

Industry 4.0 Scenario Planning
**How will the industry 4.0 transformations affect SMEs in
Germany by 2030?**

Master of Science International Management

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JULY 2017

Abstract

Digitalization is invading every aspect of our lives and modern technologies are at the helm of much disruptive change in all spheres of life. Hailed as the 4th industrial revolution every company has a mind to understand the implications of the Industry 4.0 suite of technologies and their multiple innovative applications for its operations. In this paper, we explore how the industry 4.0 transformation might affect Small and Medium sized enterprises in Germany over a 15-year horizon. We focus on SMEs because they play a significant role in ensuring the prosperity of Germany as a global industrial and economic powerhouse. We develop alternative pictures of the possible futures using the foresight technique of Scenario planning in which the factors that shape the business environment SMEs and indeed all companies operate in are identified and used to build the most plausible alternative realities. The outcome is four distinct scenarios that reflect the possible growth trajectories regarding the impending transformation for SMEs.

***Keywords:** Industry 4.0, German SMEs, Scenario planning, digitalization*

Key findings

- There is much expectation around Industry 4.0, but SMEs have real obstacles that also make the associated fear tangible. Many stakeholders and indeed SMEs are uncertain due to the disruptive nature of the innovation associated with the transformation.
- Achieving the industry 4.0 transformations will require the coordinated action from a wide range of stakeholders like government, industry associations and private sectors.
- The future of SMEs in connection to the coming transformation is not predetermined. The four scenarios illustrate this with consistent and insightful alternative futures that above all expose critical issues to consider in building a transformation ready environment that includes SMEs.

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Introduction

The fourth industrial revolution, which is also called Industry 4.0, was developed as a part of widely established German high-tech strategy aiming to maintain global leadership and competitive advantage in manufacturing sector. Nowadays it is the most frequently discussed trend not only at the academic level but also in the business environment because it is the next stage of industrialization that will change the entire value creation chain increasing interconnectivity of physical and digital worlds (Gilchrist 2016; Kagermann et al. 2013).

The peculiar features of Industry 4.0 advanced technologies are the introduction of Internet of Things and Services into production and implementation of Cyber-Physical Systems that represent a significant potential for optimization of manufacturing and business processes. The core idea lies in creating a dynamic, self-ordained smart production system enabling producers to meet the individual customers requirements and fulfill the last-minute changes in orders. In addition, Industry 4.0 technologies increase productivity and resources efficiency taking into consideration current demographic trends and changing attitudes in society toward life-work balance (Kagermann et al. 2013).

However, the digital revolution provides SMEs with an opportunity to specialize and develop downstream services, it also represents significant challenges associated with data protection, sound financial resources needed, development of comprehensive strategy to implement new technologies, availability of qualified employees and developed IT infrastructure. As a result, SMEs that are the pillar of German economy remain cautious toward adoption of Industry 4.0 technologies (Schröder 2016). The high level of uncertainty and risk regarding future development of SMEs gave the basis for the research question, which was formulated as follows:

How will the industry 4.0 transformations affect SMEs in Germany by 2030?

The research question is supplemented by several research objectives:

- Provision of the panorama of Industry 4.0 technologies and their economic impact
- Illustration of the importance of SMEs for German economy and introduction of the challenges that might be faced in terms of Industry 4.0 transformation
- Determination of relevant areas of influence

- Development of consistent scenarios that describe future possibilities of Industry 4.0 transformations for SMEs

In order to answer the research question, achieve objectives and develop possible future using scenario-planning technique, the first chapter of the paper introduces the brief historical overview of industrial revolutions and provides the definition, the main elements and distinguishing characteristics of the Industry 4.0 disruptive technologies. In the second chapter the importance of small and medium-sized enterprises (SMEs), so called “Mittelstand”, is given illustrating the role in German economy. The third part focuses on the theoretical essence of the scenario planning technique, as the main methodology of the research, whereas, the practical implementation including the introduction of the INKA 4 software and team process are given in the fourth part. Finally, the fifth chapter introduces the scenarios obtained as the results of the research and clarifies the limitations of the conducted study.

1. Industry 4.0

1.1 Theoretical basis of industrial revolutions

An industrial revolution is a complex of technological innovations which create a modern economy by replacing animal / human effort and skill with machines and inanimate power. In many circles of historians, the phrase also denotes a rapid technological change that has a large impact or significance (Landes 2003). Gregory Clark estimates that the first industrial revolution started in Britain around 1760 because before then the average rate of growth in efficiency resulting from technological advancement all over the world was close to zero. By 1860 the rate had risen to 0.5 percent per year (Clark 2013). More recently, a positive correlation has been drawn between the acceleration and the level of innovation by examining patent filing records. After 1760, patent filings increased to reflect the expansion in industrialization primarily to support the textile industry. Brian Spear notes that after James Watt’s patent on the steam engine was enforced successfully patenting increased tremendously (Spear 2016).

As for the causes of industrial revolution, historians and economists put forward many theories. Clark grouped them into three broad camps. The exogenous growth theories posit

that exogenous events created the conditions for the revolution to take root. In contrast, endogenous growth theories contend that industrialization was built into the human genome as part of our evolutionary survival response and would be inevitably triggered once a critical threshold was crossed in the advancement of efficiency. The third category are the multiple equilibrium theories whose argument is that major shocks like disease and war caused the shift from a Malthusian equilibrium as it were to a state of dynamic equilibrium in which the revolution was forged (Clark 2013). While there is no clear consensus on the root cause of the industrial revolution, the idea that a number of technological innovations present in England at the time coalesced into a new technical system has gained more acceptances among economic historians (Mokyr, Strotz 1998).

The first Industrial Revolution resulted into the transition from an agrarian economy into the age of mechanical production. Coal was used to power production and wage labor was born as productivity made huge leaps. Transport and logistics also improved a great deal with the increasing use of steamboats and the railway train (Clark 2013). The 20th century ushered in the second revolution, characterized by the introduction of the factory setting and mass production. The former allowed affordable consumer production for mass consumption. Electricity and crude oil replaced coal in powering mass production. Ford's work on assembly lines and Taylor's study of the production process further increased productivity (Mokyr, Strotz 1998). The next significant change came from the application of electronics and information technology to the industrial process. Production underwent many optimizations and automation starting in the late 1960s as computer use increased (MacDougall July 2014). Fittingly, this transformation is also called the digital revolution because it marks the transition into the information age where, with the help of computers machines are controlled and coordinated just as processes and suppliers are integrated on a global level (Wolter et al. 2015).

1.2 Industry 4.0 and nine driving trends of the fourth industrial revolution

The term "Industrie 4.0" was created in 2011 originating from a project of the German government to promote the computerization and modernization of manufacturing. The term represents the increasing digitalization of the production process and the factory as a unit of production. Industry 4.0 refers to the technological evolution from embedded systems to cyber-physical systems (CPS) capable of creating intelligent object networking and

independent process management across real and virtual worlds (MacDougall July 2014). According to Gilchrist, CPS integrates computation, networking, and physical processes allowing embedded computers and networks to monitor and control the physical processes. (Gilchrist 2016).

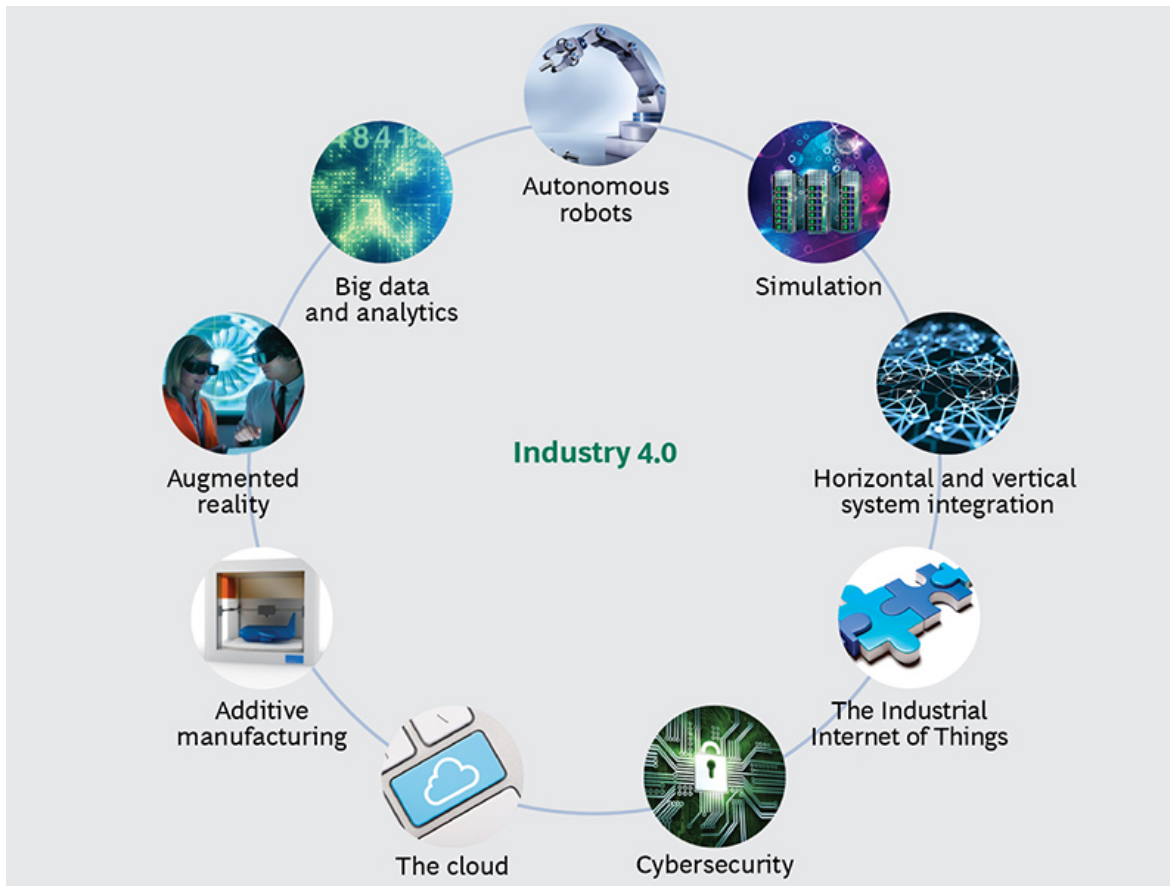


Figure 1: The nine Technological trends behind the 4th Industrial Revolution (Rüßmann et al. 2015, pp. 3)

The effect of a synergetic convergence of key digital technologies is the driver of the 4th industrial revolution (Gilchrist 2016). According to Rüßmann, the whole revolution rides on nine main technological trends that in tandem drive the interconnection of all sensors, IT systems and machines through the entire value chain (Rüßmann et al. 2015). These trends range from the use of autonomous robots, Internet of things, Big Data and Analytics, augmented-reality-based systems, cyber security, cloud computing, additive manufacturing, to horizontal and vertical system integration (Figure 1) (Rüßmann et al. 2015).

The first driving force of Industry 4.0 is the recent emergence of Big Data Analytics. According to Oracle, data makes the transition to big data when the volume, velocity and variety exceed the capacity of ordinary IT systems to capture, store and analyze it. The

aspect of analytics refers to a set of activities undertaken to derive useful insight from large data sets (Oracle Corporation March 2013). Big Data Analytics provides a great benefit for companies that conduct analysis based on large sets of data enabling them to reduce energy consumption, optimize production and improve services (Gilchrist 2016). In addition, data has become a key aid for decision making due to the abundance of both structured and unstructured data types, ranging from call detail reports, video cameras and equipment sensors to data from social networks. The standard process in dealing with the diverse data streams is warehousing, preprocessing and finally summarizing to make trend associations which are then consumed in an organization by traditional business intelligence tools (Oracle Corporation March 2013).

The second building block of digital technologies is the implementation of autonomous robots to tackle complex tasks. However, these tasks are not new in manufacturing with development of Industry 4.0 they are becoming more autonomous, cooperative and flexible. In future, they will have a wider range of capabilities less costly than they are today. In addition, in the manufacturing process, it is crucial to create a virtualized model of the physical world, which includes humans, machines, and materials to test and optimize production line in the virtual world in order to increase product quality and avoid errors in reality. Production processes with Industry 4.0 technologies use a 3-D simulation of manufacturing in the engineering phase, but in future these simulations will be extended to operations in plant leveraging real-time data, which saves time for machines' adjustment (Gilchrist 2016).

The fourth technology that is transforming industrial production is horizontal and vertical system integration. The aim of Industry 4.0 is to develop IT systems that will link engineering, production, marketing and after-sales services as well as companies, departments, capabilities, and functions. Evolving data-integration networks will create fully automated value chains. Nowadays, despite highly developed IT systems, companies, suppliers, and customers are not linked closely, which also means that processes from enterprise to shop floor are not integrated (Gilchrist 2016).

