry 4.0 initiatives since the risk is too high that the transformation do not yield any profits in the long run. During, this stage they found themselves in a critical position to maintain their capabilities and financing activities.

There is a need that organizations choose carefully new projects and fundamental change in strategies should be assigned based on their capabilities. This aspect is also reinforced by Geissbauer et al., (2014) who argues that "*the starting point is to have each company assess its own current maturity level and to take stock of its own competences and digital initiatives at the company itself*" (p. 41). The priority is to enable a digital maturity assessment with focusing on transparency by evaluating key strength and weaknesses related to the process of implementation (Bechthold, et al., 2013). It is important that organizations develop significant understanding of the status of digitalization within the organization to drive the change towards Industry 4.0 initialization. Companies located in the maturity phase have two options now to choose from. The first is to find new market opportunities to increase market share, sales volumes, and focus on cost reduction. To enable this, digitalization could be one solution, than it enables customized products and reduce costs by the efficient use of resources. Smart networks and autonomous robotics enable an efficient production process. As a result companies are able to cope with the fierce competition from Asia and North America by building new market share and increasing their sales volume.

The previous sections already described that the change towards Industry 4.0 procedures comes along with several advantageous but also with significant risk, related to the initial investment, skill profile of employees, and IT-infrastructure. Risk averse organizations within the maturity stage might choose not to transform digitally, since the risks and disadvantages could not be controlled or mitigated. Additionally, companies tend to fear within this phase the adaption of new technologies and especially disruptive innovation. This could be related to the existence of established processes, organizational structures, and business models. A disruptive change towards digitalization is a complex endeavour when companies have already established organizational and operational procedures. Or company lack the competencies to build the foundation for digitalized processes. In both cases the maturity will influence negatively the implementation of initializing Industry 4.0 procedures, therefore the following proposition is defined:

*Proposition 6: The maturity stage of organizations is negatively correlated to the success of implementing the strategic initiative - Industry 4.0.*

After gathering and investigating detailed information on the factors, which are negatively or positively correlated to the success of implementing the strategic initiative – Industry 4.0. Based on the propositions, a theoretical framework is constructed to get a better overview on the on the major critical factors and their relation to the success of implementing Industry 4.0 procedures which is illustrated in Figure 2.

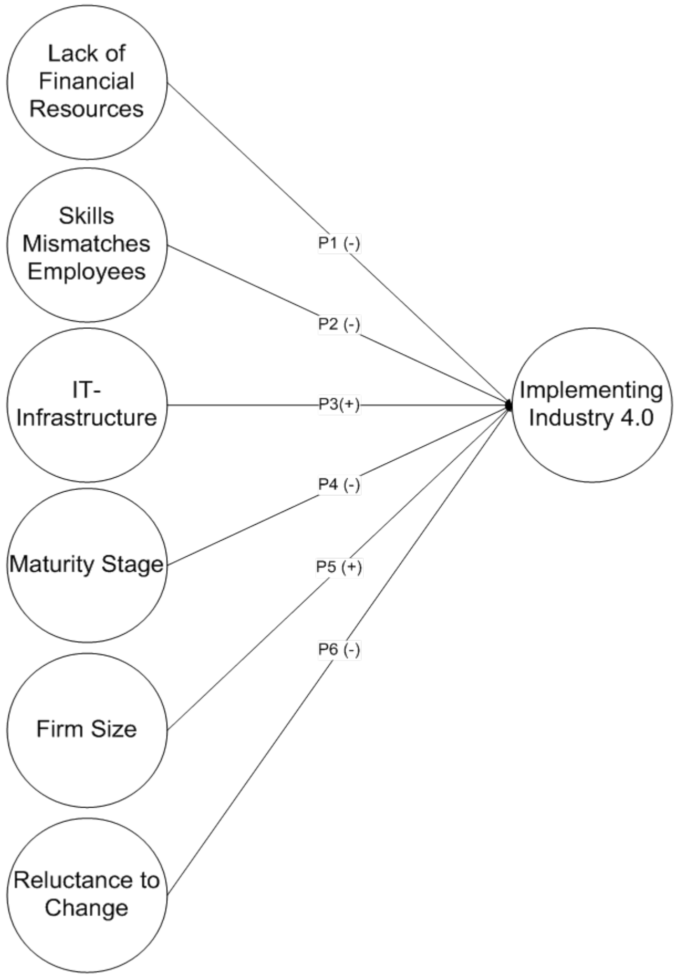


Figure 2: Overview of critical factors that are positively or negatively correlated to the implementation of digitalization.