The next trend regarding Industry 4.0 is the spread of the Internet of Things (IoT). A clear definition of this term derives from the Cisco Internet Business Solutions Group (IBSG), according to which IoT is a point in time when more objects or things are connected to the

Internet (Dave, 2011). Today, computing systems are implemented only in some machines and manufacturer's sensors that are organized in the vertical automotive chain with limited interaction. The industrial Internet of things will make it possible to connect transducers and machines in order to enable them to communicate and interact with each other and also to connect them to centralized controllers and managing systems. In addition, industrial Internet of Things decentralizes decision-making and analytics to provide a real-time response (Gilchrist 2016).

Rising connectivity and standardization of production protocol increases the importance of protection of manufacturing processes from cybernetic threats. Recognition of vulnerabilities and challenges caused by integration of processes and Internet production is the main goal of cyber security. Some companies have already solved this problem to some extent by joining forces with cyber security companies through partnerships or acquisition (Rüßmann et al. 2015).

The other transforming technology is additive manufacturing such as 3-D printing, which enables manufacturers to produce a small batch of customized products. The main advantage of additive manufacturing methods are opportunities to create prototypes of conceptual designs and individual components that reduce costs, increase time efficiency, bring more value to customers, as well as, reduce transport distances (Rüßmann et al. 2015).

Today, augmented-reality-based systems are still in the primary stage, however, in the future mobile devices will supply workers with real-time information concerning parts in a warehouse and repair instructions, hence, improve decision-making procedures. Another implication is maintenance and virtual training, which significantly decreases costs of external experts (Gilchrist 2016).

The last driving trend is cloud technology because the concept of Industry 4.0 requires broader data sharing within the value chain, which goes out of companies' boundaries. In the context of Industry 4.0, the cloud refers to the virtual space in which a large number of operations are performed. Broadly defined, cloud computing facilitates ubiquitous and on-demand network access to a shared pool of configurable computing resources. With limited intervention from a service provider and minimum effort from management, the computing resources are availed to an end user (Gamaleldin 2013). Cloud services include four

categories: Software-as-a-service, Service, Platform-as-a-service, and Infrastructure-as-a-service. These types are oriented on different customers and have different purposes, however, all of them have the same business model, namely, renting computer resources services, applications, infrastructures, and platform. The cloud service providers are capable of developing clouds suitable for companies' data storage and processing (Lin, Chen 2012).

1.3 Benefits of Industry 4.0

Germany possesses significant production technologies and plant facilities, high level of IT competencies, management qualifications as well as holistic innovative strategy targeted on digitization of manufacturing processes, thus, enabling it to utilize numerous benefits that the Fourth Industrial Revolution brings. According to Boston Consulting Group, in the next years digital technologies will boost productivity by 5 to 8 percent, reducing cost by 15 to 25 percent depending on the industry. In addition, the development of smart factories makes it possible to meet individual customers requirements on production of one-off items through integrated IT systems that adjust production lines and flexible networking throughout entire supplier chain. The increase in demand on customized products will bring additional revenue of approximately €30 billion a year, which makes around 1 percent of Germany's GDP (Rüßmann et al. 2015; Kagermann et al. 2013).

The other value of the implementation of Industry 4.0 technologies is the opportunity to solve challenges, concerning resource scarcity through increasing productivity of processes throughout entire value network. Moreover, facing demographic and social changes, as well as considering the talent shortage, assistance systems will provide flexible working conditions encouraging work-life balance (Kagermann et al. 2013).

Germany has recognized the value and opportunities that Industry 4.0 technologies bring. Large companies, anticipating potential benefits of digital era, have already started to develop innovational strategies, business models and improve their business processes. However, for SMEs, the implementation of Industry 4.0 technologies is associated with significant challenges, thus, they remain relatively cautious regarding the fourth wave of technological advancement (Schröder 2016).

2. Small and Medium-Sized Enterprises in Germany

SMEs or small and medium-sized enterprises in Germany are known as the “Mittelstand”. They are characterized by having less than 500 employees (make-it-in-germany.com, 2012). German SMEs are considered to be the strongest driver of innovation and technology in the German economy, most of them specialized in niche markets (“Future of the German Mittelstand” Mittelstand ” Action Programme, 2016) and hence, the backbone of the German Economy (KFW, 2015).

German Mittelstand companies represent the 99.6% of all the German firms, which results in more than 3.6 million companies. They range from traditional craft firms to pioneering high-tech companies. Furthermore, they are in charge of creating 58.5% of jobs in Germany (“Future of the German Mittelstand” Mittelstand ” Action Programme, 2016). Most of them are known as European or even World leaders in their market (make-it-in-germany.com, 2012).

Generally, SMEs in Germany are family-owned, led by the original owner and already in business for generations. They are known for having a special mindset in the way they manage the company. The low-hierarchies and close relations with customers allow them to respond to changes in the market in time. It is due to their diverse and innovative characteristics that they have been able to cope with many crises; this makes them in part, responsible of the economic and social stability that has prevailed in Germany (“Future of the German Mittelstand ” Mittelstand ” Action Programme, 2016).

It is important to mention that most of these companies are the most innovative in Europe. Proof of this is that 54% of them launched an innovation onto the market from 2008 – 2010 (Federal Ministry of Economics and Technology, 2014). On the other hand, these companies are very strong in the industrial sector, as well as a strong supplier of capital goods on new markets all around the world (Federal Ministry of Economics and Technology, 2014).

The role that SMEs have in Germany is significant, since they contribute 51.8% of the total economic output (Federal Ministry of Economics and Technology, 2014). Most of these SMEs enter the category of “Hidden Champion”, where they are world market leaders in their niche, offer quality products and work closely with customers. In other cases, they are

part of the supply chains for large companies (“Future of the German Mittelstand ” Mittelstand ” Action Programme, 2016).

2.1 Challenges for German SMEs in the fourth industrial revolution

Industry 4.0 carries many opportunities and challenges to German SMEs. Roughly 5% of SMEs have adopted already the new disruptive technologies. However, just a third of them are creating strategies towards its full adoption. The necessary changes for the full implementation of Industry 4.0 within German SMEs are not easy. It takes the network of various IT Systems and the infrastructure, which require resources that most of SMEs do not count yet (Schröder, 2017).

On the other hand, there is a lack of standards and norms concerning data security, which makes it difficult for SMEs to join collaborations for innovation and value chain networks. Furthermore, there is an increased concern regarding the modification of the workplace and the job losses that these transformations take. Nevertheless, it is fundamental that German SMEs take action and develop the framework conditions, which are necessary for its successful adoption.

3.1 Methodology

3.1 The origins of Scenario Planning

Scenario planning also known as contingency planning was first used as a method for military planning by Herman Kahn and his colleagues at the Rand Corporation following World War II in the 1950s and 1960s in order to build US military strategy and investigate the possibilities of nuclear war that could have evolved between the US and the Soviet Union. The main aim of this approach was to think about alternative future outcomes by combining facts and logic. As a result he developed a scenario ‘nuclear war by miscalculation’ that had a significant impact on a strategy of Pentagon In 1961 after the establishment of Hudson Institute he started to embed this approach to public policy planning and social forecasting (Bradfield et al. 2005; Wright 2000; The Economist 2008).

In terms of business application, General Electric (the US conglomerate) was one of the first companies that adopted scenario planning in the 1960s and 1970s. (Verity 2003), however, it became known to management as a strategic tool only in 1970s and 1980s after it was introduced by Pierre Wack at Royal Dutch Schell and Peter Schwartz at SRI International (Stanford Research Institute at Stanford University) (Verity 2003; Bradfield et al. 2005; Wright 2000). Work of Schell and SRI gave a rise to the ‘Intuitive Logics’ school of scenario planning following Khan’s philosophy that a scenario is not a prediction but an element of uncertain future that can affect strategic decisions. Intuitive approach based on creative thinking, imagination, subjective ideas and storytelling using qualitative information extends experiences and trends of today’s reality, in order to obtain different pictures of the future that enable managers to build long-term strategies and short-term plans. Alternatively, the ‘formal’ style of scenario building developed by Khan’s colleagues from the Rand Corporation is based on quantitative methodology underlining the importance of computer technologies, models and processes for analysis and calculations of future paths. In the 1980s, Battelle further developed formal methodology by combining it with a software program and illustrated the importance of managerial judgment for computer-based scenario simulations (Verity 2003; O'Brien, Meadows 2013).

3.2 Scenario as a planning tool

A scenario is a general and comprehensive description of a possible paths in the future, that are based on a complex network of influencing factors and plausible assumptions starting at the present point of time that are supported with comprehensive reasons (Figure 2) (Zukunftsorientierte Unternehmensgestaltung 2014). Scenarios represent complex interdependence of qualitative elements of a topic and illustrate possible alternative developments in the future (Geschka et al. 1993).

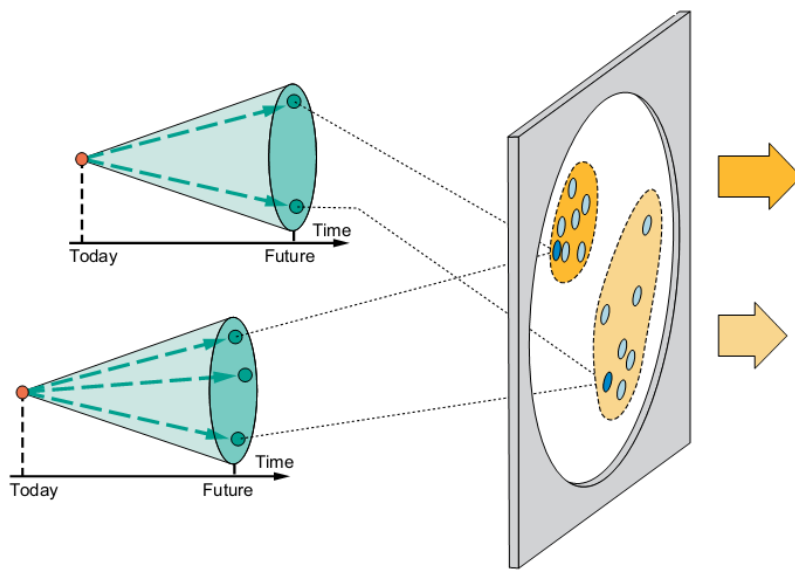


Figure 2. The path of a scenario (*Zukunftsorientierte Unternehmensgestaltung 2014, pp. 49*)

Scenarios can be developed on macro level for country or regions focusing on the major global, external and environmental trends for long-term planning. The company level analysis designed for narrower short-term oriented scenarios additionally include parameters such as internal issues, industry structure models or market demand. Both scenario levels often complement each other because broad global research represented by economic, social and political variables can be supported with investigations of a precisely defined issue, industry or topic (Verity 2003).

The exploitation of scenarios in strategic management is defined as scenario management, which main objective is to identify opportunities, potential success factors and threats in order to support strategic decision-making (*Zukunftsorientierte Unternehmensgestaltung 2014*). According to Schoemaker, companies can significantly benefit from this technique, if they operate in highly uncertain and volatile environment and in addition they do not create new business opportunities, which is accompanied with mediocre quality of strategic thinking (Schoemaker 1995). In order to remain competitive in the long-run and to build robust strategies, companies should consider the high complexity of social, economic, political and technological changes, as well as and developments in their environment more than ever before (Geschka, Schwarz-Geschka 2012).

Initially, the scenario building technique was developed for strategic planning, however, companies apply this method to operational planning, budgeting and forecasting processes in order to estimate impact of assumptions that can shape the future (Axon 2011). The main

argument for companies to apply the scenario planning tool is the advanced learning potential obtained by going through the main stages of the process while defining the research question, collecting and gathering data and generating the final model. The technique provides broader understanding of the major trends, forces and uncertainties influencing the future development of the company that can become a key pillar for the strategic management. On the other hand, this method has not gained popularity due to large amount of employed resources and high requirements to the quality of scenario team that as a rule meets on a regular basis conducting workshops, research activity and interviews (Verity 2003).

3.3 The scenario building technique

The scenario building technic is an effective multi-step approach for long-term planning in the highly uncertain and unpredictable environment. The scenario software INKA 4 represents the integrated algorithm for scenario planning developed by Geschka & Partner. The program systematically supports scenario creation for a chosen topic using description of influencing factors to evaluation of scenarios based on alternative assumptions of the descriptors (Schwarz-Geschka 2017).

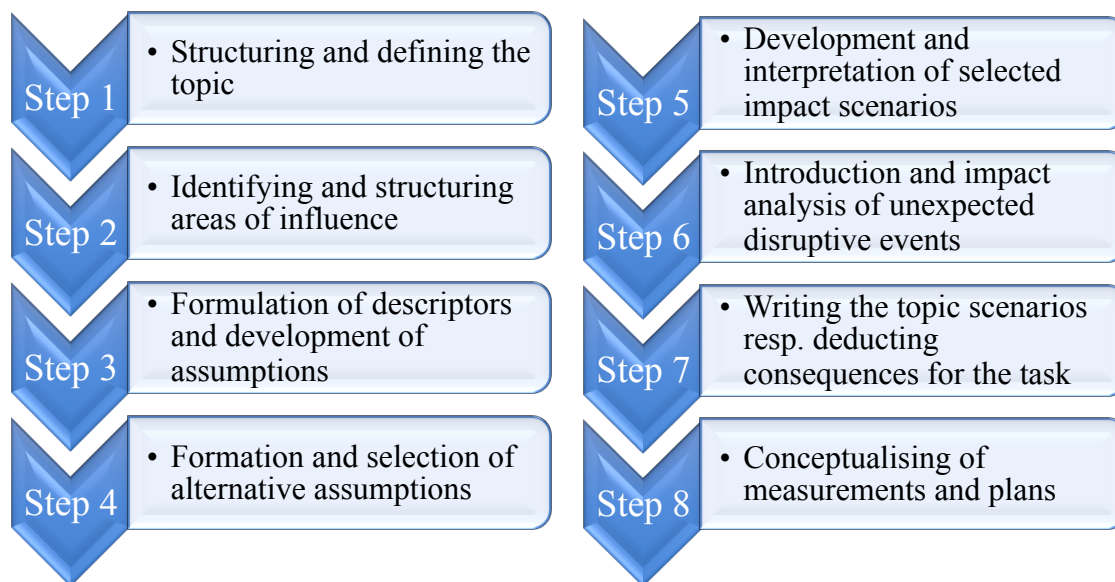


Figure 3: Eight steps of the scenario planning technique (Geschka, Schwarz-Geschka 2012, pp. 7).

The scenario planning technique comprises of eight major steps (Figure 3). The first stage implies precise definition of scope of analysis and time frame which as a rule depends on

factors such as technological changes, competition, product life cycle, state elections, etc. (Schoemaker 1995). The second step includes identification, collection and structuring of influencing factors, the number of which will determine the complexity of the future, that are to be classified into areas of influence that are related to the chosen topic. After scrupulous revision and elimination of overlapping factors, they are clustered into areas of influence. In the next step selected influence factors are formulated as quantitative or descriptive parameters, so called descriptors that cover both quantifiable trends and qualitative developments creating the projections for the target scenario year. Further, the computer software algorithm combines them into one consistency matrix, which makes it possible to compare and estimate which of alternative descriptors are reinforcing, neutral or contradictory to each other. After the consistency matrix is complete, the program conducts analysis by combining highly consistent assumptions and develops alternative scenarios. In the fifth step, from two to four scenarios are to be selected basing on the criteria such as 'high consistency' and 'significant difference' (Geschka, Schwarz-Geschka 2012).

According to scenario building technique on the later stages the impact of disruptive negative events (earthquakes, explosions), as well as positive events (technological inventions, political reconciliations) that change the direction of trends can be introduced, analysed and monitored through development of new scenario variances. Ultimately, obtained results enable to determine and design the necessary measurements and long-term strategies (Geschka et al. 1993).

4. Team methodology and process

Differing from the previous versions of the software used for the scenario planning, INKA; INKA 4 is the first Web-based version that has been released. This improvement allowed the team process to use the program from different computers without having it installed; it also gave greater flexibility and the possibility of a faster process.

The scenario-planning project in industry 4.0 is done in the context of SMEs due to the importance that they have in the German economy, as it is mentioned above, and the way they will be affected by this 4th industrial revolution. There are diverse positions regarding the way Industry 4.0 will affect companies in Germany, especially SMEs. It is argued that

the 4th industrial revolution will create plenty of opportunities for German SMEs. On the other hand, it represents a special challenge for SMEs in Germany (Sommer, 2015).

As it is mentioned above, Industry 4.0 is a term that is relatively new in Germany and has been heavily promoted by diverse entities, especially The Economic Affairs Industry together with the Research Ministry through the “Plattform Industrie 4.0”. An special focus on SMEs is implemented through the program “Mittelstand 4.0” (“ Future of the German Mittelstand ” Action Programme, 2016). Therefore, the development of this Industrial Revolution is still in progress and the next 15 years will be critical for either the successful or failed implementation. For this reason, the scenario-planning project in Industry 4.0 is forecasted by the year 2030.

Extensive literature review was done in order to obtain a general view of what different authors, as well as different governmental and private entities expect from the 4th industrial revolution, specifically in Germany. After having detected the most prominent factors that are forecasted as key elements for the implementation of the 4th industrial revolution, the following areas of influence were selected: Politics, Finance, Infrastructure, Technology & Innovation, Education & Qualification and Integration.

4.1. Infrastructure

There is a widespread consensus that success in the Industry 4.0 age will depend on the quality and reach of infrastructure. Particular attention is paid to digital infrastructure like communication networks (Heng 2014). Digitalization is invading more areas of our lives so that there is more reliance on data just as we generate larger amounts of it. It is clear that any network must be built with the capacity to manage the continuously increasing volume of data and quality requirements (Heng 2014). The OECD urges members to create sustainable national strategy for investing in digital infrastructures to serve the present needs but also meet the demand in the future (OECD 1/12/2017). Germany with a 2 Mbit per second transfer rate broadband connection and 1 percent fibre optic coverage is lagging behind (Graumann, Bertschek 2014). Intercompany internet based production and associated downstream services like evaluating data in real time as in a closed production feedback loop requires a much higher transmission rate that 2Mbit per second (Heng 2014). Perhaps realizing the gap, Germany is modeling the OECD recommended strategy and

pioneering a number of its own initiatives to increase investment in infrastructure through public and private funding. The government understands that there are stark differences in not only the way ICT is used but also on the first level of making the decision to adopt new technologies between SMEs and large firms where the latter are beset by multiple obstacles. These range from financial constraints to a lack of complementary resources like correctly skilled labor (OECD 1/12/2017).

4.2. Technology and Innovation

Germany's Mittelstand has the reputation of being both innovative and competitive on a global level. Germany boasts the largest share of hidden champions, SMEs with low public visibility, typically family owned and leading an industry or in second place globally. German SMEs typically specialize and bring to bear a very high level of expertise in their field. The country also has substantial technical knowhow with regard to numerous Industry 4.0 technologies and a well educated / trained workforce (Schröder 2016). The vision of fully digitized and networked production has created the impetus to search for both technologically and socially innovative solutions. Product end users and producers are increasingly collaborating digitally. The resultant innovations are driving further digitalization and enabling new business models that threaten the traditionally successful models from the start of the information age (Buhr 2015). Germany is already in strong a technological position. According the European Patent Office, Germany holds 16% of all new patents in 2016 and is second only to the United States of America ((European Patent Office, 2016). The swift level of innovative breakthroughs enables the development of new products just as the old ones get improved so that business and production processes are continuously improved. In this way Germany keeps up with technological megatrends like smart data, Internet of things and 3D printing (Graumann, Bertschek 2014).

4.3. Finance

Adoption of Industry 4.0 technologies require significant investment outflow to cover modernization of production facilities, replacement of the old systems to modern software, installment of the hardware, development of IT infrastructure etc. what often representing a

challenge for SMEs. Thus, the availability of financial resources is one of the main prerequisites for successful digital transformation („Erschließen der Potenziale der Anwendung von ‚Industrie 4.0‘ im Mittelstand“ Juni 2015; “Future of the German Mittelstand” Action Programme May 2016).

The key external source of finance remains to be bank loans to which SMEs have historically good access due to improved creditworthiness, higher profitability and increased equity ratios. Despite favorable borrowing terms and low interest rates, according to KfW in past three years four out of five SMEs carried out investments in digital projects, with half investing less than EUR 10 000 per year (KfW SME Panel 2016 2016).

On the other hand, young innovative SMEs and micro-businesses tend to have insufficient cashflow what make them more dependent from external financial resources, However, due to lack of creditworthiness that indicates the ability to meet credit obligations, they have limited access to bank loans. The occurred financing gap can be compensated by venture capital, although, in this area Germany is still behind other developed countries (Schröder 2016; “Future of the German Mittelstand” Action Programme May 2016). In order to strengthen this sector of capital market and encourage business angels to invest in dynamic innovative enterprises the German government has provided in total €2 billion, implemented new legislative initiatives (§8 Körperschaftssteuergesetz KStG – German Corporation Tax Act) and launched public-private incentives such as “INVEST venture capital grant”, High-Tech Start-Up Fund and ERP Venture Capital Fund Investments (“Future of the German Mittelstand” Action Programme May 2016; Schröder 2016; Bundesministerium für Wirtschaft und Energie (BMWi) 2016, 2017).

4.4. Politics (national program, security, legislation)

The German government developed Industry 4.0 as a part of the High-Tech Strategy 2020 Action Plan to secure leading competitive position of German enterprises through combination of research and innovation initiatives (Federal Ministry of Education and Research 2014). The Federal Government support SMEs through special funding programs in the area of research and innovation, promotion of digital technologies, infrastructure, as well as specialized funding activities and projects, such as "KMU-innovativ: Informations-

und Kommunikationstechnologie (IKT)", Zentrale Innovationsprogramm Mittelstand (ZIM), and „KMU-innovativ“. Additionally, four "Mittelstand 4.0-Agencies" and ten regionally active "Mittelstand 4.0 competence centers" were established to inform about perspectives of digitalization and support the development of practical Industry 4.0 solutions across different regions („Erschließen der Potenziale der Anwendung von ‚Industrie 4.0‘ im Mittelstand“ Juni 2015).

The goal of Industry 4.0 is to increase benefits of enterprises through information and communication technologies and cyber-physical systems, thus, creating demand for standardization. Furthermore, development of Industry 4.0 technologies due to increasing data generation, storage and procedure arises new legal challenges regarding general data protection regulation, development of IP law and IT security (Plöger, et al. 2015). The risk associated with data exchange across the integrated value chain make SMEs and their customers an attractive target for cyber-attacks what represents a threat not only for production processes but also for national economy (Heng 2014; Plöger, et al. 2015; „Erschließen der Potenziale der Anwendung von ‚Industrie 4.0‘ im Mittelstand“ Juni 2015).

4.5. Education & Qualification

The 4th industrial Revolution in Germany demands changes in the nature of work and also in the qualification of employees. The transformation of production processes requires new types of interaction between people and machines, which will cause the need of available qualified workforce (Lorenz, Rüßmann, Strack, Lueth, & Bolle, 2015).

Education and Qualification represents an area that is fundamental for the development of Industry 4.0 in SMEs in Germany. The availability of qualified workforce and the expansion of the technological aspect of education towards these transformations will enable employees to cope with more complex processes expected in the workplace. (Hecklau, Galeitzke, Flachs, & Kohl, 2016). On the other hand, in the workplace it is manifested as fear that increasing automation will escalate job loss (Schröder 2016).

Industry 4.0 has promised a great deal of change and this naturally comes with uncertainty (Deutsch Bank, 2014). Furthermore, it is predicted according to Constance Kurz, adviser of Industry 4.0 at I.G. Metall, “approximately 65% of employees in Germany are capable to

upgrade their skills to new requirements” (Lorenz et al., 2015). Therefore, in order to meet the present and future challenges that Industry 4.0 carries, it is critical to consider the activities that are related to professional education, learning and trainings (Hecklau et al., 2016).

4.6. Integration

One of the most important and indispensable requirements for adopting Industry 4.0 are a closer integration within companies and also a networked value chain (Kagermann et al. 2013). At the same time, there is an increased pressure for product efficiency and highly connected manufacturing processes (“Future of the German Mittelstand ” Mittelstand ” Action Programme, 2016).

It is expected that industry 4.0 will change the way business is done, which will result in new ways value creation as well as new business models (Kagermann et al. 2013). On the other hand, the interaction between SMEs and with research establishments will be highly important and determinant for the speed of adoption of these transformations (“ Future of the German Mittelstand ” Mittelstand ” Action Programme, 2016).

The areas of influence selected have the aim to group a set of descriptors, which will be as “descriptive parameters” (Schwarz-geschka & Introduction, 2014;). Each descriptor will belong to an area of influence and will have the purpose to project future trends or alternative developments that are very probable to happen according to the literature reviewed. The projections selected to every descriptor can be up to 3 and are called assumptions. The total of assumptions or alternatives derived from each descriptor had assigned a probability of occurrence, according to what it is projected in the current literature available. Per descriptor, the alternatives had to sum a total of 100%.