## 4. CONCLUSION

The major aim of the current thesis was to investigate critical factors that have an influence on digital transformation. The results show clearly that six different factors have a major influence on the successful implementation of a digital strategy. Whereas, the factors IT-infrastructure and Firm size are positively correlated to the success of implementing digitalized processes and lack of financial resources, Skills mismatches of employees, Reluctance to change, and Maturity stage have a negative correlation related to the implementation of Industry 4.0 procedures. In addition to these findings value opportunities for German manufacturers were gathered and described in order to propose the challenges and benefits of transforming towards a digitalized strategy. These were defined as positive measures: Increased competitiveness, Increased flexibility, Higher quality and efficiency, Cost reduction – and the negative impacts are Cyber risk and the Requirement of safety and security systems.

Retrieved from different scholar and surveys the critical factors for the transformation were gathered and examined. The IT-infrastructure is the backbone of Industry 4.0 procedures with the digitalized network, robotics, CPS, and smart factories enabling the efficient flow of digitalized processes. The correlation between IT-infrastructure and the implementation of Industry 4.0 procedures is positive. German manufacturers have a pioneering position in the industrial IT and there know-how in industrial engineering will enhance positively the initialization of digitalized processes.

The second factor, which has a positive influence on digital transformation, is Firm size. Larger manufacturing firms have better financial capabilities to realize the implementation of Industry 4.0. Next to this their experience and expertise related to past technological changes will support the transformation process. On the contrary SMEs might lack financial capabilities and expertise to drive the digital process.

Taking to account the negative factors correlated to the implementation process. The first factor introduced is lack of financial resources, which is negatively correlated to the implementation process. And especially in the case of SMEs, the investigation proposes that a large number of manufacturers are facing investment problems to finance the transformation process. Bank loans could be taken to account to finance the transformation, but companies fear the risk of payback and even if there is an active return.

Subsequently, the second negative factor is defined a skills mismatches of employees. It becomes obvious that the disruptive technological transformation requires also specific skill profiles from company staff. Whereas, manufacturers have two options, to obtain those skills; retrain existing employees or hire new company intern to cope with the requirements of Industry 4.0 processes. In both cases German manufacturers need to build a pool of IT-professionals, which are eligible to manage digitalized production processes.

The third factor revealed through the current thesis is reluctance to change, which is negatively correlated to the digital transformation. The analysed survey results and examined literature indicates that manufacturing companies fear the uncertainty of implementing digitalization. The expectation of both parties, employees and top-management, related to the requirements of Industry 4.0 is unclear and therefore they avoid considering the transformation. Mismatch of employees' skill profile, the change of established internal operations and business models strengthen the decision of manufacturers not to switch towards digitalized technologies.

The final factor affecting the transformation process is the maturity stage. Notably this factor is rarely discussed within the observed literature, but it tends to play also a role related to the focus to implement digitalization. Companies within this phase largely strive for new market opportunities. But new projects and fundamental changes of business strategies are only considered if the return is attractive. For most of the German manufacturing companies it is risky to completely develop new technologies and processes, since they have already build a strong position with existing business practices. A radical and complete adaption is seen as risky if the next phase of the product life cycle is the declining phase.