In the first round of descriptors created, a total of 27 descriptors were developed. It was critical to take into consideration, the fact that the descriptors were not overlapping and that the best possible factors or key elements per area were included.

After all descriptors were finished and evaluated, the final set of descriptors that were selected to use in the program were 24 descriptors in all areas together. In order to create the scenarios, it is necessary to fill the consistency matrix, Figure 4, where all descriptors

are evaluated against another descriptor. Each relationship must have a value of assessment. The value range goes from 3 to -3, as it is presented in the Table 1.

The assessment of the consistency matrix is based in the assumption that how related is each situation or how likely is to happen at the same time. This step in the process is critical for the scenario creation. The quality and precision of the assessment will determine the consistency of the future scenarios.

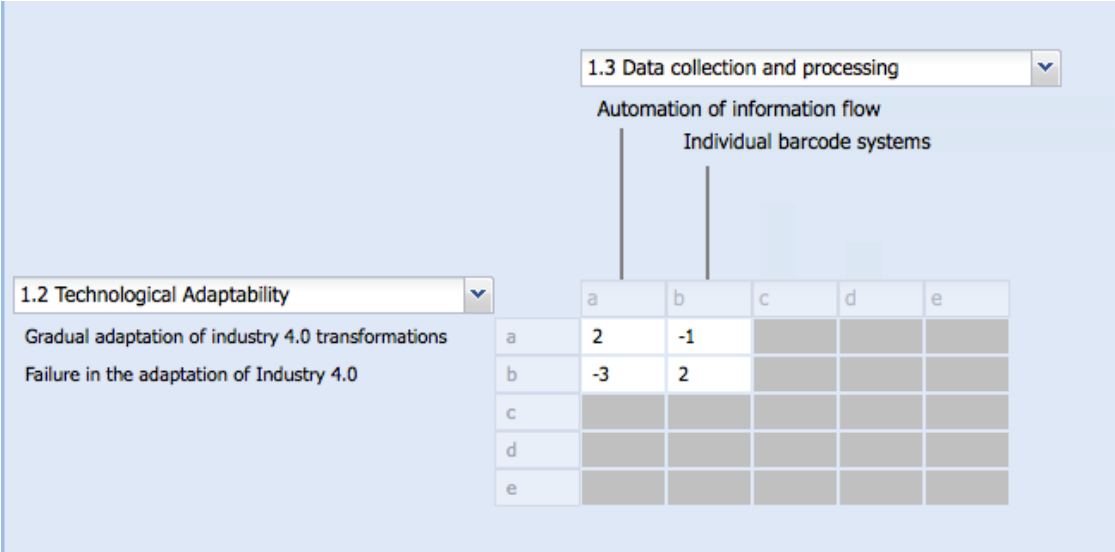


Figure 4: Example of Consistency Matrix and assignment of values.

Values	Interpretation
3	Mutually dependent
2	Mutually supportive
1	Fitting into the same category
0	Unrelated
-1	Fitting adversely
-2	Contradictory
-3	Mutually exclusive

Table 1: Values and interpretations for Consistency Matrix.

The estimation of values given in the consistency matrix is based on the judgment supported with the literature research done previously.

After the evaluation of the consistency of matrix, the program was run. As a result, 5 final scenarios were obtained (Figure 5). Each scenario has a sum of consistency, which indicates the quality of the scenario created and it is the critical element to select the final 4 scenarios. Each scenario has a set up descriptors. According to the quality of these descriptors and the number of used ones by the software, was the sum of consistency. At last, the scenarios are ranked according to this sum of consistency. The scenario ranked in 1st place is considered ad the most conclusive one. The description of the final 4 scenarios is presented below.

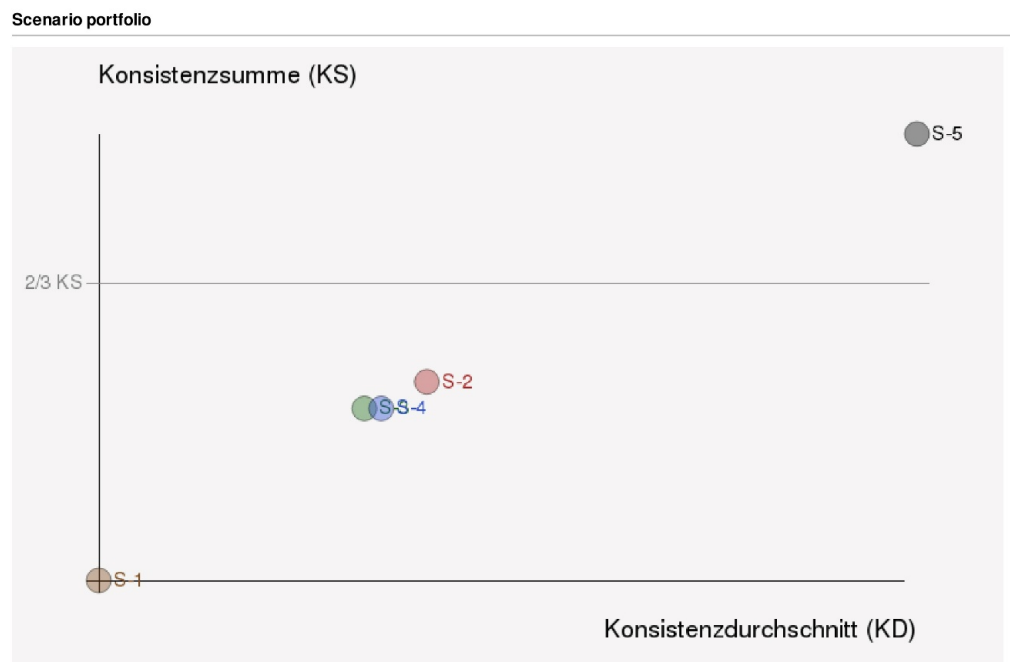


Figure 5: Consistency Sum after running the program INKA 4.

5. RESULTS

5.1 Scenario S-5 (Rank 1) – Watch out! The future is coming!

The German government has achieved the strategic goal targeted on the digitization of the economy creating the most preferable conditions for businesses what leads to global leadership of German industries and advanced economic growth. It actively shapes the operating field for SMEs through development of a holistic initiative that bundles all existing before Industry 4.0 programs. The especial emphasis is made on the spread of

competence centres and specialized agencies that support SMEs on their way towards digitization by providing comprehensive consultation on Industry 4.0 technologies. Government engage SMEs into digitalization processes through construction of a national gigabit optical fibre network with speeds upward of 50Mb and collaboration with private sector on development of internet infrastructure. Additionally, completed Machinery Directive of the EU, "machine-to-machine" (M2M) standards and directives on protection of trade secrets enabled SMEs to operate in safe and secured environment exchanging large amount of data throughout the whole value chain without a threat of cyber-attacks.

The optimistic approach toward risk and availability of external funds encouraged SMEs to implement Industry 4.0 technologies with high capital requirements. The main sources of debt capital are KfW entrepreneurial credit that covers costs of technologies that cannot be capitalized as non-current assets and ERP innovation program targeted on conduction of near-market research and development. Moreover, investments coming from the strong venture capital market enable innovative SME's to utilize business opportunities provided by digitization through sharing high average risks of Industry 4.0 projects.

Due to the full vertical integration within the company, the inter-company horizontal networks and transformation of business model SMEs are able to produce customized products in small amount for a specific market meeting the last-minute requirements from customers. The integrated value chain leads to increased collaboration between SMEs, cooperation for open innovations, eventually, gains from resource productivity and efficiency.

Industry 4.0 technologies have changed the core business processes providing virtual real-time image of the company. The automated recording, evaluation and processing of machine, plant and product data enable real-time planning and controlling of production, as well as identification of employees, materials, tools and equipment in a decentralized way, closing the gap in processes where they are currently needed and reducing the financial expenses of rework. Self-organized and self-optimized systems automatically evaluate and store the data, interact with each other ensuring the SMEs that the customer receives a high-quality product.

In terms of labor force, despite the fact that automatization overcomes the talent shortage due to adoption of CPS technologies and assistance systems, SMEs require workers with

both technical and social skills to cope with Industry 4.0 challenges. In order to develop necessary skills, SMEs located in the same region cooperate on projects and organize clubs where companies transfer employees to learn from other companies' employees. Furthermore, the implementation of Industry 4.0 at SMEs shapes the working conditions for their employees providing more personal flexibility regarding work time, content and place. Encouraged by the opportunities for self-development they actively adapt to disruptive changes caused by innovative technologies and business models.

5.2 Scenario S-2 (Rank 2) - Digital Darwinism

There are diverse and contradictory reactions of German SMEs regarding the full adoption of the new disruptive technologies of Industry 4.0. Even though the conditions for the successful implementation of Industry 4.0 technologies are favorable, some SMEs with high bureaucratic processes and high aversion towards change are less engaged in the process towards full digitalization. Their skepticism prevails, even though the young employees approach changes positively and believe in the cause. These SMEs become part of the process slowly; prefer to observe how the market reacts and be sure if the required investment is worthy.

Despite the attractive panorama for ventures capital investments and loan acquisitions, many SMEs struggle to trust in long-term financial obligations and see many disadvantages, which makes in their eyes, the implementation of Industry 4.0 a possible failure in the future. This represents a barrier for the full adoption and harmonization of Industry 4.0 among all SMEs in Germany. The establishment of successful cooperation between companies for employee development and innovation becomes difficult.

On the other hand, some SMEs, specifically start-ups and companies managed by young managers and CEOs, are the ones who are more motivated towards the implementation of the necessary upgrades and investments to fully adopt Industry 4.0. They identify the benefits that it carries for the company's long-term competitiveness. Furthermore, their production and logistics take a bigger step towards a full digitization of their processes as a direct consequence of a fully horizontal and vertical integration. Planning and control of production improves, allowing companies to better monitor quality parameters and meet last minute requirements profitably. They put more emphasis in the services and customer

post-purchase since they are now competing with large companies that at the same time are capable to deliver one-batch products. The key element to take into consideration for German SMEs in order to remain competitive is the quality of the customer services provided.

Although the German Government promotes the benefits and legal protection for adopting these disruptive transformations through the diverse platforms and the Initiative Industry 4.0 within SMEs, only some SMEs take part of the 4th industrial revolution. This makes it difficult to establish successful cooperation between companies for employee development and for the implementation of open innovation.

While the agile SMEs engage in the digitization process at a faster pace and trust in the promotion of Government to invest along with them in the necessary infrastructure, the skeptical SMEs that do not adopt Industry 4.0 technologies in the first place, start to lose competitiveness with the risk of being out of an always changing market.

5.3 Scenario S-4 (Rang 3) - The missing link

In recognition of the critical role SMEs play in the German economy, the government provides support in Industry 4.0 related fields. Sufficient resources are made available to support varied needs of SMEs that decide to embark on digitalization. Even on matters of regulation, there is strong commitment from the Government to create a complimentary legal framework for industry 4.0 technologies. Public partnerships with the private sector are successful in stimulating investment in infrastructure so that the high-speed Internet backbone of the country is well developed to reach rural areas where SMEs are predominantly located and the general public can enjoy ubiquitous Internet.

The potential to combine connectivity and automation to allow more employee autonomy and flexibility in the workplace is mature. The improved connectivity can support automated data collection and processing to power machine self-organization. SMEs have the proven ability to adapt new technologies like full vertical integration, which in turn facilitate horizontal integration into global value chains. The benefits of which are profitable customized production, resource and energy efficiency.

With a positive external environment consisting of mature industry 4.0 technologies, good connectivity and commitment to legal reforms, venture capital is attracted to industry 4.0

financing to compliment public finance initiatives. This not only makes more funds available but eases access to them for SMEs. The pressures of a shrinking workforce make the case for automation very clearly and SMEs adopting CPS in the production process would be compelled to pursue a skills development strategy that balances technical with social skills to match the changes in work configuration.

Staying true to tradition, SMEs do not take advantage of the available external resources preferring internal funds. Investment activity in new technology contracts as leaders grow older and prioritize capital accumulation over investment in new longer term and medium term projects. SMEs pursue narrow innovation agendas exclusively by collaborating with resource rich large firms. The entire eco-system is ready to support SME transformation into digital enterprises but they are not ready. The vision of a mature Industry 4.0 hangs in the balance.

5.4 Scenario S-1 (Rang 5) - Verging on Extinction

SMEs retain a traditional aversion to risk and reliance on internal resources, which severely restricts investment into new technology. The closed traditional approach to innovation undermines collaboration through SME clusters resulting in a chronic dependence on public institutions like Max Planck and Fraunhofer Institute to sustain innovation. With a reduced internal capacity for innovation, SMEs lose their ability to adapt new technology and are consequently not only left out of the industry 4.0 revolution but also threatened by digitalization.

Due to limited investment in infrastructure, transition to CPS is very slow and SMEs remain in mass production segments. There is very little automation in the production system and they still use individual barcode systems, which hamper information flow and lock SMEs outside global value chains. Production is inefficient and based on traditional business models.

The early government efforts to stimulate private investment in infrastructure in the telecom industry result in the emergence of industry monopolies. These monopolies focus on the economically viable projects in which connectivity needs for SMEs primarily located in rural areas are not met. Consequently SMEs have no access to modern fibre optic cables but instead have to contend with limited and slow Internet. The government is not

able to rally private investment in infrastructure and subsequently shifts to a balanced sustainable development strategy that diminishes the focus and support for SMEs industry 4.0 initiatives.

There is a leadership vacuum created by government shifting its focus away from industry 4.0, which precipitates a climate of distrust among industry 4.0 stakeholders and curtails the development of Industry 4.0 compatible legal reforms. The combination of a new government agenda that does not prioritize industry 4.0 implementation and an ambiguous legal environment diminishes the will of venture capitalists to extend funding for new technology in SMEs so that large enterprises thrive at the expense a modern Mittelstand.

Faced with a lack of access to external funding, SMEs consolidate in house talent development efforts with a focus on integrated engineering skills most suited to present business needs. Most employees are also opposed to change because industry 4.0 advancements are perceived as ceding their autonomy. So rather than embarking on automation SMEs relive the pressure of a declining workforce in Germany by recruiting from the large pool of refugees. Under resourced, held back by inadequate infrastructure and internally resistant to change, the age of the traditional successful change and technologically savvy German SME is at an end.

6. Discussion of Results

The final four scenarios selected portray the different possibilities in which the 4th industrial revolution could affect SMEs in Germany by the year 2030. The scenarios differ from each other in the degree of transformation that SMEs go through and the conditions under which Industry 4.0 develops. The main differences are identified in the degree of government support, attitude of SMEs towards investments and external resources, readiness to change, employee development and financial conditions. The first scenario illustrates the ideal successful implementation of Industry 4.0 technologies under the best financial and governmental panorama. It is showed the transformation that SMEs suffer due to its full adoption and the benefits obtained from it. In the second and third scenarios describe the different barriers, which can prevent SMEs from adopting Industry 4.0 and therefore loosing competitiveness. The last scenario exposes how SMEs do not take over Industry 4.0 technologies and the consequences that it carries regarding SMEs competitiveness.

Although there is still high uncertainty regarding the successful implementation of industry 4.0 among German SMEs, the presented results picture the spectrum of possible predictions based on facts and updated information. Therefore, the outcome stands on valid estimations.

7. Conclusion

The new industrial revolution is expected to be an evolutionary journey. On the other hand, it brings indeed uncertainty of how organizations will be able to cope with the increased complexity of production processes that it carries. Therefore, the course of the transformation towards the full adoption of Industry 4.0 is something that is not predetermined yet (Kagermann et al. 2013).

In order to identify the possible directions that the current trends and conditions could take in the nearest future, the scenario planning technique was employed. Those predictions illustrate all possibilities of development and effect that the 4th industrial revolution can have on SMEs in Germany. Furthermore, the results are conformed of all areas that SMEs could be affected.

Even though the report's outcome presents different possible scenarios that could be developed by the year 2030, they should not be taken as exact and unique predictions. There are several factors that should be taken into consideration such as possible disruptive changes in the nearest future, efforts of governmental and private entities, among others. The descriptors and specifications were selected based on the judgment generated from the current literature available and trends. Since the topic is relatively new, the information available is limited and still under research. Final scenarios are the result of those descriptors and specifications.

At last, there are different opinions regarding the disruptive changes that industry 4.0 entails. The shift towards this transformation is a long-term project; nevertheless it is fundamental that companies are aware of upcoming changes and start creating strategies from an early stage (Kagermann et al. 2013).

8. Annex

8.1 List of final descriptors

Descriptor name: Innovation

Area of influence: Technology & Innovation

Current situation: Large companies dominate Research and development for innovation. SMEs spend significantly less resources on innovation and R&D for that matter. There is a clear trend of declining innovation among German SMEs, where innovation is mainly self-funded and traditionally done in-house. The industry 4.0 transformation represents one of the main factors for increasing innovativeness of other regions, rapid technological changes, rising demand for novel products and services, falling transaction costs and shorter product life cycles driven by digitization.

Specification A

- **Name:** SMEs pursue open innovation
- **Description:** The rapid growth in connectivity and social media allows SMEs to make innovation truly social. They also implement open innovation with other entities and take advantage of online crowd funding platforms to scale innovation by rising funds for research.
- **Reason:** Open Innovation does not require large capital investments. SMEs traditionally don't spend in R&D.
- Probability: 30%

Specification B

- **Name:** SMEs innovate by collaborating with large firms
- **Description:** SMEs partner with large companies on innovation projects. Part of the effect of the Industry 4.0 transformation is that large companies shift the focus of their innovation investments towards riskier initiatives and breakthrough or disruptive innovations which are traditionally associated with SMEs operating in niche markets focused on clear but singular market opportunities.

- **Reason:** The size, resources and experience of large and established firms endow important advantages to SMEs for innovation.
- **Probability:** 20%

Specification C

- **Name:** Reliance on public institutions for innovation
- **Description:** Innovation attracts more funding from government to support the declining trend in SMEs. SMEs increasingly depend on funds/initiatives and government institutions like Universities, Fraunhofer Institute, and Platform industry 4.0 to sustain and fund innovation research.
- **Reason:** Germany has a robust national innovation system which is also well funded by the government.
- **Probability:** 50%

References:

- Potter, Jonathan; Lunati , Mariarosa; Marchese, Marco Marchese; Martinez-Fernandez, Cristina; Noya ,Antonella Noya (2010): SMEs, Entrepreneurship and Innovation. Available online at <http://bit.ly/2sU45Mv>
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Descriptor name: Technological Adaptability

Area of influence: Technology & Innovation

Current situation: Many German SMEs already operate as high-specialized companies with a large aptitude for innovation. They have an excellent reputation for creativity, quality consciousness and technology-orientation. This provides a great position from

which to make the required changes for the industry 4.0 transformations. Studies by Fraunhofer Institute and Hermann Simon on SMEs also indicate that German SMEs have a certain technological savvy that has enabled them to adapt and thrive in the face of previous technology disruptions.

Specification A

- **Name:** Gradual adaptation of industry 4.0 transformations
- **Description:** Industry 4.0 transformation requires less equipment replacement than previous transformations and German SMEs make the necessary upgrades. German SMEs become more agile as a result of their innate ability to adopt new technologies. They successfully integrate disruptive industry 4.0 technologies and thrive.
- **Reason:** Existing dynamic capability to manage technological changes, short hierarchies facilitating flexible decision making and strong government support network for innovation, employee training and investment in new technology.
- **Probability:** 40%

Specification B

- **Name:** Failure in the adaptation of Industry 4.0
- **Description:** New technologies disrupt markets immediately with the negative effect that markets change faster than investment cycles. Less capitalized SMEs with small specialized workforces are not able to keep up with the pace and impact of the technology changes.
- **Reason:** Characteristics like highly specialized labor force and high asset specificity serve to lock SMEs into old markets and constrain technological versatility required to take the industry 4.0 transformations in stride.
- **Probability:** 60%

References

- Wee, Dominik; Kelly, Richard; Cattell, Jamie; Breunig, Matthias (2015): Industry 4.0 How to navigate digitization of the manufacturing sector. Available online at https://www.mckinsey.de/files/mck_industry_40_report.pdf

- GiZ (2012): The German Mittelstand – an Overview. Available online at http://www.dcmsme.gov.in/Policies/International%20Policies/The%20German%20Mittelstand_An%20Overview.pdf

Descriptor name: Investment in technology

Area of influence: Technology & Innovation

Current situation: In 2015, investments remained stagnant because micro-businesses exercised restraint. In 2016 SMEs increased slightly their expenditure in new machinery, equipment and buildings by 3 billion EUR or 1.9% to 161 billion EUR. Despite the increase and good financial environment, SMEs keep investments in new technology stagnant according to the KfW SME panel survey, 2016.

Specification A

- **Name:** SMEs invest in industry 4.0 technologies
- **Description:** There are good conditions for the acquisitions of loans and/or subsidies. SMEs face troubles in the decreasing workforce productivity and invest in new technology with the expectations of productivity leaps. Industry 4.0 technologies help SMEs to raise productivity.
- **Reason:** There is a positive growth expectation for the future and the share of SMEs with a positive outlook on both turnover and returns rises.
- **Probability:** 30%

Specification B

- **Name:** SME investment activity contracts.
- **Description:** In the short term, Industry 4.0 provides little additional benefits to justify more investment. Early adopters do not experience the gains in productivity hoped for. The promotion of the industry 4.0 transformations evaporates leaving behind pessimism and more restraint around investment into new technology.
- **Reason:** The willingness of SMEs to initiate investment projects has stagnated in the past. On average, most of the investment volume of SMEs is sourced from their own funds and Industry 4.0 technology is very expensive.

- **Probability:** 70%

References

- Abel-Koch, Jennifer; Del Bufalo, Gino; Fernandez, Miguel; Gerstenberger, Juliane; Lo, Vivien; Navarro, Blanca; Thornary, Baptiste(2015): SME Investment and Innovation France, Germany, Italy and Spain Available online at <http://bit.ly/21J0SGh>
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Descriptor name: Data collection and processing

Area of influence: Technology & Innovation

Current situation: Knowledge, information and data are key factors in industry 4.0 and therefore are highly relevant for SMEs' success. Currently in this area, there is an urgent need for the structure of data in SMEs. Due to missing, inaccurate or outdated data sets, optimization approaches often fail.

Specification A

- **Name:** Automation of information flow
- **Description:** In production as well as in logistics, a virtual real-time image of the company processes is generated by the automated recording, evaluation and processing of machine, plant and product data (e.g. by the use of sensors), which enables real-time planning and control of production. The process data for capacity and resource planning are fully generated without additional manual effort and consequently minimizing large expenses for rework. In addition, systematic monitoring of the process parameters assures the company that the customer receives a high-quality product without the installation of a final inspection.
- **Reason:** Due to the continuous increase in the performance of sensors and simultaneous price declines, a large number of information can be collected in all

areas of production and logistics. As a result, the generated data can be better analyzed and communicated besides being correlated with an increase in customer satisfaction.

- **Probability:** 50%

Specification B

- **Name:** Individual barcode systems
- **Description:** Barcode systems enable easy identification of products on machines and systems. Furthermore, data is collected and processed within the company: from development to production and storage phase. However, the generated data must be additionally evaluated and communicated to other companies since it is not flowing through the entire value chain automatically.
- **Reason:** In-house the data of a company can be better managed by appropriate regulations and rules of procedure or by separate operating agreements. Moreover, personal penalties are often provided for data breaches.
- **Probability:** 65%

References

- Erschließen der Potenziale der Anwendung von Industrie 4.0‘ im Mittelstand“ (Juni 2015). Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi). Available online at http://www.zenit.de/fileadmin/Downloads/Studie_im_Auftrag_des_BMWi_Industrie_4.0_2015_agiplan_fraunhofer_iml_zenit_Langfassung.pdf, checked on 4/10/2017.

Descriptor name: Degree of machines’ autonomy

Area of influence: Technology & Innovation

Current situation: The functional area of self-organization and autonomy of machines is one of the central elements of Industry 4.0, in which production is conducted through autonomous communication of machines. In some applications control circuits, quality control, material supply and production control with intelligent and self-organizing objects

are already being used. However, the functional area of autonomy still has a low level of implementation.

Specification A

- **Name:** Autonomous self-organized machines
- **Description:** Self-organization, self-configuration and self-optimization of systems are achieved through technologies that automatically evaluate the data. Self-organization is thus an important part of the cyber-physical systems, which not only collect but also evaluate and store data. Additionally systems communicate with one another, have an identity and interact with their environment. Employees, materials, tools and auxiliary equipment are planned and used in a decentralized way, exactly where they are currently needed.
- **Reason:** An autonomous, self-organizing and flexible capacity planning leads to an improved adaptation of the resources to the current situation. The digital connection of the individual systems leads to a flexible response to unplanned events, such as a system fault. In case of fault, the system reports it and asks the service personnel, orders material to repair and provides the instruction for troubleshooting. Further potential in the field of self-organization is in the reduction of energy consumption. Machines and systems are supplied with electricity, water, compressed air, etc., only when it is necessary.
- **Probability:** 35%

Specification B

- **Name:** Human control of machines
- **Description:** An essential question in the introduction of autonomous and self-organizing systems is how operational safety can be guaranteed. The human-machine interface is still highly critical and is far from its final maturity. The technical development of autonomous production systems and logistical equipment does not yet allow safe and parallel cooperation with personnel.
- **Reason:** The acquisition of full autonomous machines is associated with a considerable investment volume and high follow-up costs for maintenance in order to guarantee safe human-machine interaction. Thus, the low availability of such

systems, due to their complexity, further reduces the profitability for SMEs to obtain them and therefore, human control is still needed.