## 5. DISCUSSION: INDUSTRY 4.0- SECURING THE FUTURE FOR GERMAN MANUFACTURING COMPANIES?

Does the implementation of Industry 4.0 processes support German manufacturers to overcome recent market volatility? Definitely, it is a big opportunity for the companies to cope with competition from abroad such as China and North America. Through the digital process manufacturers are able to build a steady competitive advantage in the long run and to further expand their unique position as one of the biggest industrialized nations with core expertise in manufacturing technology and IT-services. Industry 4.0 with its significant ability to produce customized products are lower costs and less production effort will attract new customers and will considerably affect the profitability of German manufacturers. Next to this, digitalization enables the efficient use of resources, such as human resources, natural resources and raw materials. Predominately this will reduce the environmental footprint and tends to create better living situations for the upcoming generations.

In terms of human resources through the establishment of digitalized processes even elderly people could work in smart factories with less effort, since major task include managing and controlling if the autonomous systems produce the desired outputs. Moreover, the transformation to Industry 4.0 will create additional jobs in Germany, especially "e-skills" are required such as IT-managers, big data managers, and data exchange managers. Approximately there is a need for 825.000 IT-professionals till the end of the year 2020. Another advantage of digitalization is that there is no need for German manufacturers to shift to low wage countries, because the savings through the transformation are enough to be located in Germany. According to the Federal Ministry of Education and Research (2016) the upcoming industrial revolution is especially beneficial for SMEs. The argument is based on greater competitive performance through reduced cost and less customization effort. However the investigation of the current thesis describes clearly that "Umrüstung zum null-tarif" is rarely possible. Large amounts of initial investments are needed to fuel the transformation process. Financial capabilities tend to play a significant part within the whole process of transformation, whether it is an option for SMEs needs to be elaborated carefully, since it covers also huge risk. While different German institution promised to support especially SMEs from Germany with funds to implement the transformation, it is still unclear if this is sufficient to drive the transition towards Industry 4.0 procedures. The opinion of the author form the current thesis is that SMEs will have difficulties to transform successfully to digital production. These might have several reasons; lack of investment, mismatch of required employee profile and the reluctance to change. In contrast larger manufacturing companies have especially the financial capabilities and experienced professionals to cope with the challenges of the transformation. One exception could be the maturity stage of large organization, which hinders the transformation towards digital processes. SMEs also have the opportunity to combine capabilities with competitors or suppliers to enable the transformation process.

The implementation of digitalization has also several challenges, which need to be managed carefully. The annual damage for German manufacturing industries based on cyber attacks accounts for €50 billion (Baums, 2014). Cyber risk is one of the factors described in the current paper that has a huge effect on the operational and production process. The losses of the German automotive industries caused by production downtime accounted for €28 million per year (Baums, 2014). German manufacturers should definitely employ cyber security staff to be equipped if cyber attacks and unauthorized access is suspected. To keep situations under control safety and security systems should be integrated. Similarly contingency plans need to be in place and employees and managers should know best practices if cyber attacks are suspected.

Now the major aim of German manufacturing companies is to carefully weigh the benefits against the disadvantages. There are several challenges that manufacturers need to overcome, but the implementation of Industry 4.0 procedures has a great potential to secure the future for German manufacturing industries.

## 6.LIMITATIONS AND FUTURE RESEARCH

This paper has also specific limitations that need to be addressed. The selection of different theories and concepts for the research were also retrieved from different surveys of consulting agencies, such as PwC, McKinsey, and Deloitte. They aim was to gather detailed information on critical factors that affect the implementation of digitalization within German manufacturing companies. Even if the surveys were published by famous consulting companies, there is no guarantee that the results of the survey are reliable. The validity and reliability of the survey results were not controlled and tested by the author. This could be also assigned to the usage of different sources from the Internet.

An interesting recommendation for future research is to build upon the current research by investigating through a quantitative research if the critical factors have a significant effect on the success of implementing Industry 4.0 procedures. In terms of generalizability it is appropriate to use a quantitative study to check whether the results could also be applied on other companies. Applying well-established standards of measures allows replicating or extending the research on the factors influencing the digital transformation, which could be again compared to other studies (Babbie, 2010). The study should be carried out after 2 Years, than there is a higher chance that a large number of German manufacturing companies are preparing for the digital transition.

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