- **Probability:** 65%

References

- Erschließen der Potenziale der Anwendung von Industrie 4.0‘ im Mittelstand“ (Juni 2015). Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi). Available online at http://www.zenit.de/fileadmin/Downloads/Studie_im_Auftrag_des_BMWi_Industrie_4.0_2015_agiplan_fraunhofer_iml_zenit_Langfassung.pdf, checked on 4/10/2017.

INFRASTRUCTURE

Descriptor name: Digitalization

Area of influence: Infrastructure

Current situation: Today, every company in every sector is affected by digitalization and in Germany about 1 million people are already employed in the digital economy. This is creating a demand for more robust connectivity infrastructure. Even though 88% of all companies understand the connection between digitalization and commercial success, only 51% of the SMEs say that digitalization is not yet part of their business strategy.

Specification A

- **Name:** SMEs transform into digital enterprises
- **Description:** As a result of the industry 4.0 transformations there is an Internet of things, services and most importantly a mature industrial Internet. SMEs actively engage in the digitalization process and strengthen their market positions while also capture new markets by investing in digital infrastructure.
- **Reason:** There is an attractive support from government through the Digital Investment programme for SMEs (Digitales Investitionsprogramm Mittelstand) with a volume of €1 billion.
- **Probability:** 40%

Specification B

- **Name:** Digitalization threatens SMEs
- **Description:** Large companies invest heavily in digital infrastructure and threaten the existence of SMEs as they own more infrastructure required to compete in the digital economy. Increased digitalization by large companies increases their market share leaving the financially constrained SMEs out of competition.
- **Reason:** As digitalization becomes fundamental for a company's survival, competitive advantage is derived from quantity and quality of digital resources like data. This leads to a scope of infrastructure so that investment creates a distinct advantage for large companies.
- **Probability:** 60%

References

- Federal Ministry of Economic Affairs and Energy (2016): Digital Strategy 2025. Available online at http://www.de.digital/DIGITAL/Redaktion/EN/Publikation/digital-strategy-2025.pdf?__blob=publicationFile&v=8
- OECD (2017): Key issues for digital transformation in the G20. Available online at <https://www.oecd.org/g20/key-issues-for-digital-transformation-in-the-g20.pdf>
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Descriptor name: High-speed Internet

Area of influence: Infrastructure

Current situation: Industry 4.0 technologies demand the availability of broadband Internet access. This is expected to result in an increase in the volume of data to be transferred over the Internet compared to today. Today, only 7% of households have access to optical fiber cable and Germany has the lowest fiber-optic coverage in all of Europe, with just 1 %.

Affordable gigabit connections for SMEs are in most cases not available especially as many of them are located in non-urban areas.

Specification A

- **Name:** Ubiquitous public Internet
- **Description:** The Federal government constructs a national gigabit optical fiber network with speeds upward of 50Mb. SMEs have access to fast affordable broadband with low latency and are able to access all digital technologies in the industry 4.0 transformation pack in order to improve business outcomes.
- **Reason:** As part of the policy objective for implementation of Industry 4.0, the German government prioritizes the provision of adequate infrastructure. The Internet must be available wherever Industry 4.0 application is used and it must have sufficient transport capacity.
- **Probability:** 40%

Specification B

- **Name:** Limited and slow Internet
- **Description:** Private sector is not stimulated enough by government spending on Internet infrastructure. This leads to a period of slow broadband network extension. It is mainly focused on urban centers and individual rather than enterprise customers. SMEs are left out of the Industry 4.0 transformation. Large companies thrive by building their own fiber optic networks. Many SMEs fail in the face of both local and foreign competition.
- **Reason:** Government efforts are inadequate to close the gap between the current status of the national broadband network to the desired state for Industry 4.0.
- **Probability:** 60%

References

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Available online at
http://www.de.digital/DIGITAL/Redaktion/EN/Publikation/digital-strategy-2025.pdf?__blob=publicationFile&v=8

Descriptor name: Industry Partnerships

Area of influence: Infrastructure

Current situation: Germany's Platform Industrie 4.0 is the main example of an industry partnership formed in response to demands for collaboration on a wide range of issue connected to the industry 4.0 transformations. The platform convenes experts from business, science, associations and the trade unions to develop operational solutions with representatives from various federal ministries in thematic working groups.

Specification A

- **Name:** Public private partnerships develop infrastructure
- **Description:** Development of new infrastructure in response to rising demand stimulated by the industry 4.0 transformations is achieved through public-private partnerships. This makes it possible to make sure that there is no creation of monopolies by large companies that disadvantage SMES with high connectivity tariffs. SMEs benefit from low tariffs also resulting from the removal of the existing monopolies of large network operators.
- **Reason:** Government is aware of SMEs financial limitations and considers the expansion of the national digital infrastructure in the public's interest and common economic good.
- **Probability:** 50%

Specification B

- **Name:** Rise of industry monopolies
- **Description:** Large companies form partnerships through which they invest in connectivity infrastructure that gives them a monopoly to the exclusion of SMEs. SMEs face high tariffs to access high quality digital infrastructure.

- **Reason:** In addition to large companies having more financial resources available to them, the telecommunications industry is dominated by large enterprises that recognize control over the digital infrastructure. This creates a lasting competitive advantage to large enterprises and guarantees access to the most important resource in the digital age: data.
- **Probability:** 50%

References

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- Walendowski, Jacek; Kroll, Henning; Schnabl, Esther (2016) : Industry 4.0, Advanced Materials (Nanotechnology). Available online at <http://bit.ly/2uNU0Pz>

Descriptor name: Investment

Area of influence: Infrastructure

Current situation: The industry 4.0 transformations require a much wider and faster infrastructure than what German businesses count on up today. This has stimulated both private and public investment in infrastructure in preparation to reap the benefits of the digitalization. Large companies in the telecommunication industry and the government dominate Germany's infrastructural investment. The Ministry of Transport and Digital Infrastructure started a network alliance for a digital Germany along with a number of trade federations and various telecom companies. Companies have invested 12 billion in broadband expansion and new mobile radio frequencies in 2015 and set 8 billion asides for 2016.

Specification A

- **Name:** Government stimulates investment in Infrastructure
- **Description:** In addition to the invest in affordable modern nationwide public broadband, government stimulates the private sector to invest into areas where investment in infrastructure would otherwise not be economically viable. Government also extends grant and loan facilities to SMEs to invest in upgrades and acquiring new infrastructure. SMEs have access to high-speed fiber optic data highways and enough funding to upgrade own infrastructure.
- **Reason:** Investment in infrastructure is a matter of national importance and part of the High tech strategy as a measure for stimulating matching private investment.
- **Probability:** 55%

Specification B

- **Name:** Limited investment in infrastructure
- **Description:** Government investment programs in industry 4.0 specific infrastructures come to an end, which limits access to grants and loans for SMEs. Private investors focus on the economical viable projects leaving many SMEs outside metropolitan areas with no access to modern digital infrastructure. SMEs finance infrastructure from their own limited resources.
- **Reason:** There is change in the Government Economic Policy. Government decides against artificial demand creation and austerity measure like stimulus subsidies for digital infrastructure projects due to economic pressures or change in political agenda.
- **Probability:** 45%

References

- Kimmig, Anja (2015): Germany's high-speed Internet is lagging behind. Available online at <http://www.dw.com/en/germanys-high-speed-internet-is-lagging-behind/a-18313138>
- Federal Ministry of Economic Affairs and Energy (2016): Digital Strategy 2025. Available online at

INTEGRATION

Descriptor name: Value Chain integration

Area of influence: Integration

Current situation: Nowadays we still have a very static value chain in SMEs, covering from customer requirements to production. It is technically possible to customize products by companies, however; it is still not possible for a customer to select freely their product's functions and all the features due to the high costs of production.

Specification A

- **Name:** Profitable customized production
- **Description:** Industry 4.0 will change the conventional value chain of SMEs in Germany. The inter-company networks and value chain will be developed through horizontal integration. It is possible for customers to acquire individual products with customized features in all the phases of production. Talking from the perspective of the SMEs, this customization of products will be possible and also SMEs will be able to be aware of every detail of the manufacturing process and smart products. With this horizontal integration, companies are able to control individually every stage of their production semi-autonomously.
- **Reason:** Companies will be able to create value to customers and give a competitive advantage, by offering products adapted to every requirement. Another reason is better control of quality during the manufacturing process. It will be profitable to manufacture one-off items and in very small quantities of goods for very specific markets.
- **Probability:** 55%

Specification B

- **Name:** Mass Production by SMEs in Germany

- **Description:** SMEs will keep their mass-producing process without putting emphasis in customized products. Networked value chain is not possible for SMEs due to lack of balance in their interests with companies that belong to their value chain. There is still not enough trust in the new systems and fear that other companies, including suppliers, can steal their “know how”.
- **Reason:** Companies feel that their vulnerability is increased due to lack of enough data security. Also the risks of a networked value chain are high since there is not enough efficient infrastructure and one fail in the system affects the whole production and generates high costs for all the companies involved. There are still high costs and limited market potential. It is still too costly for a company to switch into a different value chain.
- **Probability:** 45%

References:

- Kagermann, Henning; Wahlster, Wolfgang; Helbig, Johannes (2013): Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Edited by Ariane Hellinger, Veronika Stumpf. acatech – National Academy of Science and Engineering. Frankfurt/Main. Available online 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
- Jesse, N. (2016). Internet of Things and Big Data – The Disruption of the Value Chain and the Rise of New Software Ecosystems. IFAC-PapersOnLine, 49(29), 275–282.

Descriptor name: Vertical Integration

Area of influence: Integration

Current situation: The majority of SMEs do not have full vertical integration. There is only integration in the shop floor of companies and not between production processes and business processes. Companies still believe this is not yet priority, since they have been working successfully without a full vertical integration, most of the time due to its size.

Specification A

- **Name:** Full vertical Integration within the organization
- **Description:** Smart factories will have no predefined and fixed manufacturing structures. There will be an integration of the different IT systems that are used in different stages of the manufacturing and business processes, which includes exchange of materials, energy and information within all departments in a company.
- **Reason:** Full integration allows SMEs to have access to an early verification of production processes, such as decisions in the design phase. This end-to-end transparency is made in real time. It also allows more flexible responses to disruptive changes and optimization along the company, which gives them more efficiency and coordination along the organization.
- **Probability:** 40%

Specification B

- **Name:** Slow integration of CPS within an organization
- **Description:** The development of smart factories with full integration of the manufacturing systems with business processes will take a slow pace. Most of SMEs do not have a full-networked integration within the company. SMEs will not believe yet that this integration is necessary due to their size and already established coordination of the company. This full integration represents big changes that take time and focus.
- **Reason:** Costs of investment are still too high. There is uncertainty from SMEs in the implementation of CPS within the company. SMEs prefer to wait until other companies invest in CPS and show that these disruptive changes are actually happening and are necessary for their survival.
- **Probability:** 60%

References:

- Kagermann, Henning; Wahlster, Wolfgang; Helbig, Johannes (2013): Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Edited by Ariane Hellinger, Veronika Stumpf. acatech – National Academy of Science and Engineering. Frankfurt/Main.

Available online 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

Descriptor name: Resource and Energy Efficiency of German SMEs

Area of influence: Integration

Current situation: There is still production line or parts that consume and run with high quantity of energy not only during working days but also during breaks, weekends and shifts where there is no production. Even though, companies, especially SMEs, still look to deliver the highest output of products (resource productivity) using the lowest possible amount of resources in order to deliver a particular output (resource efficiency).

Specification A

- **Name:** Resource and energy efficiency strategies
- **Description:** Industrie 4.0 will make possible for companies to deliver gains in resource productivity and efficiency. SMEs, which already adopted CPS, will be capable to have manufacturing processes that can be optimized in terms of their resource and energy consumption. This goes along with vertical and horizontal integration where the aim is not only to be able to produce profitable one off items and a more efficient and coordinated integration of floors within a company, but also efficiency in the productivity of companies.
- **Reason:** For SMEs, energy and production efficiency is one of the most important topics. Energy efficiency is already an important requirement for machinery in Germany. Besides, there is a new social-technical interaction between all the actors and resources involved in manufacturing.
- **Probability:** 60%

Specification B

- **Name:** Lack of production and energy efficiency
- **Description:** SMEs don't adopt Industry 4.0 technologies and hence, cannot control every phase of their production and it becomes more difficult to implement

strategies for resource and energy efficiency. Furthermore, SMEs do not take as priority the resource and energy efficiency within their production.

- **Reason:** SMEs are not able to adopt Industry 4.0 technologies because they don't either count with the money or the belief in them. Without these technologies they cannot implement full integration of their value chain and within the company and hence, be able to control exactly every phase of their production in real time.
- **Probability:** 40%

References:

- Kagermann, Henning; Wahlster, Wolfgang; Helbig, Johannes (2013): Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Edited by Ariane Hellinger, Veronika Stumpf. acatech – National Academy of Science and Engineering. Frankfurt/Main.
Available online 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

Descriptor name: Collaboration of SMEs through clusters

Area of influence: Integration

Current situation: Over the last few years, Government, both federal and state, have been promoting diverse projects that have the objective to create networks and clusters that promote new technologies. These Networks and clusters include industrial and academic institutions in all their research and development activities. It is known that there are already various programs that promote the development of clusters structures that can strengthen cooperation between research and industry.

Specification A

- **Name:** Increased collaboration between SMEs
- **Description:** There will be an increased development of new platforms, through clusters, via which SMEs can network and set standards between them. This is the result of Government's efforts to create and strengthen networks among SMEs.

With this increased networks, SMEs can collaborate between them easier and safer. There is benefits obtained form these collaborations.

- **Reason:** SMEs consider these networks as drivers and the base of digitization, and in order to adopt more successfully the new industrial revolution. Therefore, they are considerable necessary for Germany's digital future.
- **Probability:** 35%

Specification B

- **Name:** Weak collaboration between German SMEs
- **Description:** SMEs will have difficulties in establishing networks with other German companies for collaboration. Therefore, clusters and networks are not strong enough to bring benefits to companies and increase collaboration between them. Due to this lack of collaboration, it is difficult for them to adopt fully the 4th industrial revolution.
- **Reason:** There are doubts and disbeliefs regarding the lack of data protection and know-how of every company. They still don't see the benefits of collaborating between them and do not believe yet in the benefits that can be obtained from the 4th industrial revolution.
- **Probability:** 65%

References:

- Erschließen der Potenziale der Anwendung von Industrie 4.0' im Mittelstand“ (Juni 2015). Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi). Available online at http://www.zenit.de/fileadmin/Downloads/Studie_im_Auftrag_des_BMWi_Industrie_4.0_2015_agiplan_fraunhofer_uml_zenit_Langfassung.pdf, checked on 4/10/2017.
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- “Future of the German Mittelstand” Action Programme (May 2016). In : Spree Druck Berlin GmbH. Available online at

https://www.bmwi.de/Redaktion/EN/Publikationen/aktionsprogramm-zukunft-mittelstand.pdf?__blob=publicationFile&v=6, checked on 4/10/2017.

Descriptor name: New business models adopted by German SMEs

Area of influence: Integration

Current situation: Business models have been changing due to the last transformation, as it was the inclusion of the Internet and smart phones. However, only one in five companies in Germany has adapted its business model to the possibilities offered by digitalization.

Specification A

- **Name:** Disruptive Service design model
- **Description:** Disruptive Service design model is based on the idea that a customer can buy a product for a fixed price but this includes the option to give it back to the producer after certain time of use. It is the service what it is purchase or rented rather than the product itself.
- **Reason:** Disruptive Service design model is convenient for many SMEs, since it results in a sustainable product that has certain lifetime and this is becoming more competitive than the traditional way to buy and trash a product after usage. All this is a possible thanks to the cross-company operations and the resulted networked value chain. The involvement of CPS makes possible to track the full production process.
- **Probability:** 20%

Specification B

- **Name:** One-off production business model
- **Description:** SMEs develop new business models in order to meet any last minute requirement that any customer demand in-store. That's the possible to do with Industry 4.0 technologies. Value creation and capture also turns into the customized production. There will be a highly dynamic network of business rather than just one company implementing this business model.
- **Reason:** For companies this business model results profitable since it is possible to customize its products without costs. It becomes priority to deliver value through

the customization of the products. In addition the costs saved in workforce is attractive for companies.

- **Probability:** 30%

Specification C

- **Name:** Traditional business models
- **Description:** Companies will continue with the same business models based on selling products on large scale. SMEs will still prefer to keep using their traditional business models, which have given them success and trust.
- **Reason:** SMEs do not count with a full-networked value chain what makes not possible to cope with the new emerging business models. Furthermore, SMEs do not trust yet in the adoption of new technologies that enable the full integration of their value chain.
- **Probability:** 50%

References:

- Prause, G. (2015). Sustainable business models and structures for industry 4.0. *Journal of Security and Sustainability Issues*, 5(2), 159–169.
[https://doi.org/10.9770/jssi.2015.5.2\(3\)](https://doi.org/10.9770/jssi.2015.5.2(3))
- Ferber, S. (2015). How the Internet of Things Changes Everything. *Harvard Business Review Blog* , 1-5.
- Federal Ministry for Economic Affairs and Energy . (2016). *DE.DIGITAL*.
Obtained from: WWW.BMWI.DE

EDUCATION AND QUALIFICATION

Descriptor name: Employee Development

Area of influence: Education & Qualification

Current situation: SMEs present a deficiency in trained staff capable to cope with demanding technologies. Therefore, they have an increased need in support for future training and knowledge in order to develop all the necessary skills effectively and at the same time, be able to cope with the increase complexity of future production systems.

Specification A

- **Name:** Partnerships with Higher Education Institutions
- **Description:** SMEs are participants in training partnerships with Higher Education Institutions to develop all the necessary skills that their employees need to keep up with the increased complexity of production processes. The partnership consists of the dual education where Higher Education Institutions provide technologies necessary to teach students so that they can later practically apply obtained skills within the organization.
- **Reason:** SMEs do not have enough capacity to train their staff in-house; consequently, they must complement it with support from Education Institutions. On the other hand, Government will subsidize Higher Education Institutions with the newest technologies, in order to have prepared workforce. This is favorable for SMEs that do not invest yet in these technologies.
- **Probability:** 50%

Specification B:

- **Name:** Cooperation between SMEs for employees' development
- **Description:** Companies located in the same region cooperate on projects and share the commitment to the generation of skilled workers. This is possible with the creation of clubs where companies transfer employees in order to learn from other companies' employees. There are better and more efficient standards on what is important for employees to learn.
- **Reason:** Companies that are located in the same area collaborate through cluster and industry associations already and it is less costly than investing in training within the company.
- **Probability:** 20%

Specification C

- **Name:** In-house development.
- **Description:** The development of workforce regarding the changes that Industry 4.0 carries is not a top priority for SMEs. Training programs remain internally

developed and focused on present business needs with no regard to future requirements.

- **Reason:** SMEs work at full capacity and are financially constrained; therefore they cannot focus on activities, like extra training, not related to the everyday-business tasks. In addition they have also not yet acquired Industry 4.0 technologies like.
- **Probability:** 30%

References:

- "Acatech. (2016). Skills for Industrie 4.0. Training requirements and solutions. Acatech . Munich : acatech (Ed.).
- Faller, C., & Feldmüller, D. (2015). Industry 4.0 Learning Factory for regional SMEs. Procedia CIRP, 32, 88-91.

Descriptor name: Skills needed

Area of influence: Education & Qualification

Current situation: SMEs employees are highly specialized in technical and domain-knowledge skills. It is still not prioritized the development of social-intercultural skills in highly technological SMEs. It is forecasted that employees will need specific social skills to cope with the new challenges regarding technological and organizational development.

Specification A

- **Name:** Strong social, personal and intercultural approach.
- **Description:** Companies put greater emphasis on the development of interdisciplinary, metacognitive and social skills as opposed to the previous technical focus. Employees concentrate more on creative, innovative and communicative activities. This emphasis has occurred due to an increased collaboration between companies and the extended free time that CPS allows employees to have. Companies implement this approach also due to high interests in open innovation activities.
- **Reason:** Social skills are mostly developed by SMEs due to their close customer-service approach. Routine activities are mostly replaced by machines, which also include monitoring tasks. This pattern aims to build and maintain networks of

experts where cooperation can aid finding solutions for particular problems or increased innovation within and between companies.

- **Probability:** 20%

Specification B

- **Name:** Integrated engineering skills
- **Description:** Intercultural and communication skills are not a priority for SMEs in Germany. Technological and Knowledge-based skills are still more important and considered as the foundation for coping with the increasing complexity that CPS and new technologies have.
- **Reason:** As machines start to take over the so-called “easy jobs or shop floor jobs”, companies demand highly technical qualified workers that are capable to adopt the new technologies, thus, all efforts are mainly focused either in the development of these skills or in acquiring employees with these qualifications.
- **Probability:** 30%

Specification C

- **Name:** Balanced Approach of technical and social skills
- **Description:** Companies attach equal importance to the development of all the different social and technical skills that workers need to cope with the challenges and changes that Industry 4.0 brings. For SMEs is important that employees are ready to fill their position in Industry 4.0, meaning that all existing gaps in competencies (Social, personal and technical) are closed.
- **Reason:** SMEs identify the most important competencies for Industry 4.0, taking into consideration the fact that every job profile will require different skills. Thus, skills will be evaluated according to every job profile and department.
- **Probability:** 50%

References:

- Glas, A. H., & Kleemann, F. C. (2016). The Impact of Industry 4.0 on Procurement and Supply Management: A Conceptual and Qualitative Analysis. *International Journal of Business and Management Invention ISSN (Online)*, 54, 2319-8028.

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Descriptor name: Attitude towards change

Area of influence: Education & Qualification

Current situation: In Germany SMEs, specifically the so-called “Hidden Champions” have been capable to cope with the transformative changes that have been presented in the recent years and had become market leaders in their niche.

Specification A

- **Name:** Opposition to the change within a company
- **Description:** There is conflict between existing structures and processes and the implementation of change. Company structures remain conservative and moreover, employees are opposed to the full digitalization of their tasks.
- **Reason:** Opposition toward change among employees is born from the fear of losing their jobs or their responsibilities are curtailed. For employees, full digitalization presents a latent threat.
- **Probability:** 50%

Specification B

- **Name:** Proactive approach to change within a company
- **Description:** SMEs take a proactive approach towards the changes forecasted and needed in order to adopt the new technologies, business models and practices that industry 4.0 carries. All employees feel the need to keep up with the disruptive changes that the 4th industrial revolution involves in order to survive in the market. There is a general motivation and excitement towards these changes.

- **Reason:** It is identified from top floor to shop floor that disruptive changes are necessary in order to remain competitive as a company and they are seen as a tool for more efficient and sustainable production.
- **Probability:** 50%

References:

- Stefan Heng (2014): Industry 4.0 Upgrading of Germany's industrial capabilities on the horizon. Edited by Lars Slomka. Deutsche Bank Research. Available online at https://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD000000000333571.pdf, checked on 4/10/2017.
- Hodges, J. (2016). Managing and Leading People Through Organizational Change.
- Simon, H. (2009). Hidden Champions of the Twenty-First Century. Springer-Verlag New York.

Descriptor name: Employees' Autonomy

Area of influence: Education & Qualification

Current situation: The continuous technological and organizational changes in the workplace impose challenges for SMEs on an employee level. Digitization is currently changing the role and distribution of work for employees. Therefore, it is changing the way their work life is distributed.

Specification A

- **Name:** More flexibility in the workplace
- **Description:** Workers have more personal flexibility regarding work time, work content and work place. They are able to have greater autonomy and more opportunities for self-development. CPS allows them to have more free time for the development of complementary activities.
- **Reason:** Smart production allows flexible-working conditions. It is possible to have a greater compatibility between work and personal needs. Employees have enough flexibility for continuous self-development that will keep them working and productive for longer.

- **Probability:** 60%

Specification B

- **Name:** Employees' autonomy constraints
- **Description:** It is possible for companies to use the new technology for very different purposes. Systems can be set up to impose restrictive control over every minute detail of a person's work. Furthermore, companies do not only control and manage every single process of the production but also of their personnel's performance.
- **Reason:** Workers are monitoring through managers and not by the technology. This is because there is an increased tension between the virtual world and the world of worker's own experience.
- **Probability:** 40%

References:

- Kagermann, Henning; Wahlster, Wolfgang; Helbig, Johannes (2013): Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Edited by Ariane Hellinger, Veronika Stumpf. acatech – National Academy of Science and Engineering. Frankfurt/Main. Available online 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

Descriptor name: Demographic changes

Area of influence: Education & Qualification

Current situation: Germany has an aging workforce phenomenon. The government expects the population to shrink from 81m to 67m by 2060. Businesses are reporting particular difficulty filling vacancies in a wide range of technical professions and in the healthcare sector. By 2050, under current employment patterns, the working age population (15-64) is expected to have fallen by 14.8 million. This will weaken economic growth and affect the sustainability of public social expenditures. Small and medium-sized companies

in the manufacturing industry, where business owners have an average age of 54 and are becoming victim to demographic change particularly swiftly.

Specification A

- **Name:** Extended talent pool for SMEs
- **Description:** There are an increased number of refugees and immigrants in Germany, which incentives government investment in labor market integration efforts. Most refugees and asylum seekers are successfully integrated into the German labor market. SMEs are able to replenish their aging talent base. Demographic shifts in German society have no effect of labor availability for SMEs. There is no pressure on SMEs to automate or adopt high cost new technologies designed to replace humans.
- **Reason:** Germany is the biggest refugee and asylum seeker destination. The government recognizes the long-term economic benefit of integrating the new comers into the labor force just as the social danger of leaving many out of the work force is clear. The German government has a lot of experience to draw from having had many waves of immigrants.
- **Probability:** 50%

Specification B

- **Name:** SMEs automate to overcome lack of workforce
- **Description:** Advanced automation and CPS technologies are adopted by SMEs, they require smaller and highly skilled workforce. They focus on upgrading skills and lifelong learning using advanced learning methods like virtual learning. Assistance systems are applied in order to improve utilization and extend productive lives of employees.
- **Reason:** Companies with highly automated production processes require a declining number of employees.
- **Probability:** 50%

References:

- Bräuninger, Dieter (2013): Medium-sized enterprises and demographics. Increasing pressure to take action. Available online at

https://www.dbresearch.com/PROD/DBR_INTERNET_ENPROD/PROD00000000000304451/Medium-sized_enterprises_and_demographics%3A_Increas.PDF

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FINANCE

Descriptor name: Access to financial resources

Area of influence Finance

Current situation: Small and medium-sized enterprises in Germany need access to financial resources in order to be able to innovate and invest into digital technologies, and, consequently increase long-term competitiveness. Overall, large SMEs have historically good access to loans and there are almost no denials from banks, however, micro-businesses with fewer than five employees experience difficulties accessing loans.

Specification A

- **Name:** Internal financing
- **Description:** Despite extensive financial instruments available on the capital market, both from the public and private sectors SMEs consider internal financing to be the main source of funding Industry 4.0 technologies. SMEs cannot achieve

agreements with banks on investment loans and to get access to public subsidy loan programs, therefore, share of loans in the capital structure of SMEs declines. In addition, very small enterprises with fewer than ten employees do not demonstrate the necessary capacities for the implementation of the innovation project and to fulfill market orders.

- **Reason:** Many SMEs cannot easily afford to provide application for grants for R & D projects because of comprehensive documentation regarding the investment project, as well as, their financial situation and collateral in order to prove credit worthiness. Thus, innovations are often financed from own resources.
- **Probability:** 55%

Specification B

- **Name:** External funds
- **Description:** SMEs in Germany need access to sound finance what is the main prerequisite that enables companies to invest in Industry 4.0 technologies, and thus for the long-term competitiveness. KfW and Landesbanken expand the market for SMEs by making funds available and offering co-financing of private equity investments at all stages of entrepreneurial development what is particularly relevant for implementation of Industry 4.0 technologies associated with a high capital requirement. KfW entrepreneurial credit provides SMEs with funds for maximum five years to cover their investment costs on Industry 4.0 technologies that cannot be capitalized as non-current assets, whereas, ERP innovation program enables SMEs whose degree of innovation is too small for the subsidy programs (such as ZIM (Central Innovation Program for SMEs)) to operate both near-market research and development, and to invest in Industry 4.0 machinery and equipment.
- **Reason:** Industry 4.0 solutions require large investments, which SMEs often cannot finance due to limited capacity of their financial resources. Major investments in machinery and equipment can be funded through research and innovation programs because they are often the largest financing component of an innovative development in addition to the cost of launching new products, technologies and services. Moreover, KfW entrepreneurial loan allows the financing of soft costs.
- **Probability:** 45%

References:

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Descriptor name: Attitude toward investments and risks

Area of influence Finance

Current situation: In the last three years around four in five SMEs carried out digitization projects, however, they invested comparatively low amount, with almost half investing less than EUR 10,000 a year. Overall, SMEs’ investments in digitization projects are total around EUR 10 billion a year.

Specification A

- **Name:** Risk averse attitude of SMEs
- **Description:** Negative business expectation caused by demographic change toward altering small and medium-sized enterprises decreases the propensity to invest in Industry 4.0 technologies and projects associated with long payback period and uncertainty of potential future profits of investments.
- **Reason:** Older entrepreneurs having reached high age avoid long-term financial obligation, therefore, their incentives to invest in long-term project are respectively low.
- **Probability:** 40%

Specification B

- **Name:** Optimistic attitude towards risk

- **Description:** Optimists mainly represented by start-ups invest in Industry 4.0 technologies in order to improve their competitiveness in a long run.
- **Reason:** Young, agile and innovative companies that will be tomorrow's Mittelstand mainly represent Start-ups. This is immense importance for the German economy, competitiveness and job creation.
- **Probability:** 60%

References:

- "Future of the German Mittelstand" Action Programme (May 2016). In : Spree Druck Berlin GmbH. Available online at https://www.bmwi.de/Redaktion/EN/Publikationen/aktionsprogramm-zukunft-mittelstand.pdf?__blob=publicationFile&v=6, checked on 4/10/2017.
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Descriptor name: Venture capital.

Area of influence Finance

Current situation: For young, innovative companies, the availability of venture capital is essential. This is an area in which Germany lags well behind other countries. The lack of venture capital in Germany creates a risk that young, innovative firms will be unable to grow or will relocate out of Germany. To respond to the changed competitive conditions of the digital age with its disruptive innovations, the Economic Affairs Ministry is providing a total of some €2 billion to strengthen the venture capital market.

Specification A

- **Name:** Boost of venture capital market.
- **Description:** Germany becomes to be internationally competitive and attractive for venture capital investments. Consequently, venture capital enables innovative SME's to utilize business opportunities provided by digitization through sharing high average risks of Industry 4.0 projects.

- **Reason:** The Economic Affairs Ministry continues to provide financial support and offer measures in order to strengthen the venture capital market in the era of disruptive innovation that has changed competitive conditions. Furthermore, the “INVEST venture capital grant” provides stimulus for business angels, such as an increase of investment sum and reimburse of taxes to encourage them to invest in innovative companies.
- **Probability:** 20%

Specification B

- **Name:** Lack of venture capital.
- **Description:** Venture capital market hardly plays a role in German financial system; thus, venture capital firms reduce the amount of the capital that they provide to SMEs'. As a result, SMEs bare higher risks and uncertainty while implementing Industry 4.0 technologies.
- **Reason:** Venture Capital companies require a high growth rate for potential target companies to cover the high costs of selecting and maintaining the investments. However, high uncertainty regarding Industry 4.0 project does not guarantee high profitability that covers all risk associated with it. In addition, Venture Capital requires the readiness to delegate control and ownership rights of SMEs.
- **Probability:** 80%

References:

- Bundesministerium der Finanzen (2015): Promoting venture capital in Germany, 9/16/2015. Available online at http://www.bundesfinanzministerium.de/Content/EN/Standardartikel/Topics/Financial_markets/Articles/2015-09-16-promoting-venture-capital.html, checked on 4/11/2017
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POLITICS

Descriptor name: National Initiative

Area of influence: Politics

Current situation: Currently, numerous information and advisory initiatives are being developed on Industry 4.0 and digitization in SMEs. Four Mittelstand 4.0 Agencies work to develop solutions regarding digitalization and eBusiness involving stakeholders, such as associations and business chambers. The Mittelstand 4.0 Competence Centers raise awareness about digitalization among companies and provide information, training, and the opportunity for companies to view and test new solutions out in practice across the various regions. However, a national program for promotion of Industry 4.0 in small and medium-sized enterprises does not yet exist.

Specification A

- **Name:** Initiative Industry 4.0 in the German Mittelstand
- **Description:** The existing programs or elements of existing programs that support the introduction of industry 4.0 technologies to SMEs are bundled and set up a concerted initiative "Industry 4.0 in the German Mittelstand". The major focus is Industry 4.0 competence centers that are located in such way that interested SME can easily get in contact with them. All competence centers provide an individual and comprehensive consultation regarding aspects of Industry 4.0. For efficiency reasons consultations on advanced questions are done considering thematic and technological specialization.

- **Reason:** All actors - science, business, associations, chambers, networks, etc. contribute actively to shape political framework for a concerted initiative "Industry 4.0" in five dimensions: Reference architectures, standards and norms, Research and innovation, Security of networked systems, Legal framework, Work, education and training. It is recognized that Industry 4.0 must be adopted In order to maintain and expand this competitive strength of German industry.
- **Probability:** 80%

Specification B

- **Name:** Sustainable Development Strategy
- **Description:** German in collaboration with other world leading economies adopted the 2030 Agenda for Sustainable Development approaching 17 global goals that require close cooperation between governments, the civil society, the private sector and science all around the globe. The sustainable development strategy includes three aspects of sustainability, namely, economic efficiency, social balance and environmentally stable development, thus, the government undertakes holistic measurements and forwards financial funds on climate and biodiversity protection, resource efficiency, health, education and anti-corruption policies. Consequently, taking into consideration this shifting priority, SMEs are less supported by the government on their way towards digitization and Industry 4.0 transformation.
- **Reason:** Industry 4.0 and the programs such as “Mittelstand-Digital” and “KMU-innovativ” are one of the forward-looking programs of sustainable development strategy, however German government prioritize and support areas of ecological protection and social development in order to fulfill the obligations of the 2030 Agenda for Sustainable Development.
- **Probability:** 20%

References:

- „Erschließen der Potenziale der Anwendung von Industrie 4.0“ im Mittelstand“ (Juni 2015). Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi). Available online at http://www.zenit.de/fileadmin/Downloads/Studie_im_Auftrag_des_BMWi_Industri

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Descriptor name: Change of legal basis

Area of influence Politics

Current situation: Development of new technologies has risen new questions concerning liability, consumer and data protection, etc. which require revision and adaptation of the legal basis. Furthermore, the extensive exchange of data that accompanies Industry 4.0 also makes users an attractive target for hackers. These attacks can be targeted not only on theft of valuable data, but also on damaging the entire manufacturing process, causing risks to economy of the country. Therefore, legislation regarding data security, IT security and IP law has been identified as risks what explains the skepticism of SMEs concerning industry 4.0.

Specification A

- **Name:** EU legislation
- **Description:** A comprehensive research on Industry 4.0 carried out, which identifies, analyzes, reviews and provides legal reference models for the industry that complete Machinery Directive of the EU, the product safety law and the Machinery Ordinance. European legislation and European initiatives develop directive on protection of trade secrets regarding know-how and parts of the

European Commission's Digital Agenda in the area of IP law. There is also a shift from legal operations toward more technical such as a legal obligation to take IT security into account when software, products and systems are being designed ("security by design"). The European Institute for Telecommunications Standards (ETSI) develops an interface for international standardization, so-called "machine-to-machine" (M2M).

- **Reason:** Due to technological excellence, German industry is capable to develop digitally based innovations and business models with the world industrial leaders. However, this development requires change of legal basis and closer examination in order to reveal industry-relevant aspects that cover broad areas of the law such as labor, insurance, computer, internet, competition and antitrust as well as data protection and many other areas.
- **Probability:** 45%

Specification B

- **Name:** Hampered transition to Industry 4.0.
- **Description:** In the area of IT security the EU's NIS directive disharmonize European and national IT security provisions what leads to conflicts between the interest of users and companies in a common Digital Single Market and the interests of the national industry regarding the transition to Industry 4.0.
- **Reason:** European legislation loses sight of the needs of businesses and focuses more on new laws rather than on harmonization of existing national legislation.
- **Probability:** 55%

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- „Erschließen der Potenziale der Anwendung von Industrie 4.0‘ im Mittelstand“ (Juni 2015). Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi). Available online at http://www.zenit.de/fileadmin/Downloads/Studie_im_Auftrag_des_BMWi_Industrie_4.0_2015_agiplan_fraunhofer_iml_zenit_Langfassung.pdf, checked on 4/10/2017.

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